

1.1 What Are Low-Water Crossings?

Words shown in bold throughout this document are defined in the glossary

Three main types of crossing structures are designed to be submerged at some flows: (1) **unvented (simple) fords**, (2) **vented fords**, and (3) **low-water bridges**. Because basic designs require tailoring to individual site requirements and locally available materials, many variations of each of these basic types of low-water crossing structures were developed over time. Figure 1.1 shows the basic low-water crossings types.

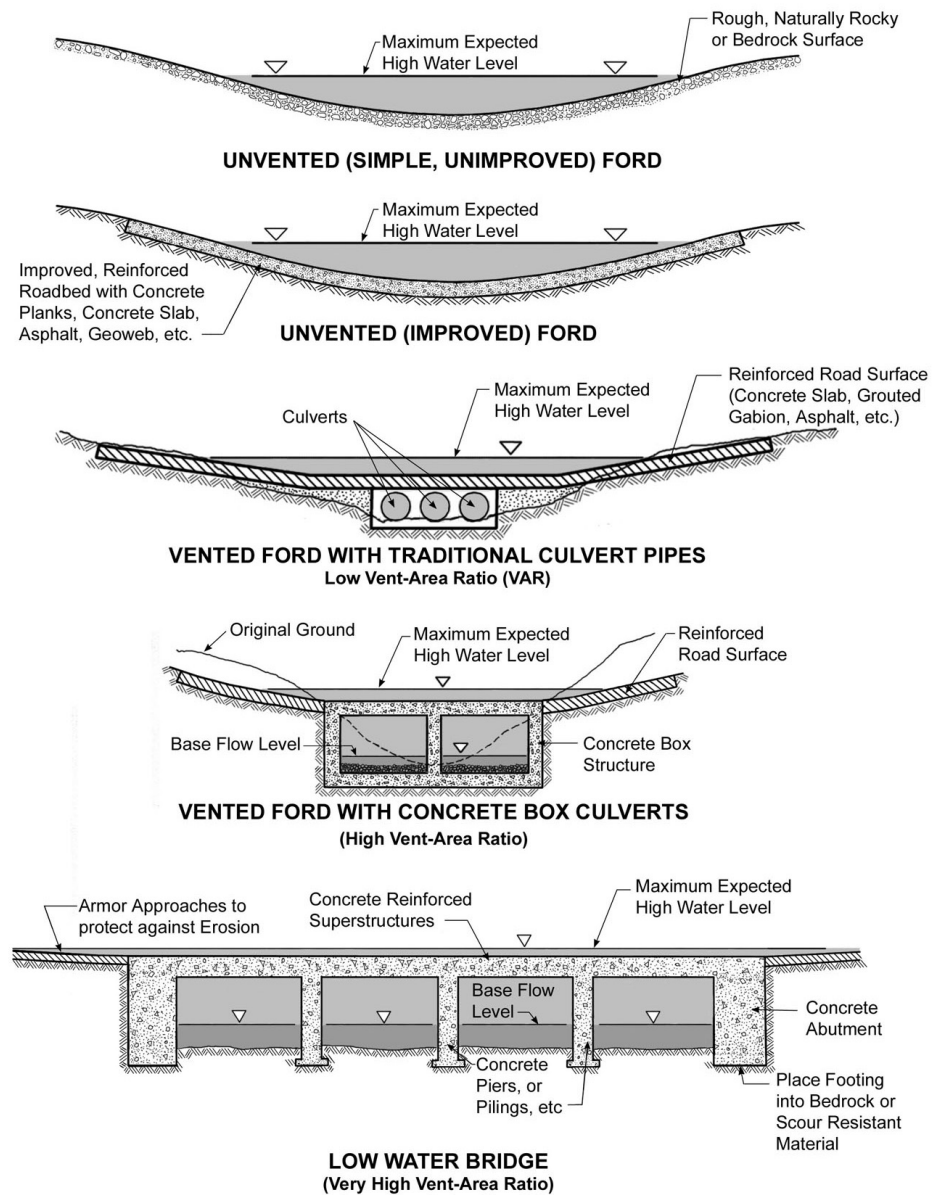


Figure 1.1—Basic low-water crossing types.

