Chapter 3

CULVERTS

Description

A culvert is a closed conduit used to convey water from one area to another, usually from one side of a road to the other side.

Importance to Maintenance & Water Quality

Disposal of runoff from roadway ditches will help preserve the road bed, ditches, and banks. Strategically placed culverts, along with road ditch turn-outs, will help maintain a stable velocity and the proper flow capacity for the road ditches by timely outleting water from them. This will help alleviate roadway flooding, reduce erosion, and thus reduce maintenance problems. In addition, strategically placed culverts help distribute roadway runoff over a larger riparian filtering area. Culverts preserve the road base by draining water from ditches along the road, keeping the sub-base dry.

Culvert Profile

General

Culverts can be divided into two functional types: *Stream Crossing* and *Runoff Management*. The first culvert type, *stream crossing culvert*, is self defining. A culvert is required where the roadway crosses a stream channel to allow water to pass downstream. The second type culvert, *runoff management culvert*, is one which is strategically placed to manage and route roadway runoff along, under, and away from the roadway. Many times these culverts are used to transport upland runoff, accumulated in road ditches on the upland side of the roadway, to the lower side for disposal. These culverts are commonly called *cross-drains*.

Installation, modification, and improvements of culverts should be done when stream flows and expectancy of rain are low. Ideally, the entire installation process, from beginning to end, should be completed before the next rain event. All existing and/or reasonable potential stream flows should be diverted while the culvert is being installed. This will help reduce or avoid sedimentation below the installation site.

Culverts For Stream Crossings

When installing culverts (and bridges) for stream crossings, seek to maintain the original and natural fullbank capacity (cross-sectional area) of the channel. Constrictions at these points are contributing factors in costly bridge and culvert "blow-outs" which generate a large volume of sediment deposited directly into the stream. Align and center the culvert with the existing stream channel whenever possible. As a minimum, align the culvert with the center of the channel immediately downstream of the outlet. If channel excavation is required to help align the culvert, it is frequently best to excavate the upstream channel to fit the culvert entrance and align the outlet with the existing natural channel. Minimal disturbance of the channel at the culvert outlet should be the priority consideration. Inasmuch as possible, the grade of culverts should be determined by the grade of the existing channel, but usually not less than 0.5% nor more than 1%. The outlet should discharge at the existing channel bottom. A professional engineer, experienced in hydrology and culvert hydraulics, should be consulted for determination of actual culvert grades when dealing with peculiar alignment or laying conditions, and upon any deviation from normal and usual installation procedures. Keep disturbance of the channel bottom, sides, adjacent land, and surrounding natural landscape to a minimum during installation. Install energy dissipating structures and/or armor at the outlet where scour and erosion are likely to occur from high exit velocity due to steep culvert installation, near proximity to channel banks, drops at the end of the culvert, etc. (See Chapter 4 on OUTLET STRUCTURES). Establish and maintain at least one foot of road bed cover over all culverts. Two feet or more cover is the desired optimum.

Culverts For Runoff Management

Where cross-drains are needed in conjunction with "turn-outs", it is ideal to place culverts no more than 500 feet apart along the roadway to control the volume and velocity of flow within road ditches. Steeper road slopes may require closer spacing to discharge accumulated runoff in excess of ditch capacity and/or to keep velocities down. Inasmuch as possible in non-stream crossing locations, a "turn-out" ("tail-ditch") should coincide with the outlet location of a cross-drain culvert to "dump" transported and accumulated water from the receiving ditch. Where private roads and driveways intersect public roadways, install culverts to maintain continuity of flow within the ditch while allowing access across the ditch. In cases of no head wall, install enough culvert to extend each end at least two (2) feet past the toes of the road bank slopes. Install energy dissipating structures and/or armor at the outlet where scour and erosion are likely to occur from high exit velocity due to steep culvert installation, near proximity to ditch banks, drops at the end of the culvert, etc. (See Chapter 4 on OUTLET STRUCTURES). Establish and maintain at least one foot of road bed cover over all culverts. Two feet or more cover is the desired optimum.

