Guidelines for Culvert Construction to Accommodate Fish & Wildlife Movement and Passage

Arizona Game and Fish Department, Habitat Branch

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Introduction/Background [(top)](#)

This document is intended as a general guideline to assist in the design, planning, and placement of culverts to minimize impacts to and ensure fish and wildlife passage and movement.

Culverts are used in road, bridge, and berm construction to prevent flooding and washing out of roads. They also minimize erosion, build-up of standing water, and provide pathways for run-off. Recent dramatic increases in urban, highway, and road development have increased interactions with wildlife and led to fragmented habitat. Each year in the United States, more than 200 motorists are killed and thousands more are injured in animal-vehicle collisions; property damage is measured in the millions, and billions of animals are injured or killed. Inadequate size, poor design, poor placement, and insufficient availability result in limited use or avoidance of culverts by wildlife and fish. Since hydrological structures may not be adequate, crossing structures developed specifically for wildlife passage are now being incorporated into roadway designs. Projects currently in the planning stages are now being developed to provide for drainage as well as fish passage and wildlife movement. Employing multiple-use designs allows planners proactively employ comprehensive strategies that incorporate watershed integrity, habitat connectivity, and provide cost savings by decreasing collisions, injuries to humans, and damage to vehicles.

General Recommendations [(top)](#)

When planning culvert use, consider designs that minimize impacts to fish and wildlife:

- Identify species in the area such as threatened or endangered or any Species of Concern as defined by state or federal agencies, paying attention to those with special culvert needs.

- Establish baseline data by monitoring fish and wildlife movements in the area in order to determine major crossing areas, behaviors, and crossing frequencies. This step is essential in designing a usable crossing structure.
- Identify the number of culverts needed to facilitate both water drainage, and fish and wildlife crossings.
- Minimize the number of times the road crosses a waterway, and avoid frequented by species known to be in the area.
- Identify structure shape and size needs for the species in the area; consider noise, temperature, light, moisture requirements and entrance cover (e.g., vegetation)of the various species potentially utilizing the structure.
- Construct culverts that are durable and able to withstand extreme flows and associated bed load and woody debris that accompany these flows.
- Fencing designed to accommodate multiple species should be installed to prevent ANY individuals from reaching the road.
- Culverts should be designed to maintain the dimension, pattern and profile of the stream geomorphology, minimizing negative impacts to that morphology.
- Construct culverts that accommodate upstream fish movement, provide for wildlife movements, and are wide enough to maintain consistent flow within the stream (i.e. bottom surface of structure should be flush with grade, no drop-offs or plunge pools, and no constriction of channel).
- Monitor and maintain culverts to ensure proper functionality (this may include clearing culverts of debris, maintaining fences, maintaining vegetation, removing invasive plant species, and ensuring structural integrity.)

Types of Structures (Top)

Different shapes and sizes of culverts may be required to accommodate the variety of species that inhabit an area. Although each species has different needs, some general design elements can ensure culverts are permeable for the many of species. The two types of culverts covered in these guidelines are pipe culverts and box culverts:

Pipe culverts are made of smooth steel, corrugated metal, or concrete material. Their primary purpose is to convey water under roads, although a variety of wildlife uses them as passageways. Pipe culverts typically range from 1- 6 feet in diameter and are the least expensive type of culvert. Round culverts are best suited to medium and high stream banks. Pipe-arch (squash) culverts provide low clearance, openings suitable for large waterways, and are more aesthetic. They may also provide a greater hydraulic advantage to fishes at low flows and require less road fill.

Box culverts are used to transmit water during brief runoff periods. They are usually dry for much of the year and are used by a variety of wildlife. They can have an artificial floor such as concrete, although this floor may be covered by sediment and/or native vegetation. Box culverts can also be designed to have an open bottom to maintain natural substrates. Box culverts generally provide more room for wildlife passage than large pipe culverts.

General Culvert Structure Design:

In general, culvert size depends on:

1) Area of drainage upstream from culvert (i.e. larger drainage areas will likely require larger culverts)
2) Volume and flow of peak run-off (suggest minimum 25-year run-off)
3) Average stream width, depth and gradient (slope) at the crossing site (i.e. water flow should be constant from upstream to downstream of culvert)
4) Amount of debris loading
5) Permanence of the culvert
6) Size and species of animals/fish expected to utilize the culvert for passage

- Culvert design and materials should not degrade water quality or repel animals and fish, therefore when installing culverts, make sure that materials used within the stream are clean, not prone to erosion and non-toxic to aquatic life.
- Research alternative concepts for construction; for example, geosynthetically-reinforced soil (GRS) is found to be easier to build, longer lasting, and less expensive than traditional retaining walls and abutments. Launched soil nails can be used to prevent more serious scour and eliminate the need for riprap and deep foundations. For further information on GRS and launched soil nails, refer to Barrett et al. 2003 (see references).
- Culverts should be long enough to span or even exceed the floodplain to minimize erosion and flooding.

