Module 110

Structure Hydraulics

Module Description

Objectives

Upon completion of this module, the participant will be able to:

- Describe the two key hydraulic parameters that affect the selection of the most economical structure type, providing site conditions are adequate.
- List the factors that affect the functioning or head-discharge relationship for four common NRCS conservation structures.
- Perform at ASK Level 3 (perform With Supervision).

Prerequisite

None

Eligibility

This module is intended for all NRCS personnel who use hydraulics in their work.

Overview

This module presents information NRCS field office personnel need to know about structural hydraulics in order to understand and explain the functioning of small water control structures such as drop spillways, pipe drop inlets, hood inlets, and culverts. The module discusses the hydraulic factors that influence selection of type of structure and factors that affect the head (stage)-discharge relationships needed to determine capacity or size of spillways.

Introduction

A hydraulic structure is a device designed to retain, regulate, or control the flow of water. It can be manufactured or it can be constructed in the field.

Hydraulic structures supplement conservation practices where vegetation and constructed channels are not adequate to do the job.

When you have completed this module, you will be able to describe the two key hydraulic parameters that affect the selection of the most economical structure type and list the factors affecting the functioning or head-discharge relationship for four common NRCS conservation structures:

- Drop structures
- Culverts
- Hooded inlets
- Drop inlets

Hydraulic Parameters

The selection of the most appropriate and economical type of structure to use in a specific situation will depend on the hydraulic parameters of the site. (To focus on hydraulics, it will be assumed that other site conditions are adequate.)

There are two hydraulic parameters to consider:

- Discharge (flow)
- Controlled head

Discharge, or flow, is measured in units of cubic feet per second (cfs). It is denoted by the letter "Q". The discharge to be safely handled by a structure is dependent on a number of factors, including:

- Size of the drainage area above the structure.
- Watershed characteristics which affect the runoff from the
- drainage area.
- The degree of control the structure will be expected to achieve. Degree of control is dependent on the design objectives of the structure and the conservation practice which it will accompany.

Calculation of discharge is discussed in modules 106 and 206 of this series.

Controlled head, measured in feet, is the change in elevation which the water will take as it passes through the structure. It is an approximate measure of the energy available to move water through the structure. In addition to the channel grades above and below the structure, water levels in those channels must also be considered. The upstream depth is called the headwater (HW), and the downstream depth is the tailwater (TW). Head is denoted by the letter "h".

Engineering Field Manual (EFM) figure 6-4 (fig. 1) provides a general guide to the selection of hydraulic structures.

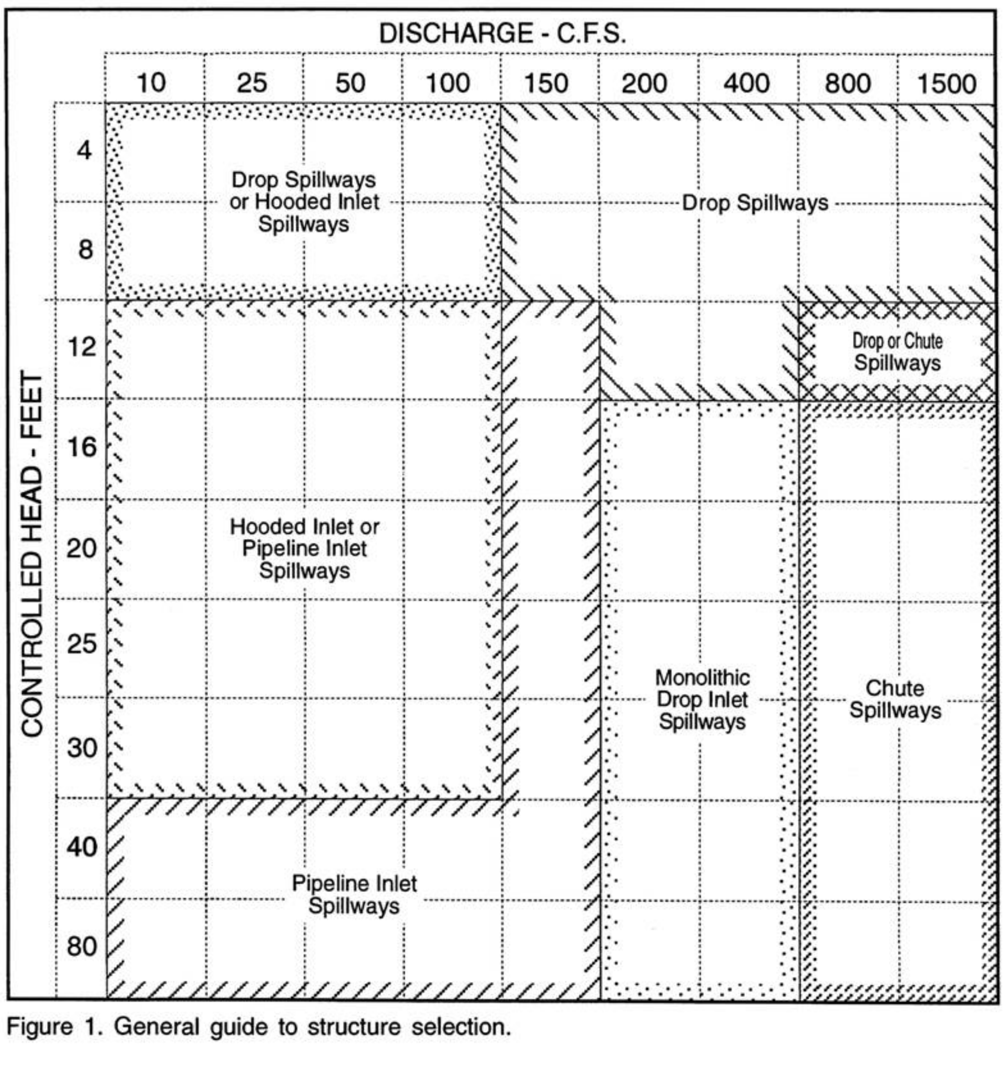

Figure 1. General guide to structure selection.