Exhibit 3.1a - Culverts for Stream Crossing

Exhibit 3.1b - Culverts for Crossing Natural Drains

Exhibit 3.1 - Culverts for Crossing Natural Streams and Water Courses

Major Cross Drains

These usually facilitate large drainage areas which may include a network of roadway ditches, field drains, etc. and often discharge at a point in or near a natural stream or drainage.

Intermittent Cross Drains

These usually connect road ditches on the upland side of a roadway to road ditches on the opposite side, or convey water to discharge points on the opposite side of a roadway.

Miscellaneous Cross Drains

These maintain continuity of flow by connecting or re-connecting road ditches which have been crossed by an intersecting road or driveway, or simply provide for drainage under roads and driveways. Also, note the need for scour protection at the outlets. This is a significant source of sedimentation.

Exhibit 3.2 - Runoff Management Culverts

Maintenance At Sensitive Aquatic Environment Crossings

Inasmuch as possible, maintain pre-existing conditions in streams when performing maintenance on culverts for stream crossings. Avoid impedances to fish and other aquatic fauna by adhering to the following:

a. Contact the state fisheries biologist or the U.S. Fish and Wildlife Service (USFWS) for assistance.

b. Do not substantially alter water velocities. Especially do not create excessive velocities. Keep in-pipe velocities within those navigable by fish.

c. Do not create vertical barriers.

d. Do not create adverse water depths. Keep in-pipe flow depths comparable to those of the associated stream channel.

e. Do not create flows outside the range of flows normally encountered throughout the year, or at least those flows which may negatively impact the aquatic life in the stream.

f. Make sure the culvert design accommodates the size and species of fish passing through it.

g. Provide resting pools at culvert inlet and outlet for culverts installed across streams with high channel gradients.

h. Use corrugated culverts to decrease water velocities through the culvert and supply resting areas for migrating fish.

i. Use bridges, bottomless arches, partially buried culverts, or other similar structures in areas where fish passage and specie habitat is an important consideration.

j. At stream crossings, select a culvert site where there will be no abrupt change in gradient and the upstream and downstream channel alignments are as straight as possible for 50 feet in either direction.

k. Consider maximum design flows which will not create adverse stream conditions.