Required culvert design elements essential for successful fish and wildlife use include:

1) Suitable Habitat (suitable habitat should occur at both ends and, where feasible, within the culvert)
2) Appropriate Size
3) Placement Near or Within Natural Movement Corridors (if known)
4) Minimal Human Activity
5) Funneling/Fencing
6) Wildlife Accessibility
7) Ongoing Maintenance and Monitoring
8) Natural Substrate
9) Lighting (e.g. installing grates or skylights at medians)

- Wide underpasses allow animals to have a broad viewing area making many individuals feel less vulnerable. However, some species prefer shorter, less open ecoducts making this culvert design ultimately contingent upon species life-history strategies.
- Give preference to crossing locations where streambed and banks are composed of firm, cohesive soils to minimize erosion.
- Maintain a natural substrate on the floor of the culvert.
- To facilitate both aquatic and terrestrial wildlife passage, culverts should be wide enough to span the stream to allow for some dry ground or an artificial ledge inside the culvert on one or both sides.

- Rip Rap is difficult for ungulates and amphibians to traverse, and should not be placed in front of or on the slopes adjacent to a passageway. If rip-rap is required, then it should be buried, back-filled with topsoil, and planted with native vegetation.

Placement of Structure:

- Placement of culverts should be near or within natural wildlife movement corridors.
- Install culvert parallel to the stream flow and perpendicular to the road it crosses to allow for line of sight and minimize the length of culvert the animal or fish will have to pass through.
- Lay culvert on the same slope (gradient) as the stream, but bury culvert about 17% (one-sixth of diameter) to provide a natural substrate that promotes animal use.
- Wildlife movement corridors often follow natural drainages and waterways.
- Use fencing to direct animals toward culverts.
- Fencing should be tied into edges of culverts with no gaps (ideally); fence tops should also bend away from the road to inhibit climbing and escape routes (e.g. ramps on the road side of the fence) should be included.
- Culverts across divided highways should be in a straight line to provide unobstructed views.

Construction Considerations:

- Construct during periods of low flow to minimize impacts to fish and wildlife and their habitat.
- Where practical, consider dewatering stream-crossing sites during culvert installation to minimize erosion and maintain stream water quality.
- During construction, minimize disturbance to the length of the natural stream channel and the natural flow of the water.
- Avoid use of multiple culverts placed side by side (design larger culverts instead).
- Remove temporary fills and structures when construction is complete.

Fencing:

Fencing is crucial to the success of a culvert because it guides/funnels animals to use the structure and minimizes road crossings and wildlife mortality. Culverts without directional fencing are often ineffective.

- To prevent animals from digging under fences (e.g. coyotes and deer); bury fences to a depth appropriate for the type of species in the area. See recommendations for large, medium, and small mammals, and amphibians and reptiles below.
- Fencing should be tied into edges of culverts with no gaps. If gaps must be present (i.e., due to cost prohibitions), fence ends should angle away from the road to help guide individuals away from the road at these gaps
- Minimize “natural ladders” adjacent to the fence which could facilitate an animal climbing over the fence (e.g. trees, large bushes, etc.) and fences should be equipped with tops angled away from the road.
- Fencing should extend on either side of the structure the entire length of the parcel boundary or just beyond a natural break in an animal’s ability to traverse the landscape and guide them to the culvert.

- Escape ramps should be constructed when extensive fencing is utilized on one or both sides of a culvert to prevent animals from being trapped on the road.
- Appropriate types and sizes of fencing should be selected based on species in the area; mesh-size should be used to accommodate all species size-classes (i.e. mesh-sizes small enough to prevent the smallest species from breaching the fence or getting stuck).

Openness Ratio:

Appropriate culvert size is determined by the size of animals using the structure, and the width of the road under which the culvert must pass. For example, as culvert length increases, the cross-sectional area of the culvert opening must also increase. You can determine if your culvert size is suitable by calculating the 'openness ratio' of the culvert, whereby:

Openness Ratio = (Culvert Height x Culvert Width)/Culvert Length

Example: The minimum openness ratio required for large mammals is 0.75 (see Large Mammals below for further details). If a culvert's dimensions are 15 feet high by 15 feet wide by 60 feet long, the openness ratio is 3.75; the culvert is probably suitable for large mammal crossings. Keep in mind that this is a rule of thumb and one size does not fit all; certain species need much larger openings before they will pass.