The chart is based on the hydraulic parameters of discharge and controlled head. Discharges are listed across the top of Figure 64, and controlled heads are shown along the left side. The body of the chart is broken into seven areas, each labeled with types of structures.

With values for discharge and controlled head, an appropriate structure type can be selected. For example, say we have to select a structure type where:

Discharge = 150 cfs
Controlled head = 20 feet

Find the value for the discharge (150 cfs) on the top of the chart. Next, find the value for the controlled head (20 ft) on the left side.

Follow down the column for the discharge and across the row for the head, to the place where they intersect. The area that the intersection occurs shows the appropriate structure type. In the case of our example, the appropriate structure is a pipe drop inlet spillway.

Similarly, if:

Q = 25 cfs   h = 20 ft

Then:
Structure should be either a hooded inlet or a pipe drop inlet spillway.
Note that three of the areas on the chart are labeled with two structure types. In these cases, either structure is appropriate from a hydraulic standpoint. Other factors, such as site conditions and costs, will help determine which of the two is selected.

Head-Discharge Relation Factors

For all structures, the discharge is dependent on, or is a function of, the head.

$Q = f(h)$

Several other factors enter into the relationship. Some apply to all structures, and can be described in general terms. These will be discussed first. Others are more specific to the type of structure, and will be treated separately for each type of structure. The head-discharge relation factors will be referred to as flow factors.

General

There are three flow factors which are common to all types of structures:

- Approach channel

- Inlet conditions
- Outlet conditions

Approach channel

The width, depth, and alignment of the approach channel upstream from the structure can all affect the head-discharge relationship.

The approach channel should be at least as wide as the structure inlet, but no wider than necessary. In an over-wide channel, the water at its extreme edges must converge inward to find its way to the structure inlet. This tends to reduce the discharge. Therefore, discharge is inversely related to channel width.

$Q = f * (1/W)$

Perhaps more importantly, a wide channel will be shallower. This brings us to the second factor in the approach channel - the depth. A narrow channel will "stack up" more water at the entrance to a structure. This depth increases the headwater (HW) on the structure. Therefore, as the approach channel depth increases, the discharge increases.

$Q = f(D)$

Alignment of the approach channel can help direct the flow to the structure inlet. The most desirable approach channel will aim the water directly at the inlet. A channel with obstructions, curves, or skewed to the structure will reduce the discharge.

$Q = f(A)$

Inlet conditions

Water enters the structure through the inlet, which may be in the form of a straight wall, a rectangular "box" a vertical "pipe drop", or a near-horizontal pipe. The various types or shapes can be adapted to different situations. It is most important that the inlet be sized to adequately supply water to the spillway. The larger it is, the more flow it can handle. Figure 2 demonstrates four types of inlets.

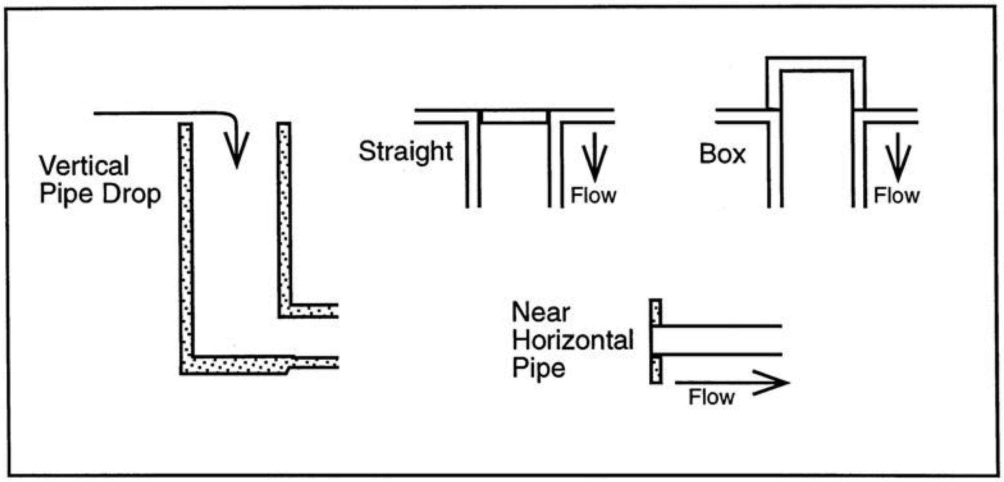

Figure 2. Four types of inlets.

Depending on upstream conditions and the size and type of structure, inlets must often be equipped with trash racks to hold back large pieces of debris which could become lodged in the structure and impede the flow. A good trash rack will keep large pieces of debris away from the inlet, but let smaller passable debris flow through. Generally, the more closed type inlets need trash racks more than other types do. Trash racks are usually fabricated from steel rods, small diameter pipe, or angle iron.

Another appurtenance which can improve inlet flow conditions is the anti-vortex device. On closed-pipe inlets with adequate headwater to supply fully pipe pressure flow in the spillway, a vortex can develop. This is similar to the swirl that occurs at a bathtub drain.

The vortex will allow air to enter the conduit, replacing water and decreasing the discharge. To correct this problem, a horizontal plate or vertical wall installed above the inlet will act as an anti-vortex device (fig. 3).

