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Guidelines for Replacement of Deficient Bridges with Low-Water Stream Crossings in the Rural Midwest

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Site assessment guidelines consider traffic, access, roadway, stream, and regulatory issues. LWSC options can be limited by conditions on federal and state-issued permits, particularly those concerning threatened and endangered species and historic resources, and by local floodplain regulations. Key design considerations are presented for LWSCs in general and for unvented fords, vented fords, and low-water bridges in particular. These considerations include roadway design issues, stream hydrology, aquatic organism passage at low flows, and debris passage and scour and erosion protection at high flows.

Nine recent LWSC projects in Kansas are examined in detail. The structures include an unvented ford, a hybrid-type ford, three vented fords, a low-water box culvert, a low-water bottomless culvert, and two low-water bridges. Eight of the projects are completed and one has been delayed by regulatory issues. Each case study includes a description of the structure and relevant information on the crossing history; road and traffic characteristics; stream characteristics and hydrology; governmental permits and regulatory issues; project costs; and maintenance requirements and performance to date.

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Abstract

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Site assessment guidelines consider traffic, access, roadway, stream, and regulatory issues. LWSC options can be limited by conditions on federal and state-issued permits, particularly those concerning threatened and endangered species and historic resources, and by local floodplain regulations. Key design considerations are presented for LWSCs in general and for unvented fords, vented fords, and low-water bridges in particular. These considerations include roadway design issues, stream hydrology, aquatic organism passage at low flows, and debris passage and scour and erosion protection at high flows.

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1.1 Introduction

In the rural Midwest, many county-owned bridges are structurally deficient or functionally obsolete and in need of replacement or closure. Rural counties generally cannot afford to replace every deficient bridge with an equivalent structure and may face the choice of closing the road or replacing the bridge with a more economical low-water structure. A low-water stream crossing (LWSC) is a structure that is occasionally overtopped by floodwaters and is likely to be impassable for a few hours or days in a normal year. LWSCs are sometimes constructed to keep very low-volume roads open when the cost of a normal bridge or culvert cannot be justified. The lower initial cost of an LWSC must be balanced against the maintenance requirements and safety considerations.

Figure 1.1: Recently Closed Steel Truss Bridge in Osborne County, Kansas

Local government officials and transportation engineers must assess the practicality of replacing a deficient bridge or large culvert with a low-water structure. This report provides useful guidance for evaluation of the site, selection of the replacement structure, preliminary design, permitting, and other issues. Further guidance on a variety of LWSC-related issues can be found in reports published by the U.S. Army Corps of Engineers (USACE, 2011), the U.S. Forest Service (Clarkin, Keller, Warhol, & Hixson, 2006), Iowa State University (McDonald &

Anderson-Wilk, 2003), and the Federal Highway Administration (Motayed, Chang, & Mukherjee, 1982a & 1982b). These reports are all readily accessible online at no cost.

Safety is a key consideration with low-water crossings. Over half of all flood-related drownings occur when a vehicle is driven into flood waters. Drivers may not be able to judge the depth of water over the roadway. A 6-inch depth of water can cause a car to stall or cause the driver to lose control (National Weather Service, 2010). Twelve inches of flowing water can displace a passenger car, and 18 to 24 inches of flowing water can displace most light trucks and sport-utility vehicles. Low-water crossing structures have no guardrails to hold a displaced vehicle on the roadway. Roadways can be badly damaged by flooding, and the damage may not be visible to drivers. The risk of accidentally driving into flood water increases after dark. These concerns limit the use of low-water crossings at some locations.

1.2 Types of Low-Water Crossings

The term “low-water stream crossing” encompasses a wide variety of structure types ranging from simple fords to open-span bridges. Only permanent structures that would be used on public roads are considered here. These structures can be categorized in various ways. This report distinguishes five categories of LWSCs: unvented fords, vented fords, low-profile culverts, low-profile bottomless culverts, and low-water open-span bridges.

1.2.1 Unvented Ford

Unvented fords are structures constructed at or just above the streambed level where all streamflow passes over the roadway. The ford and the approach sections are typically constructed of reinforced concrete. Cut-off walls of reinforced concrete or sheet pile may be needed to prevent the stream undermining of the roadway slab. Unvented fords work best on ephemeral streams with small drainage areas, low banks, and beds of rock or cobble.

Figure 1.2: Unvented Ford on an Ephemeral Tributary of the Agua Fria River in Arizona
Source: Clarkin et al. (2006)

1.2.2 Vented Fords

A vented ford is a ford with one or more conduits beneath the roadway to convey very low flows. The vents are typically circular, elliptical, arch-shaped, or rectangular conduits made of concrete, corrugated metal, or high-density polyethylene (HDPE). Vented fords tend to trap woody debris and can require frequent maintenance. Vented fords can also restrict aquatic organism passage. Installing the flowlines of the vents below the streambed and using larger vents may mitigate this impact to some extent. Federal environmental regulations have made it difficult to obtain permits for vented fords in some locations, particularly where threatened or endangered aquatic species may be present. The ford and the approach sections are typically constructed of reinforced concrete. A low roadway profile is preferred to minimize backwater effects and reduce debris accumulation. Vented fords work best on ephemeral or intermittent streams with small drainage areas and low banks.

Figure 1.3: Vented Ford in Kiowa County, Kansas

1.2.3 Low-Profile Box Culverts

A low-profile box culvert is overtopped much more often than a culvert designed for higher volume roads or critical routes. The roadway surface is typically no higher than the channel banks. Headwalls and wingwalls retain the embankment and roadway, toe walls protect the structure from undermining, and rock riprap protects the embankment from erosion. The floor of the culvert should be placed below the stream bed to facilitate aquatic organism passage. Culverts with total clear spans over 20 feet are classified as bridges and are subject to federal bridge inspection requirements.

Figure 1.4: Low-Profile Box Culvert in Shawnee County, Kansas

1.2.4 Low-Profile Bottomless Culverts

Bottomless culverts can be three-sided box culverts or semi-circular, semi-elliptical, or arch-shaped structures of reinforced concrete or corrugated metal. A variety of precast concrete and prefabricated metal structures are available. Bottomless culverts are better for aquatic organism passage than non-embedded pipes or box culverts. From a hydraulic standpoint, a bottomless culvert is no different than a culvert with an embedded bottom. However, a bottomless culvert may have less structural strength than an enclosed conduit and is more susceptible to undermining by scour. Consequently, a bottomless culvert requires a more substantial foundation. The type and cost of the foundation depends on subsurface conditions. A geotechnical investigation is needed to determine the appropriate type of foundation. If a firm rock layer is present at a shallow depth, the structure can be supported on spread footings keyed into rock; otherwise, a deeper pile foundation might be needed.