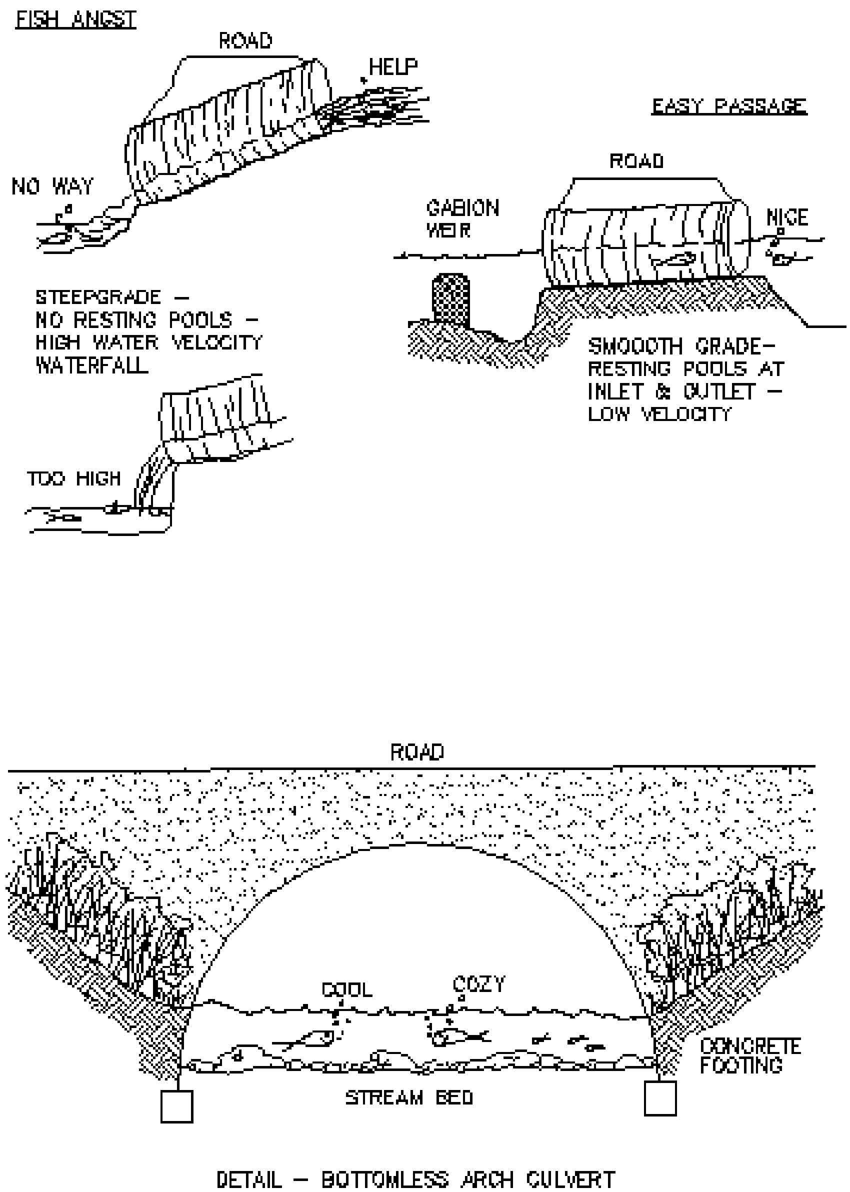


Figure 3-1. Examples of Fish Friendly Designs

Culvert Installation/Replacement

In live (flowing) streams install sandbags, silt fences, earthen dikes, or other appropriate measures to inhibit flow when possible. Use a pump to convey water around the excavation/work site. Discharge pumped water onto a stable outlet to prevent scour. With live stream flows which cannot be impounded, divert the flow to one side of the culvert alignment. Enough room should be allowed to properly excavate the entire pipe trench and bed the entire culvert. Minimize disturbance of the surrounding soil and vegetation.

Excavate trench side slopes on a safe grade to prevent caving. Inasmuch as possible, the bottom of the trench should be at least twice the width of the culvert to be installed and graded as near to designed culvert grade as possible.

One method of properly installing a culvert is to start at the outlet end, lay the culvert up-slope, properly bedding each joint as installation proceeds. The first section or "joint" is critical, and special attention should be given to proper installation, grade, and alignment to reduce the potential for scour and erosion from water discharge, and, to ensure the whole culvert is aligned properly. Pipe joints should be wrapped 1-1/2 times around with geotextile filter fabric. The fabric should extend at least two feet either side of the joint or edges of the connecting band if one is used. This is especially true with concrete or other types of pipes which may not have rubber or mastic seals at the connecting joints. Once the culvert is installed and secured in place, divert the flow through the culvert and commence filling the by-pass channel, if any, and complete the backfilling around the culvert. Backfill around and over the culvert should be placed evenly and level in maximum 12" loose lifts and thoroughly compacted before adding successive lifts. Scarify (roughen) the top two inches of compacted surfaces which have a slick, smooth, or glossy finish after compaction. Six (6) inch loose lifts should be used below the midpoint of the culvert. Do not use or operate machinery closer than two feet of the culvert.

Mulch and vegetate all disturbed areas. Use silt fences or other appropriate erosion control measures to prevent or reduce erosion and sedimentation until stabilizing vegetation is established.