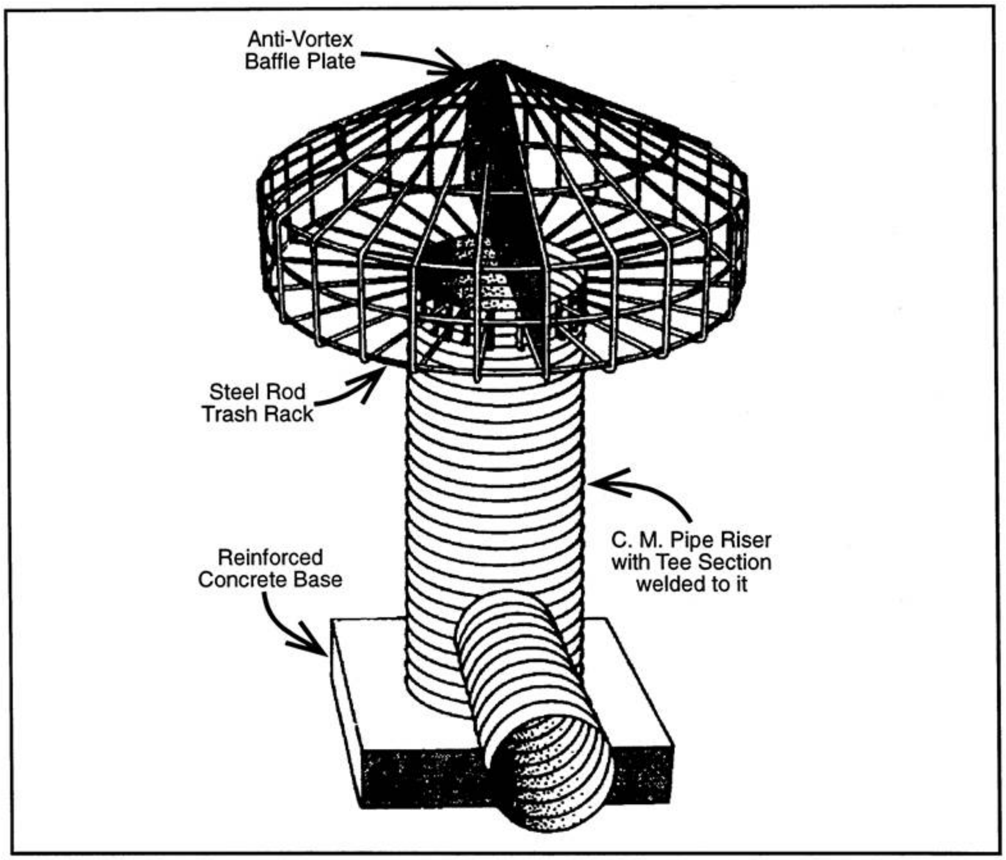

Figure 3. Vertical pipe drop inlet with anti-vortex device and trash guard.

Outlet conditions

Outlet conditions also affect the head-discharge relationship. A structural outlet carries the water away from the spillway into the downstream channel at a safe velocity. As the water makes its vertical drop through the structure, it gains energy in the form of velocity. This energy must be dissipated to prevent downstream erosion.

This can be done with a structural outlet and tailwater on the structure. Outlets can be simple horizontal aprons, stilling basins, or special basins with floor blocks, impact walls, and end sills (fig. 4).

The outlet must be sized properly so that the tailwater in it is deep enough to assist in energy dissipation. But the outlet should not be located so that a tailwater floods out the structure. Excessive tailwater can submerge a spillway and drastically reduce its discharge capacity.

The condition of the outlet can be a factor in structure performance. An outlet that is unstable, eroding, or clogged with debris will not perform as intended. Its condition can affect the tailwater, which can then affect the discharge capacity.

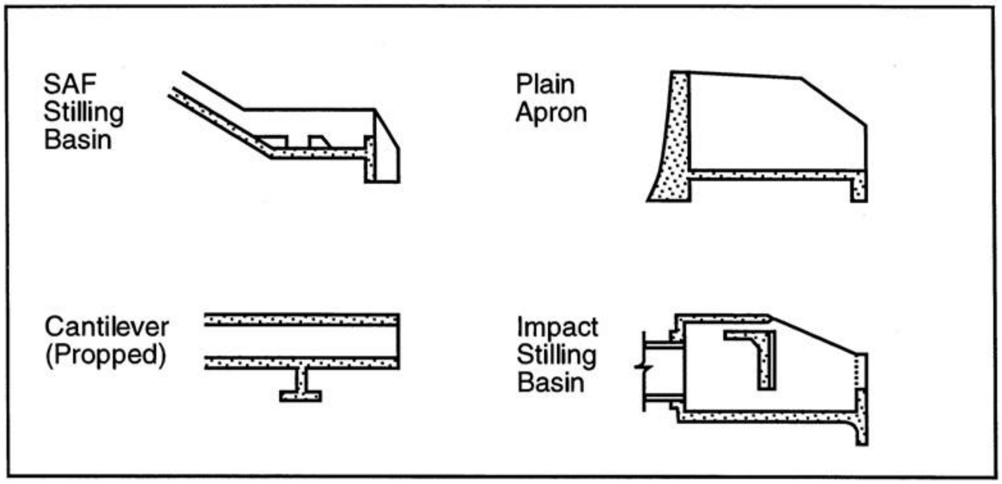

Figure 4. Four types of outlets.

Drop Structures

The drop structure is a wall set in an embankment or across a channel or gully. The flow must pass over a weir, which is a notch in the wall. The water then drops onto an approximately horizontal floor called an apron, or a stilling basin. Drop structures have a unique set of features which affect their performance.

The most obvious of these is the shape of the weir. The notch can be any regular shape, depending on the purpose of the structure. For conservation practices, weirs are designed with a rectangular shape. That is, the notch has a horizontal bottom and vertical sides. There are two kinds of drop structure-the straight drop spillway and the box inlet drop spillway-which are differentiated by their shapes.

The straight drop spillway (fig. 5) is simply a vertical wall with a notch in it. In the case of the box inlet (fig. 6), the notch is still a rectangular shape, but the horizontal bottom of the weir is lengthened by placing a "box" on the upstream side of the wall. This effectively increases the weir length without increasing the size of the notch in the wall, or of the apron or stilling basin.

The length of the weir is the total horizontal distance along the surface of the notch. The water flows over this surface, which is known as the crest of the weir. The length of the crest is represented by the letter "L".

The measured length of the crest would have to be adjusted downward to accurately calculate the discharge. This would be done to account for end contractions which occur where the water must flow laterally from the sides of the approach channel. The convergence of this flow into the weir notch results in an effective weir length which would be shorter than the measured length.

For most conservation work, this is an unnecessary refinement. The measured weir length is used for calculating discharge. The discharge capacity increases with an increase in the weir length.