* **Below are some general recommendations for the types and sizes of culverts suitable for fish and wildlife. Keep in mind that the most suitable culvert design will differ depending on the species that require passage.**

Large Mammals (top)

This group includes species such as mountain lions, deer, bears, coyotes, wolf, elk, and bobcat. Large mammals generally stand at least 1.5 ft at the shoulder, and have a length of at least 2 ft (not including tail). As suggested by many studies, large mammals typically prefer large, open crossing structures, such as bridge underpasses and box culverts.

To be conducive for use by large mammals, culverts must:

- Be at least 6 feet high and likely larger depending on the species.
- Have an openness ratio of at least 0.75, but preferably 0.9.
- Be easily accessible.
- Have a fence height of approximately 8 ft to prevent large animals from jumping or climbing over. In addition, studies recommend chain link or woven wire fencing for large mammals.

Studies indicate that an open field of view must exist in order for large mammals to use a culvert. A large mammal is more likely to pass through a culvert if suitable habitat is clearly visible on the other side. The need for an open field of view also correlates with the preference for a large openness ratio.

Structural Dimensions:
Data indicates preferences for structures that are taller in height, shorter in length, with larger cross-sectional areas and openness ratios. In general, the cross-sectional area of the structure entrance should become larger as the length of the structure increases to maintain a minimum openness ratio of 0.75. For a typical two-lane road (approximately 30 ft wide), the cross-sectional area of the structure opening should be 22 sq ft to accommodate a large mammal. For a typical four-lane road (approximately 60 ft wide), the cross-sectional area of the structure opening should be 45 sq ft for a road with six or more lanes (75 ft or wider), the cross-sectional area of the structure opening should be 60 sq ft.

Locating culverts near natural travel corridors is crucial to successful use of these structures by wildlife. For carnivores, this means placing the structures close to stream corridors or drainages, as these areas are frequented by prey and are commonly used by carnivores for travel. Wolves and bears are more likely to use culverts where there is no sign of human activity nearby. Distance from humans is the most important consideration in designing crossing structures for large carnivores. For ungulates, ensure there is a clear view of the structure's entrance and exit with no overhead ledges.

Medium Mammals (top)

This group includes species such as javelina, opossum, skunk, raccoon, fox, and rabbit. Medium mammals generally range in height between 6 inches to 1.5 ft at the shoulder, and range from 16 inches to 2 ft in length. Most studies suggest that medium mammals may tend to prefer box or pipe culverts.

To be conducive to use by medium sized mammals, culverts must:
- Be at least 3 feet high depending on the species.
- Have an openness ratio of at least 0.4.
- Be easily accessible.
- Have natural vegetation surrounding the approach and entrances.
- Have a fence height of approximately 3-6 ft to prevent medium mammals from jumping or climbing over. A fence material such as chain link is suggested.

Structure Placement:
Structures should be placed with a frequency that corresponds to the spatial scale over which targeted species move because medium sized mammals have smaller ranges. If the area designated to facilitate wildlife crossings encompasses more than a ½ mile of roadway, structures should be incorporated every 500 to 1,000 ft.

Structural Dimensions:
Medium mammal preferences are generally for structures that are taller in height, shorter in length, with larger cross-sectional areas. The cross-sectional area of the structure entrance should become larger as the length of the structure increases to maintain a minimum openness ratio of 0.4. For a typical two-lane road (approximately 30 ft wide), the cross-sectional area of the structure opening should be 12 sq ft to accommodate a medium mammal. For a typical four-lane

road (approximately 60 ft wide), the cross-sectional area of the structure opening should be 24 sq ft. For a road with six or more lanes (75 ft or wider), the cross-sectional area of the structure opening should be 30 sq ft.

Small Mammals (top)

This group includes species such as squirrels, prairie dogs, rats, voles, and mice. Small mammals are generally a few inches high and up to 16 inches long. Most studies suggest small mammals will utilize a mixture of small pipes, box culverts, or pipe culverts.

To be conducive to use by small mammals, culverts must:

- Be at least 1 foot high, depending on the species.
- Provide low stature natural vegetation surrounding the approach and entrances.
- Be easily accessible.
- Have a fence height of at least 3-4 feet to prevent small animals from jumping or climbing over. Studies recommend impenetrable mesh as the most appropriate fencing material for small mammals.

Structure Placement:
Since many smaller animals are less mobile than medium or large mammals, movement corridors may be defined on a much smaller scale. Consequently, travel distances between structures may influence use by small mammals. This suggests that smaller structures should be placed with a frequency that corresponds to the spatial scale over which targeted species move. As a result, studies specify the importance of high frequency of structure placement for small mammals, generally at least every 150 - 300 ft.