Figure 1.5: Low-Profile Bottomless Culvert in Johnson County, Kansas

1.2.5 Low-Profile Bridge

A low-profile bridge is a stream-spanning structure designed to be overtopped much more often than a standard bridge. The roadway surface is typically lower than the tops of the channel banks. Because guardrails can trap floating debris, low-profile bridges typically have no guardrails. The foundation requirements for a low-profile bridge are the same as for a standard bridge. The abutments must be protected against scour and erosion from frequent pressure flow resulting from flow impingement on bridge superstructure elements. Like other low-water structures, low-profile bridges require inspection and maintenance after overtopping events.

Figure 1.6: Low-Profile Open-Span Bridge in Geary County, Kansas

Figure 1.7: Low-Profile Open-Span Bridge in Sumner County, Kansas

Chapter 2: Site Assessment

2.1 Introduction

Many issues must be considered carefully before deciding to replace a bridge with a low-water crossing. These issues include safety concerns, the acceptability of occasional service disruptions, and maintenance demands and costs. In many cases, a low-water crossing may not be an appropriate alternative to bridge replacement. A preliminary site assessment will help determine suitable options.

2.2 Traffic and Access

Low-water crossings may be impassible several times a year for hours at a time. For this reason, LWSCs should be considered only on roads with very low traffic volumes. An average annual daily traffic (AADT) of 10 or less is ideal. A higher AADT may be workable in some cases. Low-water structures are generally not recommended for critical routes such as school-bus or postal routes or routes used regularly by emergency service vehicles. A crossing that provides the only access to one or more residences or businesses is generally not a good candidate for a low-water structure. Where an alternative route is available, the extra distance of travel should not be excessive. Sites and conditions vary, but 10 miles is suggested as a reasonable upper limit and 5 miles or less is preferable. The detour length affects safety as well as convenience. Drivers might be tempted to cross through flowing water to avoid a long detour.

2.3 Roadway Characteristics

Low-water crossings should be considered only where drivers would have ample time to observe flooded conditions and stop safely before entering the crossing. Low-water structures should not be used on paved roads because drivers traveling at higher speeds have less time to see and react to flooding. The roadway alignment should be such that the crossing is illuminated with headlights from a safe distance. Appropriate signage alerting drivers to the possibility of a flooded crossing is essential.

2.4 Stream Characteristics

Stream characteristics relevant to site assessment include the amount, variability, and velocity of streamflow, the depth and stability of the channel, and the amount of debris transported at high flows.

2.4.1 Streamflow

Streams are generally classified as perennial, intermittent, or ephemeral based on the regularity of streamflow. Perennial streams flow continuously in normal years and go dry only during periods of severe drought. Intermittent streams flow continuously during periods of wet weather and cease to flow during prolonged periods of dry weather. Ephemeral streams are usually dry, and flow only briefly during and immediately following periods of rainfall over the watershed.

The streamflow regime may limit LWSC options. Unvented fords should not be considered for crossings of perennial and intermittent streams because even shallow flow over the roadway can result in slippery conditions from buildup of biofilm, silt, or ice. Vented fords are generally not appropriate for perennial streams and some intermittent streams because they may restrict aquatic organism passage and are prone to clogging with debris. Low-water box culverts, bottomless culverts, and bridges may be used on perennial, intermittent, and ephemeral streams.

2.4.2 Channel Depth and Stability

Low-water structures work best at crossings where the stream is stable and not deeply entrenched. (An entrenched stream is a stream that rarely if ever overtops its banks. A non-entrenched stream overtops its banks one or more times in most years.) A location that exhibits active degradation or aggradation of the streambed or instability or lateral shifting of the banks is not a good candidate for a low-water structure. Streambed degradation can undermine the structure, aggradation can diminish the area of the waterway beneath the roadway, and lateral shifting can wash out the approach on one side.

The stream should be investigated for stability for some distance upstream and downstream of the crossing. Any changes affecting the channel’s plan or profile or the flow of water or sediment either upstream or downstream of the crossing may eventually lead to channel instability at the crossings. Examples of such changes leading to instability include channelization, cut-off of meanders, clearing of riparian areas, and construction or removal of watershed dams. Any instability observed downstream may propagate upstream and eventually affect the crossing. Any lateral migration of the channel upstream of the crossing may introduce culvert-clogging sediment and debris into the channel.

Unvented and vented fords are particularly ill-suited for deep crossings. The grades of the approaches to a low-water crossing generally should not exceed 10%. Steeper approaches can be difficult to traverse under icy conditions. Deep crossings require long approaches and wide cuts. Additional right-of-way may be needed to accommodate the width of the cut. Deep approaches and associated side-slopes can be excessively wide, requiring additional right-of-way. Deposition of sediment on the approaches is a common problem. Sediment removal may be needed after each high-flow event.

2.4.3 Debris

The amount of woody debris or crop residue that a stream carries at high flow is also an important consideration. Unvented fords and low-water box culverts, bottomless culverts, and bridges may trap floating debris. The accumulation of debris starts at the water-surface level and grows downward toward the streambed. Trapped debris obstructs the waterway beneath the roadway, and increases the depth and duration of flow over the roadway. Vented fords and very low-profile structures are not recommended on streams that carry debris loads at high flows due to the high cost of frequent debris removal. The presence of a heavily wooded riparian area upstream of the crossing may indicate a potential debris issue, particularly if the channel is laterally unstable. Figures 2.1 and 2.2 show examples of woody debris accumulation at the upstream face of a vented ford and a low-water bridge.

Figure 2.1: Woody Debris Trapped on Upstream Side of Vented Ford in Phillips County, Kansas

Figure 2.2: Woody Debris Trapped on Upstream Side of Low-Water Bridge in Sumner County, Kansas

Low-water structures require much more frequent inspection, maintenance, and repair than so-called "standard" bridges. Low-water structures should be checked after every high-flow event and at routine intervals. Silt and debris on the roadway and trapped debris and accumulated sediment should be removed, and any erosion damage should be repaired in a timely manner.

2.5 Preliminary Investigation of Regulatory Issues

Regulatory concerns may affect LWSC feasibility or limit design options. These concerns include issues related to aquatic organism passage, threatened and endangered species, the historical significance of existing structures, FEMA floodplain regulations, and other applicable federal, state, and local requirements. Regulatory issues should be investigated early in the site assessment process to avoid wasting time and money on the pursuit of infeasible options.