$Q = f(L)$

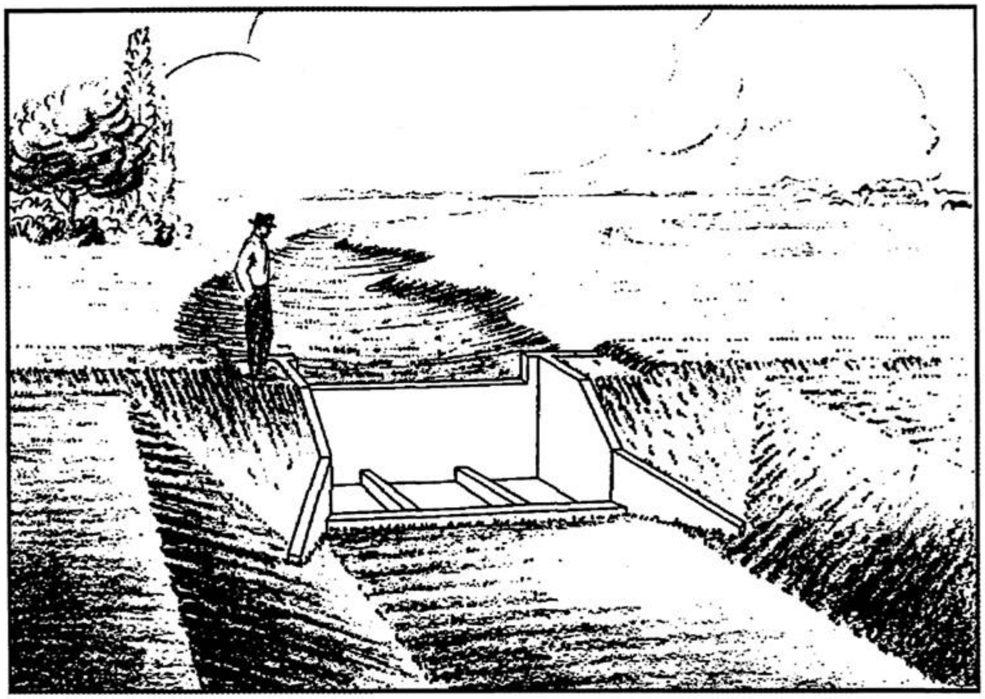

Figure 5. Straight drop spillway.

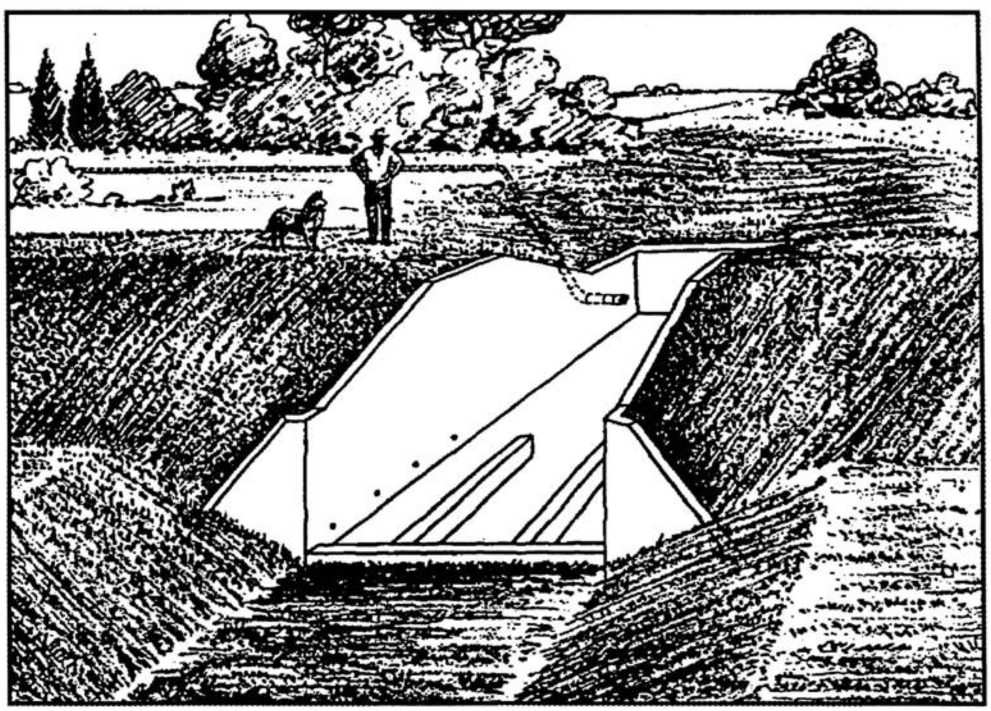

Figure 6. Box inlet spillway.

The cross sectional shape of a weir, in the upstream to downstream direction, can be either sharp crested or broad crested. Sharp crested weirs are not used in conservation structures, and are not discussed here.

The crest on a broad crested weir has a horizontal breadth over which the water flows. The upstream and downstream faces of a drop spillway are usually vertical. A broad crested weir is, therefore, rectangular in cross section.

As the height of the water over the weir crest increases, so will the discharge increase. The height, H, is measured far enough upstream from the crest to be away from the lowered water surface due to the structure itself. This is usually a distance of about 3H.

$Q = f(H)$

The velocity of the flow in the approach channel can also affect the discharge capacity. 'The velocity in feet per second (fps) is converted to feet of energy by the equation

$H=v^2/2g$

where "g" is the acceleration due to gravity, 32.2 feet per second per second (ft/sec2). The value of h, called the velocity head, would then be added to the height of the water over the crest to get the total head. The effect of the velocity is usually small enough to be ignored on conservation structures.

If the crest of a drop structure is submerged by tailwater, its discharge capacity can be appreciably reduced. If the upstream head is H_u and the depth of the submergence over the crest is H_d, the effects of submergence can be related to the ratio H_d/H_u. There is no great reduction in the discharge until H_d/H_u reaches 0.67. Then the discharge is reduced rapidly as the submergence increases.

Culverts

A culvert is a pipe which carries water under an embankment. The most common example is a culvert under a road. A culvert is the simplest form of closed conduit structure (fig. 7a., b.).

All conduits, regardless of the type of structure they are part of, have several common factors which affect their discharge capacity.

The most apparent of these are the size and shape of the conduit. The larger a pipe is, the more water it can carry. Shape is a factor because it influences the cross sectional area of a pipe. (The cross sectional area of a two foot diameter round pipe is smaller than a 2' x 2' square conduit.)