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Unvented or simple fords cross streams at or slightly above the elevation of the streambed without pipes (vents). Unvented fords fall into two categories—unimproved and improved.

Unimproved fords are simply natural crossings. Figure 1.2 shows an example of an unimproved ford.



Figure 1.2—Unimproved ford on the Fishlake National Forest, Utah.

Improved fords have a stable driving surface of rock, concrete, asphalt, concrete blocks, concrete planks, **gabions**, **geocells**, or a combination of materials (fig. 1.3). Sometimes a small channel or slot is included at the structure's low point to pass very low flows and aquatic animals. The downstream roadway edge may be stabilized and defined with logs, riprap, gabions, or **Jersey barriers**.

Vented fords have a driving surface elevated some distance above the streambed with culverts (vents) that enable low flows to pass beneath the roadbed. The vents can be one or more pipes, box culverts, or open-bottom arches. In streams carrying large amounts of debris, the driving surface over the vent may be removable, permitting debris to be cleared after a large flow event.



Figure 1.3—Improved ford on an ephemeral tributary of the Agua Fria River, Arizona.

Vented fords fall into two categories—low **vent-area ratio (VAR)** and high VAR—each of which affects stream channels differently (fig. 1.4).

Vented fords with culverts that are small relative to the **bankfull** channel area have a low VAR.

A vent opening that approximates or exceeds the size of the bankfull channel has a high VAR.

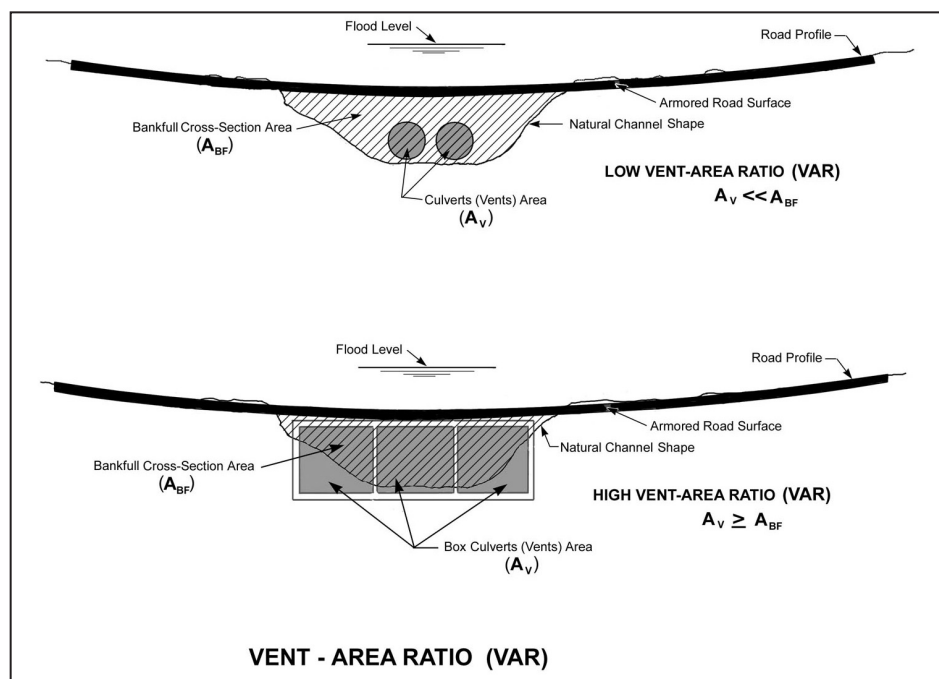


Figure 1.4—VAR-ratio definition sketch.

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Bankfull is the flow that just overtops the streambanks and begins to flow out over the **flood plain** (fig. 1.5) (Leopold et al. 1964, Leopold 1994). In many areas of the United States, flow approaches or exceeds bankfull on average once every 1 to 2 years. Generally this frequent high flow is considered to do much of the work of rearranging streambeds and maintaining aquatic habitats by transporting and depositing sediment and woody debris.

For information on identifying bankfull, see the two-DVD set *Identifying Bankfull Stage in the Eastern and Western United States*. It is available on the USDA Forest Service Stream Systems Technology Center Web site.