LWSC projects must comply with the requirements of Section 404 of the federal Clean Water Act as administered by the U.S. Army Corps of Engineers (USACE). Most LWSC projects are authorized by Nationwide Permit 14, Linear Transportation Projects, and must comply with all associated permit conditions. Some USACE regulatory districts have imposed regional conditions that limit LWSC options. For example, Regional Condition 1 of the USACE Kansas City District specifies minimum requirements for the sizing of waterway openings and the embedment of conduits above a certain size. The local USACE regulatory office should be contacted early in the feasibility/planning stage to learn of all permit conditions relevant to low-water crossings.

The potential presence of threatened and endangered species should be investigated as early as possible through a preliminary environmental review by the appropriate governmental agency. The U.S. Fish and Wildlife Service (USFWS) is the federal agency responsible for protection of federally listed threatened and endangered species. USFWS's online Information for Planning and Conservation (IPaC) system is useful for project planning. IPaC lists potential impacts on any federally listed species, critical habitat, migratory birds, or other natural resources based on project location. Many states also have designated state agencies that oversee the protection of state-listed threatened and endangered species. A preliminary review can be initiated by contacting the appropriate state agency that oversees the protection of threatened and endangered species. To initiate a preliminary environmental review in Kansas, the Kansas Department of Wildlife, Parks and Tourism (KDWPT) requires the project location and conceptual sketch plans for the options under consideration. Ohio applicants who submit a Natural Heritage Data Request Form to the Ohio Division of Natural Resources (ODNR) Division of Wildlife will receive information regarding state and federally listed plants and animals in the vicinity of their project. The Illinois Department of Natural Resources (IDNR) provides an online Ecological Compliance Assessment Tool (EcoCAT) that identifies potential impacts to threatened and endangered species.

The site assessment should include an investigation of any possible historic resource issues. Each state has a State Historic Preservation Office (SHPO) that reviews Section 404 permit applications for potential impacts on historic properties. An adverse finding can cause delays and require changes to project plans. If the old bridge is found to have historic value, it may need to be left in place. Discussing the project options with SHPO staff during the site assessment can help avoid delays and changes later.

Floodplain-related requirements should also be investigated. Some rural counties participate in the National Flood Insurance Program and others do not. FEMA's Map Service Center provides online access to the applicable Flood Insurance Rate Map, Flood Insurance Study, and other relevant documents for any specified location within an NFIP-participating community. If the crossing site is located in a FEMA-mapped floodplain without a regulatory floodway, then the replacement of the old bridge with a new structure must not increase the level of the 1%-annual-chance flood by more than 1.0 foot. If the FEMA-mapped floodplain includes a regulatory floodway, then the bridge removal and LWSC installation must result in no increase in the existing 1%-annual-chance flood level unless the floodway is remapped. Remapping requires coordination and approval from the community and FEMA, and typically involves a FEMA Letter of Map Revision (LOMR) with detailed hydraulic modeling. This process can be time-consuming and cost-prohibitive for an LWSC.

2.6 Site Assessment Checklist

This checklist can be used to record relevant information that should be considered and weighed in deciding whether an LWSC might be an appropriate option for a particular location.

Roadway surface type: ☐ paved ☐ gravel ☐ dirt

Operating speed: ___________ Types of heavy or large vehicles:___________________________

Current average daily traffic count (estimate): ___________

Anticipated trend in traffic volume over next decade: ☐ increase ☐ little change ☐ decrease

Primary access route for:

_________ residences (#) _________ businesses (#) _________ field access (farm or ranch)

Alternative access route available when crossing impassable? ☐ yes ☐ no

If yes, detour distance in miles: ___________

School bus route? ☐ yes ☐ no Postal route? ☐ yes ☐ no

Stream type: ☐ perennial ☐ intermittent ☐ ephemeral

Channel depth (flowline to top of bank): ________________

Debris load at high flows: ☐ light ☐ moderate ☐ heavy

Debris type: ☐ large woody debris ☐ crop residue ☐ other _________________

Stream bed composition: ☐ gravel ☐ cobble ☐ silt ☐ sand ☐ clay ☐ confined by bedrock

Stream bank composition: ☐ gravel ☐ cobble ☐ silt ☐ sand ☐ clay ☐ confined by bedrock

Apparent trend in stream-bed level: ☐ no change ☐ degradation ☐ aggradation

Apparent stream-bank condition: ☐ stable ☐ unstable

Located in FEMA-designated Special Flood Hazard Area? ☐ yes ☐ no

If yes, is a regulatory floodway shown on the FEMA flood map? ☐ yes ☐ no

Threatened & Endangered species or designated critical habitat issues? ☐ yes ☐ no

Might the existing structure be considered historically significant? ☐ yes ☐ no

2.7 Summary Guidelines for LWSC Siting

2.7.1 Guidelines for Low-Water Structures in General

An LWSC might be appropriate for a site that meets the following guidelines.

1. The road is unpaved. A dirt road is preferable.
2. The traffic volume is very low.
3. An alternative wet-weather access route is available for any residences or businesses.
4. The wet-weather detour distance is reasonable. Less than 5 miles is preferable.
5. The crossing is not on a critical route such as a school-bus or emergency service route.
6. The road alignment allows for drivers to view flooded conditions and stop safely.
7. The channel not is not unstable (actively degrading, aggrading, widening, or migrating laterally).

2.7.2 Additional Guidelines for Unvented Fords

An unvented ford might be appropriate for a site that meets these additional guidelines.

1. The streamflow is ephemeral.
2. The channel is shallow enough for approaches at grades ≤ 10% within right-of-way.
3. The location and conditions are such that environmental permitting requirements do not rule out unvented fords.

2.7.3 Additional Guidelines for Vented Fords

Environmental regulations relating to aquatic organism passage make vented fords infeasible in many locations. A vented ford might be appropriate for a site that meets these additional guidelines.

1. The streamflow is ephemeral or intermittent.
2. The channel is shallow enough for approaches at grades of 10% or less within existing right-of-way.
3. The debris load at high flows is light.
4. The location and conditions are such that environmental permitting requirements do not rule out vented fords.

Chapter 3: Governmental Regulations and Permits

3.1 Introduction

Stream-crossing projects require coordination with multiple regulatory agencies. This chapter provides an overview of the permits and approvals that may be needed. All LWSC projects require a Clean Water Act Section 404 permit from the U.S. Army Corps of Engineers. If the crossing is located within a FEMA-regulated floodplain, the project will require a floodplain development permit from the local floodplain administrator. Projects that are likely to impact threatened and endangered species may require a Federal Fish and Wildlife Permit from the U.S. Fish and Wildlife Service and the corresponding state natural resource agency.