Q = f(a)

Another closely related pair of conduit flow factors are type of material in the conduit and roughness of the flow surface. Roughness causes friction which retards flow. A smooth material such a concrete pipe will offer less frictional resistance and will convey water easier than an irregular surface such as corrugated metal. Discharge is inversely related to roughness. The effect of roughness or friction is represented by roughness coefficients, commonly known as Manning's n-values, which were determined experimentally. A smooth surface has a lower n-value than a rough or irregular surface.

Q=f(1/n)

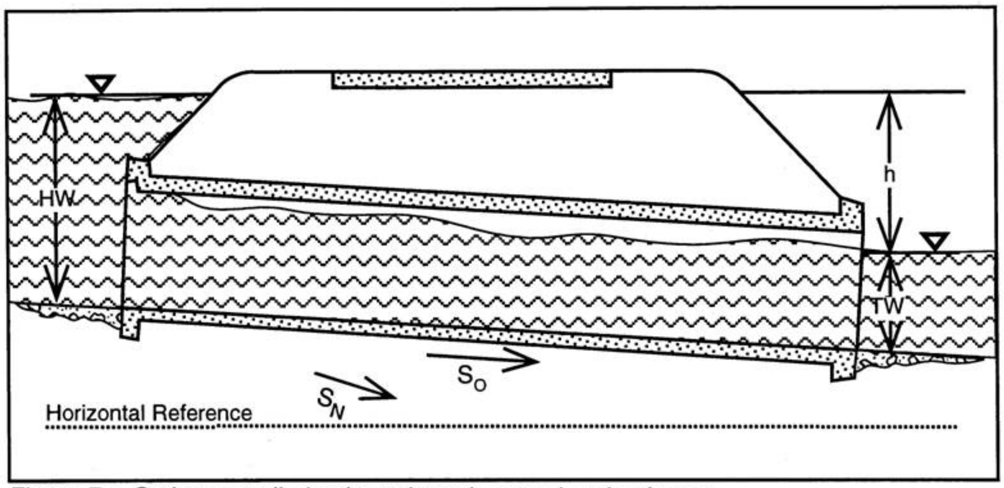

Figure 7a. Outlet controlled culvert through a road embankment.

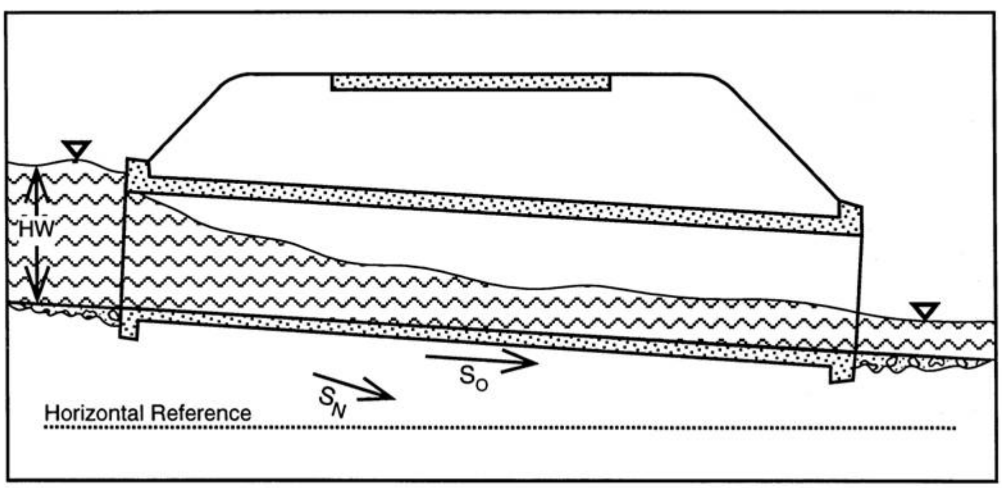

Figure 7b. Inlet controlled culvert through a road embankment.

Conduit entrance conditions will also affect flow. As the water converges to enter the pipe, it loses energy and the ability to flow is reduced. This loss of flow capacity is accounted for with the use of entrance coefficients, denoted by K_e. Discharge capacity is inversely related to the entrance coefficient.

$Q=f(1/K_e)$

Slope is the remaining flow factor applicable to all conduits. The slope of the conduit provides energy in the form of vertical fall, or head. This accumulation of head along the fall of the pipe can offset the energy loss due to friction along the pipe. As the slope increases, so will the discharge capacity.
$Q=f(S_O)$

There are two types of culvert flow: inlet control and outlet control. With inlet control, the pipe does not flow full downstream of the entrance. Outlet control means that the pipe will flow full of water throughout its length. Because of these differences, each type has its own set of flow factors.

For any given discharge and culvert configuration, only one flow type will occur. That is, for any given set of conditions, a culvert must be either inlet or outlet controlled. To determine the flow type, the slope of the culvert must be compared to the neutral slope. This is the slope which provides an energy gain equal to the friction loss along the pipe. Neutral slope is denoted as S_n.

If the slope of the culvert, denoted as S_o, is greater than the neutral slope, the flow is inlet controlled. Regardless of how much headwater is provided above the culvert, it will not flow full.

Inlet control means that the discharge capacity is regulated by culvert entrance conditions. In addition to size and shape of the culvert entrance, the type of entrance can affect capacity. There are three basic types of culvert entrances:

- projected outward from the embankment
- mitered to conform to the slope of the embankment
- headwall

These are listed in order of increasing hydraulic efficiency. A further refinement would be a beveled entrance rather than a square or flush entrance at the upstream free of the headwall.

The other factor affecting discharge capacity in inlet control is the upstream depth, or headwater. Headwater is denoted as HW. This is the available depth from the bottom, or invert, of the culvert entrance to the maximum available or designed water level on the upstream side of the road or embankment.

If no ponding of water were to occur upstream of the entrance, there would also be a velocity head to be added to the headwater to get a total head. This usually does not occur, and HW is used as the total head. Of course, the discharge will increase with increased HW.