Head Walls (Headers)

Head walls may be used when hydraulic capacity needs to be increased, and/or when installing a head wall will be more efficient than culvert replacement. Head walls should be flush with the end of the culvert. Head wall "wings" (extensions) help mold and direct channel flow into the culvert and protect the area around the inlet from scour. Head walls may be of poured concrete, bagged concrete, concrete blocks, bricks, logs, cut wood, or may be shaped loose rock riprap, etc.

Cleaning and Maintenance

One method to account for all culverts is to maintain an inventory of culverts and under-drains and use a checklist from this inventory to account for culverts during inspections. Inspect culverts often, especially in the spring and autumn, and after storm events, checking them for signs of corrosion, joint separation, bottom sag, pipe blockage, piping, fill settling, cavitation of fill (sinkhole), sediment buildup within the culvert, effectiveness of the present inlet/outlet inverts, etc. Check inlet and outlet channels for signs of scour, degradation, agradation, debris, channel blockage, diversion of flow, bank and other erosion, flooding, etc.

Practice preventive maintenance to avoid clogging of pipes and other situations which may damage the culvert or diminish its design function. If a culvert is plugged with sediment, flush it from the outlet end with a high pressure water hose. Take measures to reduce downstream sedimentation and clean debris and sediment from the outlet ditch afterwards.

When replacing damaged culverts which handle the flow adequately, use the same size, shape, and type of pipe. Changing any of these criteria may adversely effect the established stability of the ditch, stream, and/or roadway.

Culvert head walls come in many shapes, sizes, and materials.

Head walls can stabilize culvert outlets and entrances and improve flow efficiency at inlets.

Exhibit 3.3 - Head Walls (Headers)

Chapter 4
OUTLET STRUCTURES

Description

Outlet structures are used to reduce and/or control energy from ditch or culvert discharge, and release the discharge downstream under controlled, stable conditions.

Importance to Maintenance & Water Quality

Outlet structures reduce the velocity of water carried by road ditches and culverts, therefore helping to control sedimentation. Water should outlet to areas with moderate slopes and vegetative filter strips or riparian areas before entering surface waters. This type of outlet, often referred to as day-lighting, will allow for most of the sediments and other pollutants to be removed before runoff enters surface waters.

Location

Outlet structures should be located where concentrated, turbulent, and/or high velocity flows are discharged onto areas which can be erosive, or where the discharged water requires filtration or settling of sediments. This can be outlets for swales and road ditches, flumes, runoff management culverts within the road ditch system, or culverts used at stream crossings.

Implementation

Structures

Splash/Stilling/Plunge Basin

Basins (usually rock-lined) which are water-filled, or will fill with water during runoff events, located at high-energy outlets of conveyance structures such as steep flumes, and more usually, cantilevered pipe outlets.

The purpose is to use the pooled water to dissipate the energy of the flowing water discharged by the conveyance structure. Basins are usually constructed as a depression below the outlet channel elevation as shown in figure 4-1, but can be constructed with the basin bottom at the outlet channel elevation and the basin formed by constructing a weir (riprap, gabion, etc.) across the outlet channel as shown in figure 4-2. The basin is usually wider than the outlet channel by design and tapers to fit the existing channel at the basin exit point. The basins must always be lined with a properly sized and/or classified, non-erosive lining such as riprap, concrete mats, gabions, etc. underlain with filter fabric or a graded aggregate filter. These structures require the design services of a professional engineer.