Additional permits may be needed to comply with state laws and regulations. This chapter focuses on the requirements in Kansas, Illinois, and Ohio, the three states that funded this report. In Kansas, many LWSC projects require a stream obstruction permit from the Division of Water Resources (DWR) of the Kansas Department of Agriculture. Projects that could impact threatened or endangered species or their critical habitat also require a permit from the Kansas Department of Wildlife, Parks and Tourism. Illinois stream crossings projects require a permit from the Illinois Department of Natural Resources; projects that impact threatened and endangered species may need an authorization from IDNR if a Federal Fish and Wildlife Permit is required from USFWS or if there are any state-listed species on the site. Ohio generally relies on the federal permits for stream crossing projects but applies several conditions to the use of these permits.

3.2 Section 404 Permit from USACE

As authorized by Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act, the U.S. Army Corps of Engineers regulates the discharge of dredged or fill material in all waters of the United States.

General permits are authorizations that are issued on a nationwide, statewide, or regional basis for a category or categories of activities that are similar in nature and do not cause more than minimal individual and cumulative adverse environmental effects. General permits include nationwide permits (NWPs), regional general permits, and programmatic general permits. A project that does not qualify for general permit or letter of permission authorization is to be reviewed through the standard individual permit process, which involves a public interest review, including public notice.

The USACE issues general permits covering particular categories of activities on a nationwide, regional, or state basis. The owner of a project covered by a general permit must comply with all terms and conditions associated with the permit. Nationwide permits and associated general and regional conditions are issued for a period of 5 years. In 2012, the USACE issued 52 NWPs authorizing different types of activities. These NWPs include 31 general conditions and regional conditions, where applicable.

Currently, most LWSC projects are authorized by Nationwide Permit 14, Linear Transportation Projects (NWP 14). NWP 14 applies to activities required for the construction of linear transportation projects located within waters of the United States. For linear transportation projects in non-tidal waters, the discharge cannot cause the loss of greater than $^{1}/_{2}$ acre of waters of the United States. For linear transportation projects located in tidal waters, the discharge cannot cause the loss of greater than $^{1}/_{3}$ acre of waters of the United States. A pre-construction notification (PCN) is required if the loss of waters of the US exceeds $^{1}/_{10}$ acre or there is a discharge in a special aquatic site, including wetlands. Certain general conditions may require the project owner to submit a PCN to the USACE. Two general conditions of particular interest for LWSC project planning are #18 Endangered Species and #20 Historic Properties. Issues related to threatened and endangered species or historic properties may require the project owner to submit a PCN. The local USACE regulatory office will provide guidance on PCN requirements upon request. The USACE district engineer reviews the PCN to determine whether the proposed activity meets the terms and conditions of the nationwide permit and will result in minimal adverse impacts. Prospective permittees will be notified in writing by the district engineer that the activity may proceed. General Permit verifications from the USACE, may include case-specific special conditions necessary to ensure impacts to the aquatic environment are minimal.

3.2.1 Section 401 Water Quality Certification

Section 401 of the Clean Water Act requires state-level water quality certification prior to issuance of the Section 404 permit. The designated state agency must certify that the proposed improvements will not violate the State's water quality standards. The Kansas Department of Health and Environment (KDHE), the Illinois Environmental Protection Agency (Illinois EPA), and the Ohio Environmental Protection Agency (Ohio EPA) are responsible for Section 401 water quality certification in these states. To streamline the permitting process, many states have issued standard Section 401 water quality certifications that apply to different Section 404 general permits. KDHE, the Illinois EPA, and the Ohio EPA have all pre-granted Section 401 water quality certifications for most of the Section 404 nationwide permits and some regional permits, in some cases subject to special conditions. Any special conditions in the Section 401 water quality certification are also included in the Section 404 permit conditions.

3.2.2 Threatened and Endangered Species

Federal law requires USACE to consult with the U.S. Fish and Wildlife Service (USFWS) to ensure that permitted activities will not impact the habitat or range of habitats of any threatened or endangered species. Stream-crossing projects that impact the habitat or range of habitat for a threatened or endangered species may require an Incidental Take Permit from USFWS. An approved habitat conservation plan is needed for the Incidental Take Permit.

3.2.3 Section 106 Historic Resources Review

Section 106 of the National Historic Preservation Act (NHPA) requires USACE to consider a project's impact on historic properties before issuing a Section 404 permit. In many states, Section 106 enforcement has been delegated to a specific state agency. The State Historic Preservation Offices of Kansas and Ohio and the Illinois Historic Preservation Agency perform the required Section 106 reviews in those states.

3.2.4 Section 404 Permit Requirements in Kansas

Section 404 nationwide permits for culverts and low-water crossings in Kansas are subject to Regional Condition 1, "General Guidelines for Stream Crossings" (USACE, Kansas

City District, 2012). This regional condition specifies measures “that will allow for the passage of flows and promote the safe passage of fish and other aquatic organisms.” It provides guidelines for the sizing of waterway openings for structures on perennial, intermittent, and ephemeral streams. To promote aquatic organism passage, culverts over 48 inches in diameter in streams with erodible beds must be embedded to a depth of 1 foot or more.

3.2.5 Section 404 Permit Requirements in Illinois

Section 404 permitting activities in Illinois are performed by five USACE Districts: Chicago, Rock Island, St. Louis, Louisville, and Memphis. Most stream-crossing projects in the Rock Island, St. Louis, Louisville, and Memphis Districts are issued Nationwide Permit 14. The Chicago District issues its own Regional Permit 3 (RP3) in place of NWP 14 for road and bridge projects. The Chicago District’s RP3 requires waterway and wetland crossings to be “culverted, bridged, or otherwise designed to prevent the restriction of expected high water flows” and “designed so as not to impede the low water flows or safe passage of fish and aquatic organisms.” RP3 requires embedment of culverts to facilitate aquatic organism passage.

3.2.6 Section 404 Permit Requirements in Ohio

Section 404 permitting activities in Ohio are performed by four USACE Districts: Huntington, Buffalo, Louisville, and Pittsburgh. Section 404 nationwide permits in Ohio include numerous conditions imposed by the Ohio EPA. Culverts must be sized to accommodate the bankfull discharge, and culverts larger than 36 inches in diameter must be embedded or bottomless. A pre-construction notification is required for projects in critical habitats or designated waters of special concern.

3.3 State-Issued Permits

In some states, stream-crossing projects also require one or more state-issued permits. These states include Kansas and Illinois but not Ohio.

3.3.1 Kansas DWR Permit

In Kansas, any construction in a “designated stream” requires a stream obstructions permit from the Kansas Department of Agriculture’s Division of Water Resources (DWR). A designated stream is defined as a natural or man-made channel that conveys drainage or runoff from a watershed with an area of 1 or more square miles in eastern Kansas, 2 or more square miles in central Kansas, or 3 or more square miles in western Kansas. Low-impact projects that meet certain criteria are issued a general permit; other projects are issued non-general permits.