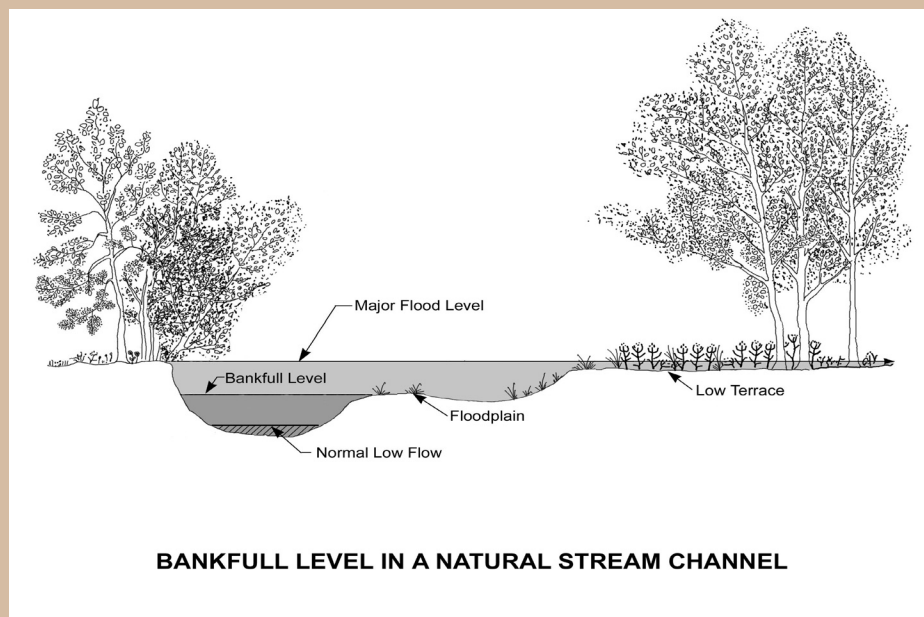


Figure 1.5—Bankfull level in a natural stream channel.

Figure 1.6 illustrates the difference between high- and low-VAR fords. The California example (fig. 1.6A) is an old structure that mostly blocks the bankfull cross section area. The Arkansas vented ford (fig. 1.6B) was constructed in 2004 with the express goal of allowing fish and sediment passage.



Figure 1.6—(A) Low-VAR ford on the Eldorado National Forest, Northern Sierra Nevada, California. (B) High-VAR ford on the Ouachita National Forest, Arkansas. Note that this site is on a curve and needs safety warning signs.

A common type of high-VAR ford is a series of box culverts that approaches or matches stream width and bankfull depth (figs. 1.6B and 1.7). These structures typically look like bridges and, where the bottoms are embedded, can be mistaken for bridges. High-VAR fords may not significantly obstruct flow until the water surface rises to the top of the structure.

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Figure 1.7—High-VAR ford composed of three box culverts, Mark Twain National Forest, Missouri.

In this publication, we define *low-water bridges* as open-bottom structures with elevated decks and a total span of at least 20 feet (fig. 1.8). They may be designed with one or several piers. Low-water bridges generally have greater capacity and are able to pass higher flows underneath the driving surface than most vented and unvented fords. As with fords, however, low-water bridges are designed and installed with the expectation they will be under water at higher flows. “Forest Service Manual” (FSM) 7720 (Transportation System Development) requires all structures receive specific hydrologic, hydraulic, structural, and foundation design in accordance with the American Association of State Highway Transportation Officials (AASHTO) “Standard Specifications for Highway Bridges.” A qualified engineer must design the low-water bridge and review the completed structure.



Figure 1.8—Low-water bridge at Boiling Springs, Big Piney River, Missouri.

1.2 Potential Benefits of Low-Water Crossings

Choosing the type of structure for any crossing is highly site-dependent. Depending on the site, the main advantages of low-water crossings over culverts and bridges may include the following:

- Lower construction and maintenance costs.
- Less channel and flood plain blockage.
- Adaptability.
- Stormproofing.

Cost

Low-water crossings are generally less expensive to construct. More often than not, designs are less complicated, construction is quicker, and fewer materials are involved. Although the initial cost of more complex low-water crossings may exceed those of simple culvert installations, the lower long-term maintenance and repair costs may still make selecting a low-water crossing more economical.