Q = f(HW)

If culvert slope is less than or equal to neutral slope, outlet control occurs. Outlet controlled culverts have *two* additional flow factors. The more important of these is the depth of tailwater at the culvert outlet. Tailwater (TW) is measured from the invert of the culvert outlet to the water surface in the outlet channel. The vertical difference between headwater and tailwater is head, or energy, available to produce flow through the culvert. As with any structure, discharge will increase with an increase in head.

h=HW-TW

Q = f(h)

The other outlet control factor is culvert length. This is combined with pipe roughness to determine frictional energy lost as water passes through the culvert. Therefore, the longer an outlet controlled culvert is, the less discharge capacity it has.
Q=f(1/L)

Length is also used with the vertical distance between upstream and downstream inverts to determine slope. If invert elevations are fixed, and the culvert length increases, both slope and the discharge will decrease.

Q=f(1/L)

Hooded Inlets

The hooded inlet spillway, (fig. 8) is, in appearance, a type of culvert installed on steep slopes. Its unique feature is the inlet, formed by cutting the conduit at an angle. The long side of the cut is placed on top and forms a hood over the entrance. An anti-vortex plate is mounted over the inlet.

Hooded inlets are installed on relatively steep slopes with a maximum slope of about 30%. Even when the slope exceeds the neutral slope, the hooded inlet pipe will flow full if enough head-water is provided. To achieve full conduit flow, the headwater depth measured above the invert of the pipe must be at least 1.8 times the pipe diameter.

$HW \geq 1.80$

Due to its steep slope, the hooded inlet goes through a series of flow conditions at headwater depths less than 1.80. If the headwater over the inlet is less than the diameter of the pipe (HW<O), then weir flow will occur at the entrance. In this case, the pipe flows partially full, similar to an inlet controlled culvert.

As headwater over the hooded inlet exceeds the pipe diameter and water seals the entrance to keep air from entering, the pipe flows full momentarily. This causes a sudden increase in flow, which draws down the headwater and stimulates creation of a vortex, so that air can again enter the pipe. A "slug" of pipe-full flow travels down the pipe, followed by partially-full flow. As headwater depth increases, "slugs" become more frequent.

When the headwater depth reaches 1.80, the "slugs" are continuous, and pipe-full flow begins. Since this is the desired condition, proper headwater depth is especially important to hooded inlet performance. As pipe flow, the hooded inlet capacity is dependent on the same factors as a culvert with outlet control. Adequate headwater is necessary to obtain pipe-full flow, but the discharge capacity is dependent on head.

$H = HW - TW$

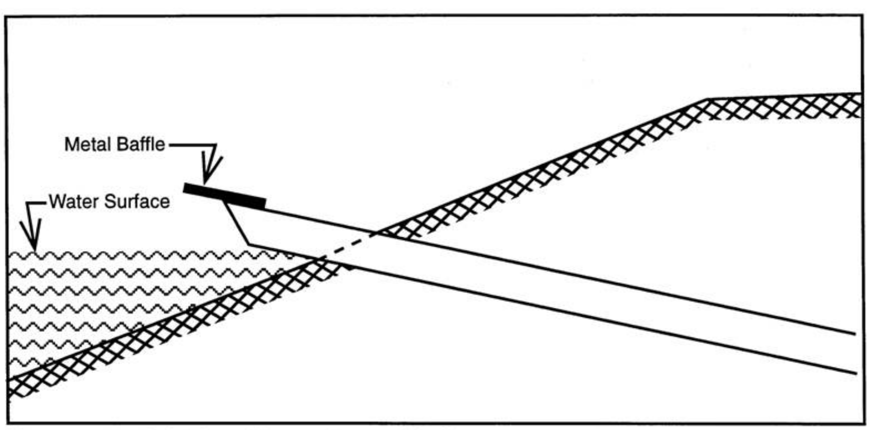

Figure 8. Hooded inlet spillway with metal baffle.

Drop Inlet Structure

The drop inlet (fig. 9) combines weir flow and conduit flow in one structure. The weir is used to maintain an upstream pool level or channel grade, and to supply flow to the conduit. The capacity of the conduit determines the flow released downstream.

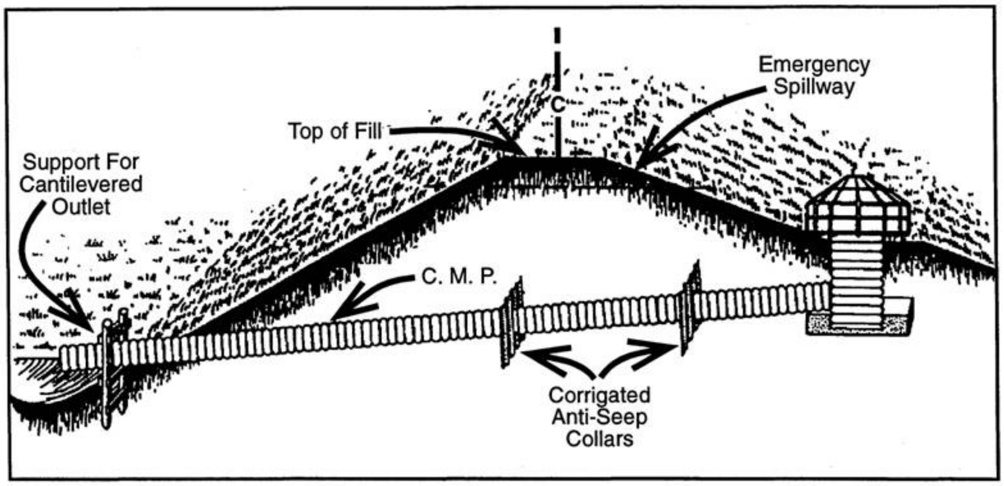

Figure 9. Drop inlet structure.

The pipe, or barrel, has conduit flow factors, including size and shape, material and roughness, entrance conditions, and conduit length. Flow in the barrel of a drop inlet spillway is similar to that in an outlet controlled culvert. The headwater on the barrel is the water level in the pool or channel above the structure.

The inlet, or riser, is a vertical conduit whose top edge acts as a weir. The upstream end of the barrel is connected to the base of the riser. It is the job of the riser to supply enough flow to maintain pipe-full flow in the barrel. The riser can be a circular pipe or a cast-in-place concrete structure.