The application process for the DWR permit is similar to the application process for the Section 404 permit. The completed application form is submitted with a location map, plan, and cross-sectional drawings and other project information relevant to the application. DWR’s Water Structures Program staff will assist as needed. The fee for a general permit is currently $100. The fee for a non-general permit for a bridge, culvert, or low-water crossing currently ranges from $100 to $500, depending on the drainage area. Higher fees apply to projects that permitted belatedly.

To comply with Kansas’s Water Projects Environmental Coordination Act, DWR sends all permit applications to seven other state agencies for review. These seven agencies are the Kansas Department of Wildlife, Parks and Tourism, the State Historic Preservation Office, the Kansas Biological Survey, the Kansas Department of Health and Environment, the Kansas Forest Service, the Kansas Conservation Commission, and the Kansas Corporation Commission. These agencies may suggest ways in which projects may be modified to minimize or mitigate environmental impacts. By law, the agencies have 30 days to submit comments.

3.3.2 Kansas KDWPT Action Permit

In Kansas, any project that could adversely impact the habitat of a threatened or endangered species requires an Action Permit from the Kansas Department of Wildlife, Parks and Tourism. KDWPT makes this determination in its review of the DWR permit application and/or the public notice for the Section 404 permit. If informed that an Action Permit is needed, the project owner should submit the permit application and supporting documents at least 90 days before the intended start date for construction. Project plans and other relevant information should be submitted with the completed application form. As a general rule, permit applications are processed within 30 days of receipt. Every Action Permit includes a set of general conditions with special conditions added as needed. For example, a special condition might prohibit construction activity during the spawning period of a particular aquatic species.

3.3.3 Illinois IDNR Permit

The Illinois Department of Natural Resources (IDNR) regulates all streams in rural areas where the drainage area equals or exceeds 10 square miles and all streams in urban areas where the drainage area equals or exceeds 1 square mile. Any construction in the floodway of a river, lake, or stream requires a permit from IDNR's Division of Water Resource Management. It is important to note that Illinois defines the regulatory floodway differently than FEMA. Floodways as defined by Illinois are wider than floodways as defined by FEMA.

IDNR issues four different types of permits for stream-crossing projects: individual, statewide, regional, and general. Statewide, regional, and general permits are simplified permits for limited-scope projects that meet certain criteria. No permit application is required for projects covered by statewide or regional permits. General permits are used for some dams and shoreline protection projects. Projects that do not meet the requirements for a statewide, regional, or general permit are issued an individual permit. Illinois has developed a joint application form for projects requiring authorizations from USACE, IDNR, and Illinois Environmental Protection Agency (IEPA).

3.3.4 Illinois Endangered Species – Incidental Take Authorization

Stream-crossing projects that could adversely impact threatened or endangered species may need an Incidental Take Authorization from IDNR, which requires an IDNR-approved conservation plan. The conservation plan must include the likely impacts on listed species, steps to be taken to minimize and mitigate impacts, alternative actions considered, and an implementation agreement. IDNR has 30 days to review and preliminarily approve or reject the conservation plan. The final authorization decision for projects receiving preliminary approval follows a 30-day public comment period and a 10-day response period.

3.4 Floodplain-Related Requirements

Stream-crossing projects located within FEMA-mapped floodplains are subject to floodplain-related requirements. At a minimum, a floodplain development permit must be obtained from the local floodplain administrator prior to construction. Application procedures vary locally. Some communities have floodplain regulations that are stricter than the minimum requirements of the National Flood Insurance Program (NFIP). If the proposed project meets the requirements of the NFIP and the community's floodplain management ordinance, the floodplain development permit is issued.

If the crossing is located within a mapped floodplain with no regulatory floodway, the basic NFIP requirement is that cumulative effect of the proposed project and all other existing and proposed development must not increase the 1%-annual-chance flood level by more than 1.0 foot at any point. If the map includes a regulatory floodway, all fill and construction within the floodway is prohibited unless (1) Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) applications are submitted and approved, or (2) the proposed encroachment would not cause any increase in the 1%-annual-chance flood level – the so-called no-rise condition. CLOMR and LOMR applications require detailed hydraulic studies. The proposed impacts to the limits and level of the floodplain must be approved by the local community before the application and study are submitted to FEMA for review. The CLOMR/LOMR process can be lengthy and expensive. A no-rise submittal, which is reviewed only by the local floodplain administrator, is typically less expensive and time-consuming than obtaining a CLOMR and LOMR. A CLOMR or No-Rise Certification is required for issuance of a floodplain development permit for any project that encroaches upon a regulatory floodway. No-Rise Certification is issued by the local floodplain administrator on the basis of a detailed hydraulic study submitted by the applicant. If a CLOMR/LOMR is required, then the hydraulic study must be reviewed and approved by FEMA.

Chapter 4: Design Considerations

Low-water crossing structures range from simple unvented fords to low-water open-span bridges. Design requirements vary greatly with structure type and setting. Any LWSC structure should be designed by a qualified engineer with knowledge of local conditions. This chapter highlights some basic design considerations for LWSCs. Several public reports available online provide more extensive guidance for design of different types of LWSCs. These reports include the U.S. Forest Service's *Low-Water Crossings: Geomorphic, Biological, and Engineering Design Considerations* (Clarkin et al., 2006), Iowa State University's *Low Water Stream Crossings in Iowa: A Selection and Design Guide* (McDonald & Anderson-Wilk, 2003), and FHWA's *Design Guide: Low Water Stream Crossings* (Motayed et al., 1982b).

4.1 Roadway Issues

When considering possible designs for a low-water crossing, certain safety-related roadway issues should be kept in mind. A low-water crossing should be at least as wide as the road on which it is located, and preferably wider. Ice, snow, mud, or algal slime can cause slippery driving conditions, particularly on unvented and vented fords. A wider roadway provides some margin for a driver to recover from any loss of control. The grades of the approaches to the crossing should not exceed 10%. Milder approaches make the crossing more visible and safer to traverse under slippery conditions.

Low-water crossings require appropriate signage to alert drivers to the possibility of a flooded roadway. The *Manual on Uniform Traffic Control Devices for Streets and Highways* (FHWA, 2012) does not specify standard signage for low-water crossings. The *Handbook of Traffic Control Practices for Low Volume Rural Roads* (Russell, Mulinazzi, & Kornala, 2005) recommends as many as three signs on each side of the crossing. Figure 4.1 shows examples of the recommended signage. The *Handbook* provides general guidelines for locating the signs. The distances from the crossing to the signs should be adjusted for local conditions based on engineering judgment. The first sign should be placed ahead of the last detour opportunity before the crossing.