Structural Dimensions:
Generally, the literature recommends smaller cross-sectional areas and openness ratios are more appealing for small animals. A cross-sectional area of 2 to 4 sq ft for the structure entrance is recommended for small mammals.

Interior Cover:
Small mammals usually prefer some type of low cover on the interior of the structure to function as protection from predators. Typically, small mammals will pass through a structure along the interior wall because it may feel more protected. Vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, will provide small animals with cover from predators, encouraging them to pass through a structure. However, any cover substrate placed inside the culvert should not impede flood flow (if the primary design is for draining) as this could ultimately damage the structure and hinder long-term wildlife connectivity.

Bats (top)

The Department recommends that project coordinators consider design elements that allow the use of culverts by bats because such structures have been identified as suitable habitat. Bats typically use concrete box culverts when they are located in relatively warm areas.

To be conducive for use by bats, culverts must:

- Have dimensions between 5 and 10 feet tall and be preferably 300 feet or more long, with openings protected from high winds.
- Not be susceptible to flooding.
- For roosting, provide inner areas that are relatively dark with roughened walls or ceilings, and have crevices, imperfections, or swallow nests.
- Be retrofitted with rough-textured concrete forms.
- Incorporate bat domes that provide suitable roosting habitat.

Refer to the Bat Conservation International (BCI) handbook (Bats for American Bridges) for specific information regarding bat use of culverts.

Amphibians & Reptiles (top)

This group includes species such as frogs, toads, salamanders, turtles, lizards, snakes, and tortoises. Although amphibians/riparian reptiles have been known to use a mixture of crossing structure types, most studies suggest riparian amphibians and reptiles tend to prefer small pipes, as well as box or pipe culverts with natural substrates while upland amphibians and reptiles prefer box culverts. Larger crossing structures (bridges) can be modified to accommodate amphibian and reptiles by incorporating smaller tunnels along the sides of the crossing structure.

To be conducive to use by amphibians and reptiles, culverts must:

- Be at least 1 foot high depending on the species.
- Provide low stature natural vegetation surrounding the approach and entrances of a culvert.
- Be easily accessible.
- When possible have a moist substrate for riparian species or a sandy substrate for reptiles.
- Have an open top fitted with an open grate positioned flush with the road surface. The grate should allow for adequate rain, light, and air circulation (for riparian species).
- Be placed frequently along the road through relevant habitat. Frequency of placement depends on species in area (see structure placement below).
- Have a fence height of approximately 1.5 to 2.5 ft with a preventative fence top, such as a lipped wall or overhang (6 in. wide) to prevent amphibians & reptiles from jumping or climbing over.

Opening Cover:
Amphibians and riparian reptiles are prey species and rely on low stature cover for protection from predators. If low stature cover around the structure entrance is absent, these animals may be reluctant to enter. Furthermore, preserving the natural vegetative cover is important for maintaining habitat continuity.

Structure Placement:
Culverts are generally placed at streams; however, for many amphibians and reptiles, movements and migrations are not associated with streams, but rather, between upland and wetland areas.

Travel distance to the culvert can be an important factor in facilitating movement of amphibians/riparian reptiles. Although there is evidence mammals can learn to use culverts and may transfer this knowledge to future generations, this is unlikely for amphibians and reptiles. Smaller structures, such as pipes and culverts, should be placed with a frequency that corresponds to the spatial scale over which the targeted species moves. Structures should be placed at least every 150 to 300 feet.

Funneling/Fencing:
Impenetrable materials to use include galvanized tin, aluminum flashing, plastic, vinyl, concrete, or a very fine mesh. Snakes and tree frogs have been observed climbing vegetation along funneling mechanisms. Therefore, monitoring and removal of vegetation along fences is suggested to ensure passage through the structure.

Structural Dimensions:
Generally, amphibians and reptiles utilize both concrete box culverts and metal structures such as pipes provided the appropriate internal habitat is present.

Internal Habitat:
Riparian amphibians and reptiles will readily use a culvert with a natural substrate, if it has adequate moisture and hiding cover that functions as protection. Culverts that accommodate amphibians and riparian reptiles must maintain moist travel conditions, without creating standing water or flooded conditions; standing water prevents most species from utilizing a structure. Therefore, proper drainage of the culvert is another important consideration. In larger culverts, maintaining or replicating streambed conditions facilitate use by amphibians and riparian reptiles. Slotted drain culverts are proven to be successful in maintaining proper moisture and drainage, while also providing ambient light.