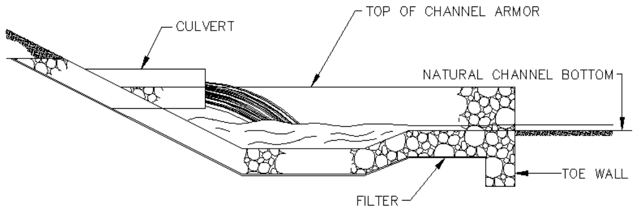


Figure 4-1. Depressed Type Plunge Basin Illustration

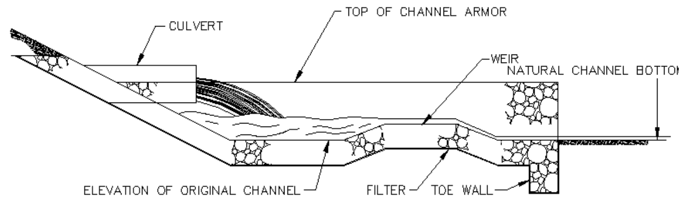
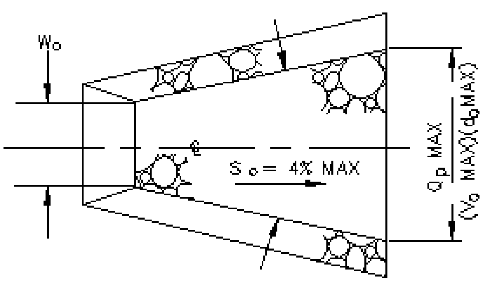


Figure 4-2. Weir-formed Plunge Basin Illustration

Splash Apron

A widened, flat, armored area, level to slightly sloping, located at the low-energy discharge point of conveyance structures and/or splash/plunge basins. Flow exiting this structure should enter a stream or vegetated outlet.



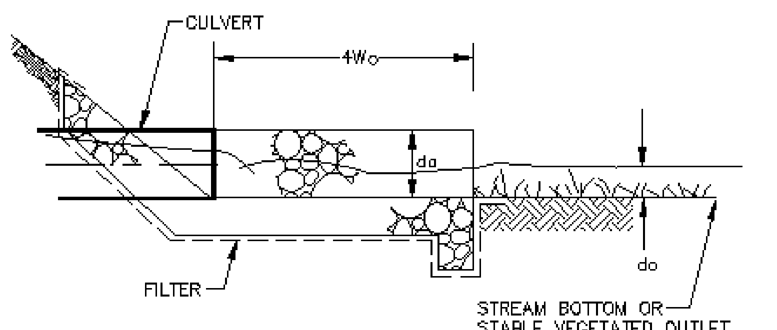


Figure 4-3. Splash Apron Illustration

As shown in figure 4-3, the structure's bottom dimensions taper from a narrow width at the conveyance structure discharge point to a wider dimension at the outlet some distance downstream. This spreads the water in a fanning action over the rough, armored surface reducing the velocity, and promoting sheet flow as the water exits into streams or onto vegetated

Exhibit 4.1a - Depressed-type energy dissipating basin at culvert discharge with transition apron to outlet channel.

Exhibit 4.1b - Depressed-type plunge basin at culvert discharge with transition apron to outlet channel.

Exhibit 4.1c - Weir-formed plunge basin at culvert discharge with transition apron to narrow outlet channel.

Exhibit 4.1 - Splash/Stilling/Plunge Basins

Exhibit 4.2 - Drop Inlet/Box/Manhole

Exhibit 4.3 - Stilling Well

areas. Armored side slopes are often necessary to prevent scour and erosion along the edge of the structure. The armor usually extends above and around pipe structures and blends into other conveyance structures to prevent scour and undermining at the discharge point. Toe walls may also be necessary where the structure outlets onto earthen surfaces. Armor material should be sized and/or classified to withstand the maximum design discharge velocities.

Drop Inlet/Box/Manhole

An enclosed structure, constructed or prefabricated from reinforced concrete, concrete blocks, bricks, plastic, or other sound structural material, which will receive the discharge end of a culvert, flume, ditch, etc., dissipate the energy, and safely release the discharged runoff at a lower elevation. See figure 4-4 below.