Figure 4.1: Examples of Recommended Signage for Low-Water Crossings
Source: Russell et al. (2005)

4.2 Hydrology

By definition, a low-water stream crossing will be impassable upon occasion, but it should be passable a great majority of the time. The tolerable frequency and duration of impassable conditions depends on the types and volume of traffic, the detour time, and other factors. As a general guideline, an LWSC should be impassable fewer than 10 times in an average year and the duration of impassable conditions should not exceed 3 days. Some locations merit a higher level of service.

Estimates of streamflows that exceeded different percentages of time (so-called flow-duration estimates) are useful for LWSC design. The U.S. Geological Survey (USGS) has developed regional regression equations for making flow-duration estimates based on geographic location, drainage area, and other basin characteristics. Flow-duration estimates for many locations in the US can be obtained through the USGS's StreamStats online application (USGS, n.d.). The local (state) USGS Water Science Center may be able to provide flow-duration estimates for locations where these estimates are unavailable through the nationwide StreamStats application.

Unvented fords are generally considered impassable when the depth of flow over the roadway exceeds 6 inches. A hydraulic calculation will yield the discharge corresponding to a 6-inch depth of flow for any given roadway profile. Comparison of this discharge with the flow-duration estimates for the crossing location can provide a rough estimate of the percentage of time that the crossing would be impassable. If this percentage is unacceptably high, then a different type of structure should be considered.

For vented fords, the vents should be sized to pass a discharge that is exceeded no more than 5% of the time (as can best be estimated). Some allowance should be made for the likelihood of partial blockage by debris. Low-water culverts and bridges are typically designed for a somewhat higher level of service (i.e., less frequent disruption of service).

In sizing the waterway openings for vented fords and low-water culverts, hydraulic calculations should be performed as directed in FHWA's *Hydraulic Design of Highway Culverts* (Schall, Thompson, Zerges, Kilgore, & Morris, 2012). Vents and low-water culverts should be embedded in the stream to facilitate the passage of fish and other aquatic organisms where appropriate.

Minimum areas for culverts and vents may be specified by environmental permit conditions. For example, within the regulatory area of USACE's Kansas City District (all of Kansas and part of Missouri), all culverts and low-water crossings permitted under a Nationwide Permit must comply with Regional Condition 1 (USACE, Kansas City District, 2012). This condition specified approximate minimum areas for culverts on perennial, intermittent, and ephemeral streams. The approximate minimum area for a culvert on a perennial stream is 85% of the preconstruction bankfull area upstream and downstream of the crossing. The approximate minimum area for a culvert on an intermittent stream is 50% of the bankfull area. A culvert on an ephemeral stream should be sized to convey the geomorphic bankfull discharge without overtopping the roadway. For locations in Kansas, the geomorphic bankfull discharge can be estimated from basin characteristics with a statewide regression equation (Young, McEnroe, Gamarra, Luo, & Lurtz, 2014). Regional Condition 1 also states that conduits larger than 48 inches in diameter must be embedded at least 1 foot below the streambed.

4.3 Foundations, Scour, and Erosion

Any structure placed within a stream channel is susceptible to failure from scour and erosion unless properly protected. Scour and erosion at high flows can attack and destabilize the foundation, abutments or wing walls, and approaches. Low-water structures face a higher risk of erosion-related failure than standard bridges and culverts because they are overtopped much more often.

Foundation requirements depend on the structure type, the streambed composition, and the subsurface geology. Fords and low-water culverts require cutoff/toe walls, typically of reinforced concrete or steel sheet piling, to prevent undermining. Cutoff/toe walls should extend into the streambed below the anticipated scour depth or to bedrock. A geotechnical investigation may be needed to determine the appropriate depth for the cutoff walls.

Low-water bridges and bottomless culverts must be placed on spread footings or concrete shaft or pile foundations. Spread or “strip”-type footings may be used where bedrock is present at a shallow depth. The spread footings must be adequately keyed into the rock. Where bedrock is too deep for spread footings, bridges and bottomless culverts must be supported on structural piling or concrete shaft-type foundations. Auger-cast concrete piles, treated timber piles, steel H-piles, and steel pipe piles are the most common deep foundation elements for these types of structures. A geotechnical study is needed to determine foundation requirements. Foundations must be deep enough to withstand expected scour or must have properly designed scour countermeasures. Scour depths should be estimated by the methods in FHWA’s *Evaluating Scour at Bridges* (Arneson, Zevenbergen, Lagasse, & Clopper, 2012).

When the roadway of a vented ford is overtopped, the plunging flow on the downstream side can scour the channel bed to a considerable depth. The channel bed directly downstream of a vented ford should be armored with rock riprap or gabions to protect against excessive scour.

The approaches and the channel banks directly downstream of a low-water structure are particularly vulnerable to erosion damage at high flows. Unpaved approaches often require extensive repairs after overtopping events. Paving the approaches helps protect against erosion damage and the associated repair costs. Wherever practical, the pavement should extend far enough to protect the roadway in a bankfull flow event. Abutments, wing walls, approaches, and the channel banks upstream and downstream of structure should be well protected against erosion by rock riprap, gabions, or other measures. The erosion countermeasures should be designed in accordance with FHWA's *Bridge Sour and Stream Instability Countermeasures: Experience, Selection and Design Guidance* (Lagasse et al., 2009).

4.4 Other Design Issues

4.4.1 Unvented and Vented Fords

An unvented or vented ford should be designed to obstruct the channel cross-section as little as possible. A low profile facilitates the passage of aquatic organisms and debris and minimizes downstream scour. The roadway of an unvented ford should be at or only slightly above the channel bed. The profile of a vented ford should be no higher than needed to provide the required cover over the vents. Using several smaller vents instead of a single large vent allows for a lower roadway profile and also reduces downstream scour. The vent pipes need not be all the same size. Vents should be installed with flowlines below the streambed level to allow for aquatic organism passage where appropriate. The upstream and downstream faces of a vented ford structure should be sloped to minimize debris retention and reduce toe scour.

The roadway of the ford should be constructed of reinforced concrete. The slab thickness should be 6 to 8 inches. Flexible paving materials are not recommended for permanent structures on public roads. Temporary fords are sometimes paved with flexible materials such as aggregate-filled geocells, interlocking concrete blocks, and mats of cable-connected concrete blocks or planks, but these flexible pavements can deform excessively over time. The driving surface of a ford should be constructed with a cross-slope of 2–4% in the downstream direction to promote drainage and minimize ponding, icing, and siltation on the roadway. The concrete driving surface should have a roughened texture to enhance traction.