Low-water crossings may also make sense when there is little funding for structure condition monitoring and maintenance, especially on roads with yearlong or seasonal closures. Unvented fords are more reliable in passing peak flows than culverts (which can plug with debris), and usually require less maintenance than other structure types (Doyle, personal communication; Warhol 1994; Warhol and Pyles 1989). Economic evaluation should take into consideration all lifecycle costs including maintenance, repairs, user costs, and the cost of environmental impacts.

Channel and Flood Plain Blockage

When streamflow approaches the design capacity of a crossing structure, water tends to pond upstream of the inlet, causing sediment deposition and often bank erosion. The less a crossing structure blocks the channel during sediment-transporting flows, the more it can avoid these effects. Unimproved at-grade fords and low-water bridges generally have the least potential for impeding flow and sediment transport through a crossing.

On broad flood plains, road approaches must **ramp up** to a high-profile bridge or large culvert, damming the flood plain to some degree. Unless drainage through the roadfill is provided for, the roadfill obstructs the downstream transport of water, wood, and sediment across the flood plain during large floods, reducing the erosional and depositional processes that create diverse flood plain habitats. Road approaches to low-water crossings can be low across the flood plain and generally dip down toward the stream, minimizing any impairment of flood plain processes.

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Adaptability

Simple low-water crossings like unvented fords are useful in naturally unstable channels such as alluvial fans and braided streams, or in channels with extreme flow variations. Because they obstruct flows less than most culverts, they are less likely to cause flow diversions or accelerations both of which can exacerbate a channel's inherent tendency toward instability. They can also be inexpensive to reconstruct in a new location if the channel does move.

Stormproofing

At ordinary culvert crossings, streamflow can back up when the culvert plugs or when its capacity is exceeded during a flood. If this happens where the road surface or ditch slopes away from the crossing, water can run down the road or ditch before breaking over the roadfill, and it can cause major erosion on receiving slopes and channels (Flanagan and Furniss 1997). Because fords are shaped as dips in the road profile, water is likely to stay in the channel rather than diverting down the road or ditch. Well-designed overtoppable structures avoid the roadfill failures that occur during large floods when deep roadfills over culverts are breached. The types of structures appropriate for these incised channel locations are, however, limited (case study 16).

For the same reasons, low-water crossings are very useful in watersheds that have experienced severe disturbances and where substantial mobilization of rock and woody debris is expected.

Other Possible Functions

Like other crossing structure types, low-water crossings can be designed to do the following:

- Enable passage of **aquatic organisms**.
- Protect endemic species from invasive competitors.
- Provide a **grade control** in an incised stream system for protection or restoration of upstream reaches.

Many low-water crossings and culverts create passage problems for aquatic organisms. For this reason, the current trend is designing both culverts and low-water crossings to provide passage for as many of the local species as possible (section 4.3).

Conversely, the survival of a native population may depend on preventing an exotic species from invading new habitats. Although exclusion was usually an unintentional effect of existing road crossings, crossings can be designed as barriers. This choice, however, requires careful consideration

(Fausch et al 2006). Exclusion can also prevent nontarget species from accessing their habitats, possibly putting their populations at risk over the long term.

Like culverts, low-water crossings can function as grade-control structures in situations where a **headcut** is moving upstream. In these situations, it may be necessary to provide alternative passage for aquatic organisms. For more information on headcuts and channel **degradation**, see Castro (2003). Case study 15 is a good example of a vented ford with a fish ladder used as a grade control.

The following list summarizes the general advantages and disadvantages of low-water crossings. Individual structures may or may not exhibit these characteristics depending on how well they are designed to fit their sites.

Advantages of low-water crossings are as follows:

- Structures designed for overtopping.
- Less likely than culverts to be damaged by debris or vegetation plugging.
- Typically less expensive structures than large culverts or bridges.
- Less susceptible than other structures to failing during flows higher than the design flow.
- Good for “stormproofing” roads where large amounts of sediment and debris are expected, like after a large storm event or forest fire.

Disadvantages of low-water crossings are as follows:

- Have periodic or occasional traffic delays during high-flow periods.
- Are not well-suited to deeply incised drainages.
- Are typically not desirable for high use or high-speed roads.
- Can be difficult to design for aquatic organism passage.
- Can be dangerous to traffic during high-flow periods.
- Can be dangerous to boaters and other recreational users.