The inlet factors for a drop inlet are similar to those for a drop structure. The weir length of a round riser is the circumference of the pipe. To improve hydraulic performance and provide continuous flow, the riser must be at least a minimum height, Z. If barrel slope is greater than neutral slope, then Z equals at least five times the barrel diameter. If barrel slope is less than or equal to neutral slope, then Z equals at least two times the barrel diameter.

If

$S_o > S_n$, $S_o < S_n$,

then $Z > 5D$

$Z > 2D$

A drop inlet requires temporary storage capacity upstream of the structure, because the spillway barrel restricts flow. This can be summarized in the equation:

Inflow = Outflow + Storage.

The larger a drop inlet structure is, the less storage it requires. Conversely, more temporary storage will reduce the required size of a drop inlet structure.

A special adaptation of the drop inlet is the drop box inlet, which is a riser used with a culvert. In this case, the pipe is large enough so that temporary storage is not required. The crest of the box is used to maintain an upstream channel grade where a culvert is installed at a lower grade under a road.

Another use for a drop box inlet is with a hooded inlet. For the same crest elevation, a hooded pipe with a diameter larger than 24 inches will require a greater headwater depth ($HW > 1.8D$) than a drop inlet would to achieve full conduit flow. Combining a drop box with a hooded pipe will overcome this problem.

Summary

You should now be able to describe the key hydraulic parameters that affect the selection of the most economical structure type and list the factors that affect the head-discharge relationship for four common NRCS conservation structures. If you cannot do this, you may want to review the material again.

Retain this Study Guide as a reference until you are satisfied that you have successfully mastered the material covered. It will provide an easy review at any time should you encounter a problem.

If you have problems understanding the module or need to take additional, related modules, contact your supervisor.

When you are satisfied that you have completed this module, remove the Certification of Completion Sheet (last page of the Study Guide), fill it out, and give it to your supervisor to submit, through channels, to your Training Officer.

Activity 1

At this time, complete Activity 1 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers by referring to "Activity Solutions" near the back of this module. When you are satisfied that you understand the material, continue with the Study Guide text.

1. A hydraulic structure is a device designed to_____________, or _______________the flow of water. It can be manufactured or it can be constructed in the field.
2. The two hydraulic parameters to consider in selecting a structure type are:

   a. ________________(flow), cfs
   b. ___________, ______________,ft
3. A structure is to be designed to handle a discharge of 200 cfs and have a controlled head of 8 feet. What type of structure should be used?

Activity 2

At this time, complete Activity 2 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers by referring to "Activity Solutions" near the back of this module. When you are satisfied that you understand the material, continue with the Study Guide text.

1. The three flow factors common to all types of structures are_________ ___________, and __________ __________, and ___________ _________.

2.__________, ___________ and __________ are the three characteristics of the approach channel that affect the head-discharge relationship.

3. T _F An approach channel several times as wide as the structure inlet helps to decrease the discharge capacity of the structure.

4. Why did you answer question 3 as you did?

5. An increase in the depth of the approach channel increases the __________and therefore increases the discharge____________.

6. Improved alignment of the approach channel improves the discharge capacity of a structure by aiming the water directly at the ___________.

7. The four kinds of inlets a structure can have are _________ wall, ___________ box,_________ pipe drop and___________-__________pipe.

8. Two appurtenances that are added to structure inlets to improve flow conditions are_____________and____________devices.

9. An anti-vortex device prevents the formation of a vortex(___________) which would allow air to displace______________in the structure.

10. Tailwater at the outlet of a structure helps dissipate__________ __________ in the water.

11. If there is too much tailwater, it can__________ the structure and _____________ the discharge capacity.

Activity 3

At this time, complete Activity 3 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers by referring to "Activity Solutions" near the back of this module. When you are satisfied that you understand the material, continue with the Study Guide text.

1.A weir is a_______ _______through which water flows.

2 . Two kinds of drop structures are_______drop spillway and _______drop spillway.

3. T _F The length of a weir is the horizontal length along the surface of the notch plus a vertical length of each side of the notch.

4.Conservation structures are usually *Sharp Crested/Broad* Crested. (Choose one).

5. T _F The cross sectional shape of a broad crested weir is rectangular.

6. How far upstream from the crest should the height of the water over the crest (H) be measured? About_________H.

7. Velocity head helps to *increase/Decrease* discharge capacity.   (Choose one).

8. The tailwater of a drop structure is found to be level with the spillway crest. This in itself would not be a problem, but if more tailwater depth occurs, the __________ ___________could be reduced.

Activity 4

At this time, complete Activity 4 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers by referring to "Activity Solutions" near the back of this module. When you are satisfied that you understand the material, continue with the Study Guide text.

1. Name the flow factors common to all conduits, including culverts.
   a. ________and shape
   b. material and _________.
   c. __________conditions
   d. ___________

2._T _F Discharge varies inversely to the roughness of a conduit.

3. Slope provides energy in the form of_____________ ____________in a conduit to increase discharge.

4. What are the two types of culvert flow?
   a._________control
   b.___________control

5. Culvert flow type is determined for a given set of conditions by comparing the slope of the culvert to____________ ___________.

6. A culvert found to have a slope greater than the neutral slope is *Inlet Controlled/Outlet Controlled.* (Choose one).

7. What are the two factors affecting the capacity of an inlet controlled culvert?

a.______________

b.______________

8. What two additional factors affect the capacity of an outlet controlled culvert?

a.________________

b.________________

Activity 5

At this time, complete Activity 5 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers by referring to "Activity Solutions" near the back of this module. When you are satisfied that you understand the material, continue with the Study Guide text.

1.- T _F A hooded inlet conduit is formed by cutting the inlet end of the conduit at an angle and placing the long side of the cut at the top.

2. Both a hooded inlet and an inlet controlled culvert are installed on slopes greater than the neutral slope. What flow characteristic distinguishes the hooded inlet from the inlet controlled culvert.

3.The maximum slope for a hooded inlet is_________________%.