The vent-pipe material may be reinforced concrete, corrugated metal, or high-density polyethylene (HDPE). The requirements for pipe spacing, bedding, and cover depend on the type and size of pipe and the design load. The structure should be designed for the same load as a standard highway bridge. Vent pipes must secured against buoyant uplift with concrete endwalls or other measures.

4.4.2 Low-Water Bridges

Low-water bridges must be designed to withstand the downstream-directed hydraulic forces on the structure during floods. The girders and slabs must be strongly secured to the abutments and any piers. The drag force on the superstructure is proportional to the frontal area of the superstructure measured perpendicular to the flow. Trapped debris on the bridge's upstream face can greatly increase the hydraulic drag force. Rounding or otherwise streamlining the elements on the bridge's upstream face can reduce the debris retention and drag. Low-water bridges are constructed without railings and often without curbs. Railings and, to a lesser extent, curbs tend to retain debris and increase hydraulic forces during floods. However, on longer bridges, low curbs with drainage openings may be advisable for vehicle safety.

Chapter 5: Case Studies

This chapter presents case studies of nine recent low-water crossing projects in Kansas. The new structures include an unvented ford, a hybrid-type ford, three vented fords, a low-water box culvert, a low-water bottomless culvert, and two low-water bridges. Eight of the projects are completed and one has been delayed by regulatory issues.

Streamflow estimates are provided for each site. The flow-duration estimates were obtained from the U.S. Geological Survey's most recent streamflow statistics report for Kansas (Perry, Wolock, & Artman, 2004) and the flood-frequency estimates were computed with the USGS's flood-frequency regression equations for Kansas (Rasmussen & Perry, 2000).

5.1 Case Study 1. Unvented Ford in Washington County

5.1.1 Location

This unvented ford is located on Fox Road approximately 1300 feet north of 12th Road at an unnamed tributary to Parsons Creek. This location is approximately 8 miles SW of Washington, Kansas (39.7445, -97.2562).

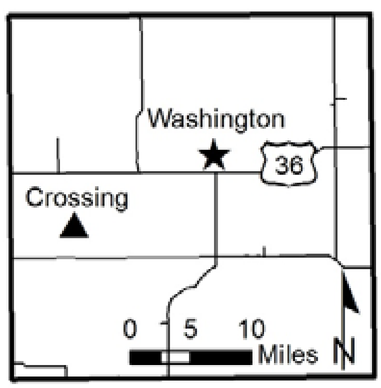

Figure 5.1: Location of Crossing in Washington County

Figure 5.2: View of Structure from Upstream

Figure 5.3: View of Structure from Downstream

Figure 5.4: View of Structure from Road

Figure 5.5: Low-Flow Channel on the Upstream Side of the Ford

Figure 5.6: View of Channel Upstream of Ford

Figure 5.7: View of Channel Downstream of Ford

5.1.2 Crossing Description

This unvented ford was completed in April 2014. The reinforced concrete slab is 60 feet long, 20 feet wide, and 9 inches, underlain with 6 inches of aggregate base. The upstream and downstream faces of the concrete slab are protected by 60-foot-long sheet-pile cutoff walls driven to a depth of 10 feet to prevent undermining. The crossing is constructed on a 100-foot vertical curve. The grades at the ends of the vertical curve are -11% and 12%. Large riprap placed directly downstream of the crossing provides scour protection.

5.1.3 Crossing History

The previous structure was a 30-foot-long steel-truss bridge that was over 90 years old. Stream aggradation had greatly reduced the vertical dimension of the waterway opening. The old bridge was removed because it was often flooded and the timber deck was failing.

5.1.4 Road and Traffic

Fox Road is owned and maintained by Grant Township. The road surface consists of compacted native soil. The crossing is used mainly by farm vehicles. It is not used by school buses or postal vehicles. The average daily traffic count is less than 10.

5.1.5 Stream Characteristics

The unnamed tributary to Parsons Creek is an intermittent stream. The drainage area at the ford is 1.9 mi^2. The bankfull channel is 10 to 12 feet wide and 2 to 4 feet deep. The channel bed is composed of silt, sand, and some gravel. The channel banks are composed of sand and silt. Soil is deposited over most of the ford’s concrete surface.

Table 5.1: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)
90%	0
75%	0
50%	0
25%	0
10%	1

Recurrence interval (years)	Flow (cfs)
2	286
5	662
10	997
50	1,950
100	2,450

5.1.6 Governmental Permits and Regulatory Issues

This project required two permits: a Section 404 Nationwide Permit 14 issued by USACE and a Stream Obstructions General Permit issued by the Kansas Division of Water Resource (DWR). There were no concerns with nearby threatened or endangered species or historic resources. The ford is located in a FEMA Zone A floodplain.

5.1.7 Project Cost

The new ford was designed and constructed for a total cost of $51,955. The lump-sum includes the design fee, earthwork, and materials. This sum does not include the cost of removing the old bridge.

5.1.8 Maintenance Requirements and Performance to Date

The unvented ford has required little maintenance since its construction in 2014. When needed, accumulated debris is removed by a single person with a wheel loader in 1 to 2 hours. The road surfaces in the vicinity of the crossing have not required maintenance since the completion of construction. Washington County officials are pleased with the performance of the ford.

5.1.9 Project Owner

Washington County owns and maintains the crossing. The current project contact is Justin Novak, the Road and Bridge Supervisor.

5.1.10 Project Designer

The project was designed by CFS Engineers in Topeka, Kansas.

5.1.11 Summary

This unvented ford was part of a six-bridge replacement project in Washington County. A grant from the Community Development Block Grant Program (CDBG) provided partial funding for this project. The crossing provides an example of a simple, low-cost solution at a location where a new bridge was not needed. An unvented ford was chosen because the channel is shallow and the streamflow is usually minimal.

5.2 Case Study 2. Hybrid Unvented Ford in Miami County

5.2.1 Location

The hybrid ford is located on an unimproved access road within the Hillsdale Lake Wildlife Refuge at an unnamed tributary to Little Bull Creek. This location is 0.2 miles south of 223rd Street and 0.9 miles east of Cedar Niles Road in Miami County, Kansas (38.6875, -94.8737).