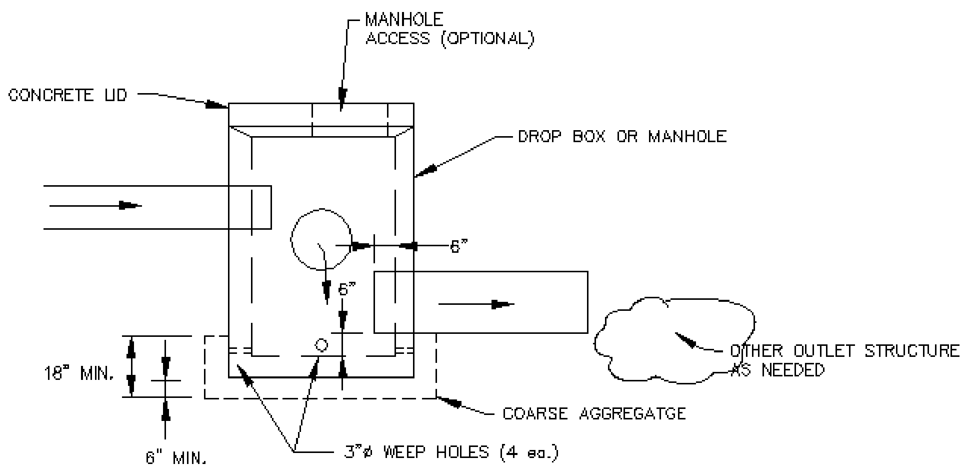


Figure 4-4. Drop Inlet/Box/Manhole Illustration

This structure works well where there is a severe cross-slope from one side of the road to the other and a cross-drain culvert is installed, or where there is a desire to reduce road ditch and flume slopes. This situation is often found where head cutting gullies have eroded up to the roadway. These structures require the design of a professional engineer.

Stilling Well

An enclosed structure, constructed or prefabricated from reinforced concrete, concrete blocks, bricks, plastic, or other sound structural material, which will receive the discharge end of a culvert or pipe, dissipate the energy, and safely release the discharged runoff at a higher level.

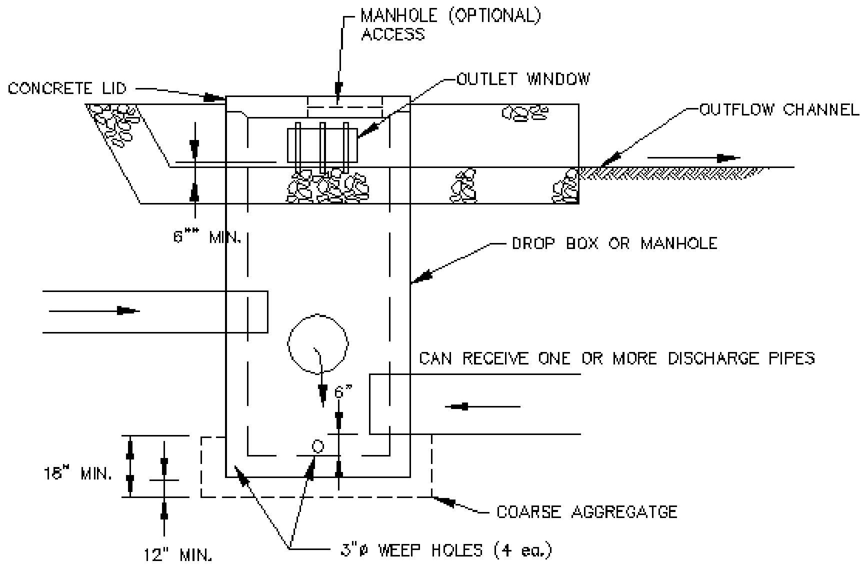


Figure 4-5. Stilling Well Illustration

a. To be used only at the singular outlet location of one or more pipes.

b. Use only when lowest pipe *inlet* invert will be higher than the outlet invert of the stilling well structure.

c. This structure works well in areas where energy dissipating structures are needed at the ends of pipes and there is limited space to install such structures. Also can be a cost-saving structure.

d. These structures require the design of a professional engineer.