4. How much headwater is required for a hooded inlet to flow full?

5.The term used to describe the flow condition when the headwater is greater than the pipe diameter, but not enough to give pipe-full flow is____________ ____________.

6. How is the head determined for a hooded inlet?

Activity 6

At this time, complete Activity 6 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers by referring to "Activity Solutions" near the back of this module. When you are satisfied that you understand the material, continue with the Study Guide text.

1.The two types of flow used in drop inlet structures are__________ flow and __________ flow.

2. The two parts of a drop inlet structure are______________ and ____________.

3. - T _F The riser controls the discharge rate.

4. The flow in the barrel is similar to that in what other types

of structure?

5. - T _F The flow factors for the riser of a drop inlet are similar to those for a drop structure.

6. The two dimensions of the riser that must be sized to pro vide adequate flow to the barrel are ________length and _________height.

7. If the barrel of a drop inlet structure is installed on a slope greater than a neutral slope, the minimum allowable height of the riser is ____________times the barrel diameter. ('

8. Since the barrel of a drop inlet restricts the discharge, this type of structure requires_____________ ______________.

9. What equations shows the relationship between discharge

and storage?

10. What are two special adaptations of the drop inlet structure?

a.___________________

b.___________________

Activity 1

1.A hydraulic structure is a device designed to *retain, regulate,* or *control* the flow of water. It can be manufactured or it can be constructed in the field.

2. The two hydraulic parameters to consider in selecting a structure type are:

   a. *discharge* (flow), cfs

   b. *controlled head,* ft

3. A structure is to be designed to handle a discharge of 200 cfs and have a controlled head of 8 feet. What type of structure should be used?
drop spillway (from EFM, Figure 6.4 (fig. 1))

Activity 2

1.The three flow factors common to all types of structures are approach channel, inlet conditions, and outlet conditions.

2. Width, depth, and alignment are the three characteristics of the approach channel that affect the head-discharge relationship.

3. **X** T _F An approach channel several times as wide as the structure inlet helps to decrease the discharge capacity of the structure.

4. Why did you answer question 3 as you did?
Water at the extreme edges of the channel has to converge inward to find its way to the structure inlet.

5. An increase in the depth of the approach channel increases the *headwater,* and therefore increases the discharge *capacity*.

6. Improved alignment of the approach channel improves the discharge capacity of a structure by aiming the water directly at the *inlet*.

7. The four kinds of inlets a structure can have are *straight* wall, *rectangular* box, *vertical* pipe drop and near *horizontal* pipe.

8. Two appurtenances that are added to structure inlets to improve flow conditions are *trash rack* and *anti-vortex* devices.

9. An anti-vortex device prevents the formation of a vortex *(swirl)* which would allow air to displace *water* in the structure.

10. Tailwater at the outlet of a structure helps dissipate excess *energy* in the water.

11. If there is too much tailwater, it can *submerge the structure* and *reduce the discharge capacity*.

Activity 3

1.A weir is a *rectangular notch* through which water flows.

2. Two kinds of drop structures are *straight drop* spillway and *box inlet drop* spillway.

3.- T -**X**..F The length of a weir is the horizontal length along the surface of the notch plus a vertical length of each side of the notch.

4. Conservation structures are usually Sharp Crested/***Broad Crested.*** (Choose one).

5. -**X**.. T _F The cross sectional shape of a broad crested weir is rectangular.

6. How far upstream from the crest should the height of the water over the crest (H) be measured? About 3 H.

7. Velocity head helps to *Increase* /*Decrease* discharge capacity. (Choose one).

8. The tailwater of a drop structure is found to be level with the spillway crest. This in itself would not be a problem, but if more tailwater depth occurs, the *discharge capacity* could be reduced.

Activity 4

1. Name the flow factors common to all conduits, including culverts.

a.size and shape
b. material and *roughness*
c. *entrance* conditions
d. *slope*

2 . **X** T _F Discharge varies inversely to the roughness of a conduit.

3. Slope provides energy in the form of *vertical fall* in a conduit to increase discharge.

4. What are the two types of culvert flow?

   a. *inlet* control

   b. *outlet* control

5. Culvert flow type is determined for a given set of conditions by comparing the slope of the culvert to *neutral slope*.

6. A culvert found to have a slope greater than the neutral slope is *Inlet controlled/Outlet* controlled. (Choose one).

7. What are the two factors affecting the capacity of an inlet controlled culvert?

a. *entrance conditions*
b. *headwater*

8. What two additional factors affect the capacity of an outlet controlled culvert?

a. *tailwater*
b. *culvert length*

Activity 5

1.**X** T _F A hooded inlet conduit is formed by cutting the inlet end of the conduit at an angle and placing the long side of the cut at the top.

2. Both a hooded inlet and an inlet controlled culvert are installed on slopes greater than the neutral slope. What flow characteristic distinguishes the hooded inlet from the inlet controlled culvert.

The hooded inlet will flow full if given enough headwater.

3. The maximum slope for a *hooded* inlet is *30%.*

4. How much headwater is required for a hooded inlet to flow full?

HW> 1.8D

5. The term used to describe the flow condition when the headwater is greater than the pipe diameter, but not enough to give pipe-full flow is *slug flow.*

6. How is the head determined for a hooded inlet?

h = HW - TW

Activity 6

1. The two types of flow used in drop inlet structures are *weir* flow and *conduit* flow.

2. The two parts of a drop inlet structure are *riser* and *barrel.*

3. - T AF The riser controls the discharge rate.

4. - The flow in the barrel is similar to that in what other types of structure?

Outlet controlled culvert

5. **X** T _F The flow factors for the riser of a drop inlet are similar to those for a drop structure.

6. The two dimensions of the riser that must be sized to provide adequate flow to the barrel are *weir* length and *riser* length.

7. If the barrel of a drop inlet structure is installed on a slope greater than a neutral slope, the minimum allowable height of the riser is 5 times the barrel diameter.

8. Since the barrel of a drop inlet restricts the discharge, this type of structure requires *temporary storage*.

9. What equations shows the relationship between discharge and storage?

Inflow = Outflow + Storage

10. What are two special adaptations of the drop inlet structure?

a. *drop box inlet (culvert)*
b. *drop box with hooded inlet*