Upland reptiles will readily use culverts with a natural or fabricated substrate if it has adequate hiding cover that functions as protections from predators.

Both upland and riparian reptiles and amphibians prefer low stature vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks as cover for passage. Ongoing maintenance of these structures to clear debris and maintain openness is essential.

Fish (top)

Fish generally prefer open-box culverts to pipe culverts.

To be conducive to use by fish, culverts must:
- Maintain a constant grade along the length of the culvert, and avoid large drops at culvert entrances.
- Accommodate both juvenile and adult fish.
- Maintain water flows through culverts that do not exceed flows in the natural stream.
- Maintain water depth within the culvert similar to those in the natural stream.

- Minimize turbulence and flow contraction at culvert inlets because turbulence inhibits or prevents animal passage.
- Allow upstream fish passage.

Structure Placement:
Culvert alignment should be similar to that of the natural stream – a culvert with an extreme skew (>30º to the stream) will affect the success of fish passage by increasing contraction and turbulence. In-channel deposition and bank scour will also often occur, leading to stream degradation. Culverts that are not skewed may be considerably longer than one that is skewed.
Drops greater than 2-4 inches or scour pools will obstruct upstream and downstream fish passage.

Structural Dimensions:
Culvert dimensions should not change the cross-sectional area of the stream channel or impede fish migration. Culvert design should also provide bank-edge areas within the culvert that weak-swimming organisms can utilize.

Internal Habitat:
Ensure water depths are sufficient to allow passage of fish and other aquatic organisms during all seasons. Construct culvert bottoms with natural stream substrates and design a channel in the bottom of the culvert to provide fish passage during low-water periods.

Multiple Animal Type Use (top)

Multiple group recommendations
These recommendations are intended to provide the most desirable culvert characteristics for multiple groups of species.

Funneling/Fencing:
Appropriate funneling mechanisms vary widely across groups of animals. To accommodate several species, a fine mesh wire fence or flashing is often applied to the bottom one-third to one-half of a taller fence to prevent both small and large animals from accessing the road right-of-way. Additional measures include combining fencing for large mammals along the road with lipped walls for amphibians and reptiles along the banks for the structure entrance.

Structure Approach:
Vegetation surrounding the approach to the structure is an important consideration when designing for multiple species. While some level of natural vegetation is important to maintain habitat continuity, the type of vegetation can play an important role in culvert use. Most small mammals, amphibians, and reptiles prefer low stature cover in the form of vegetation, rocks, and logs to protect them from predators. Medium and large mammals that are prey species (rabbits, deer) may be wary of using structures with extensive vegetation where predators can hide. Eliminating potential predator ambush opportunities, while providing good visibility for medium and large mammal prey species, will encourage use of a culvert.

Structure Design:
While considering the variety of internal habitats preferred by different animal groups, it is not surprising specific design elements for particular species may be contradictory. For example, open-top culverts may provide favorable lighting, temperature, and moisture conditions for amphibians but may be too noisy for some mammals. Structures can be designed to facilitate multiple groups by incorporating design elements preferred by each. For instance, a large bridge underpass designed to facilitate the movement of large mammals could also accommodate small mammals by incorporating low stature vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, in the interior of the structure. Similarly, a structure could accommodate small mammals, amphibians, and riparian reptiles by maintaining moisture in the bottom of the structure but also providing a dry elevated ledge or animal access shelving. Alternatively, multiple structures in the same area could be incorporated to accommodate several groups. Large box culverts that accommodate large and medium mammals could be flanked by smaller pipes on both sides to accommodate smaller mammals, amphibians, and reptiles. This option addresses the need for different light, noise and moisture needs particularly well. Ultimately, there is no simple single approach. A variety of alternatives can and should be explored, with particular attention paid to local threatened and endangered species, and known wildlife and fish migration corridors. A structure that incorporates as many design elements as possible will most likely be the most successful at accommodating wildlife movement.

Post Construction & Monitoring (top)

Following culvert installation, there are several measures that can be taken to ensure continued effectiveness of the culvert and use by fish and wildlife. These include:

- Installation of traffic control measures (animal crossing signs).
- Monitor structures to ensure they are clear of obstructions such as detritus or silt blockages that impede movement.
- Monitor fencing to minimize duration of any breaches that may compromise wildlife connectivity.
- Monitor and evaluate effectiveness of culvert as a fish and wildlife crossing and make appropriate adjustments if necessary (e.g. Retrofit fencing or other modifications), and coordinate and report findings to fish and wildlife management agencies.
- Evaluate culvert impacts on erosion, and riparian areas to ensure habitat integrity.

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