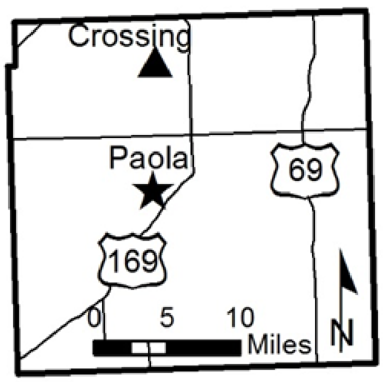

Figure 5.8: Location of Crossing in Miami County

Figure 5.9: View of Structure from Upstream

Figure 5.10: View of Structure from Downstream

Figure 5.11: View of Structure Looking South

Figure 5.12: View of Submerged Structure Looking North

Figure 5.13: View of Upstream Channel

Figure 5.14: View of Downstream Channel

Figure 5.15: Close-Up View of the Grated Troughs

Figure 5.16: Rock Surface Material on South Approach

5.2.2 Crossing Description

This hybrid ford, which was constructed in November 2009, provides access to cropland adjacent to Little Bull Creek and Hillsdale Reservoir. It is 16 feet wide with a 20-foot-long center section and two 20-foot-long approach sections. The center section is horizontal and the approach sections are on 7.5% grades. Two grated troughs, each 30 inches wide by 12 inches deep, traverse the center slab. This crossing is termed a hybrid ford because the grated troughs have minimal hydraulic capacity but allow for passage of juvenile fish. The open-top troughs are more conducive to aquatic organism passage than enclosed vents.

5.2.3 Crossing History

The previous structure was a bridge with a steel superstructure, a wood-plank deck, and concrete abutments. Broken timber floor-beams and extensive abutment scour led to its closure. The road was a county section-line road before Hillsdale Lake was constructed.

5.2.4 Road and Traffic

The Kansas Department of Wildlife, Parks and Tourism (KDWPT) owns and maintains this road and crossing. This gated dead-end road provides the only access to some cropland within the Hillsdale Wildlife Area. It is used only by farm vehicles, KDWPT personnel, and hikers. The 16-foot-wide road, constructed of compacted gravel and native soil, receives only minimal maintenance and is often overgrown.

5.2.5 Stream Characteristics

This crossing is located on an unnamed tributary 200 feet upstream of its confluence with Little Bull Creek. The contributing drainage area is 1.9 mi^2. At times the crossing is flooded by backwater from Hillsdale Lake, a flood-control reservoir owned by USACE. The bankfull channel is approximately 30 feet wide and 6 feet deep. The channel bed and banks are mainly silt. The channel's flowline is approximately 1 foot below the deck of the crossing. The watershed is composed mainly of pasture, cropland, and woods. The streamflow is intermittent with estimated characteristics shown in Table 5.2.

Table 5.2: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)	Recurrence interval (years)	Flow (cfs)
90%	0	2	562
75%	0	5	1,100
50%	0	10	1,540
25%	1	50	2,700
10%	2	100	3,290

5.2.6 Governmental Permits and Regulatory Issues

This project required two permits: a Section 404 Nationwide Permit 14 issued by USACE and a Stream Obstructions General Permit issued by the Kansas Division of Water Resource (DWR). There were no issues with threatened or endangered species or historic resources. The ford is located in a FEMA Zone A floodplain. A hydrologic and hydraulic investigation showed that the structure would not increase the 1%-annual-chance flood level.

5.2.7 Structure Details

The 60-foot-long reinforced-concrete slab is 8 inches thick. Reinforced-concrete cutoff walls on the upstream and downstream faces extend 4 to 5 feet into the streambed. The top grates on the two troughs are removable for cleaning when needed. Beyond the ends of the concrete slab, the approaches are surfaced with 6 inches of AB-3 aggregate.

The channel banks adjacent to the crossing are graded to provide a gradual transition between the natural channel cross-section and the roadway profile at the ford. Eighteen-inch rock riprap protects the banks on both sides of the ford. Disturbed areas beyond the concrete and riprap-protected areas were stabilized with a native vegetation seed mix and biodegradable erosion-control blankets.

5.2.8 Project Costs and Funding

The total cost of the project was $110,000, which includes a design fee, demolition of the old bridge, and construction of the new crossing. The project was funded in part by the U.S. Fish and Wildlife Service's Wildlife and Sport Fish Restoration Program.

5.2.9 Maintenance Requirements and Performance to Date

Hillsdale Wildlife Area personnel are satisfied with the crossing's performance to date because it is usually passable and requires minimal maintenance. The crossing has not required maintenance since its completion. The crossing has been impassable only when inundated by backwater from Hillsdale Lake.

5.2.10 Project Owner

The Kansas Department of Wildlife, Parks and Tourism own and maintain the crossing. Eric Kilburg, the Hillsdale Wildlife Area Manager, is the best point of contact.

5.2.11 Project Designer

This project was designed by Poe & Associates, Inc., in Topeka, Kansas.

5.2.12 Summary

This hybrid ford provides an example of a low-profile, low-maintenance ford that is conducive to aquatic organism passage. Because the road is no longer open to public vehicle access, the safety risk is minimal.

5.3 Case Study 3. Vented Ford in Kiowa County

5.3.1 Location

This structure is located on 21st Avenue at Mule Creek, 0.42 miles north of V Street. This location is approximately 12.5 miles southwest of Greensburg, Kansas (37.4314, -99.3741).

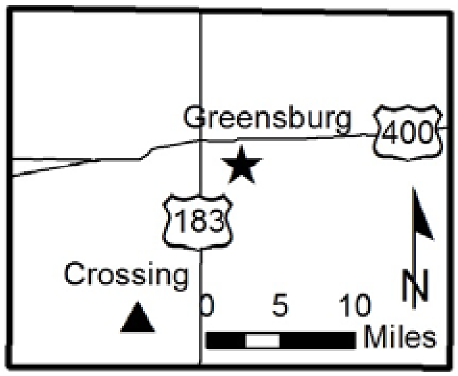

Figure 5.17: Location of Crossing in Kiowa County

Figure 5.18: View of Structure from Upstream

Figure 5.19: View of Structure from Downstream

Figure 5.20: View of Crossing from Road

Figure 5.21: View of Upstream Channel

Figure 5.22: View of Downstream Channel

Figure 5.23: Washed-Away Aggregate Stabilization on Downstream Left Bank

Figure 5.24: Bank Stabilization and Silt Accumulation on Downstream Side of Structure

5.3.2 Crossing Description

This vented ford was completed in January 2015. The reinforced-concrete structure is 60 feet long and 28 feet wide. Four 40-inch by 32-inch corrugated-metal arch culverts are installed on a 30° skew to match the channel alignment. The bottoms of the conduits are embedded in the stream to facilitate aquatic organism passage. The reinforced-concrete slab is 9 inches thick with 8-inch-thick toe walls on the upstream and downstream faces. The embedded culverts are spaced 2 feet apart, edge to edge, with 1 foot of concrete cover over the tops. The driving surface is approximately 1 foot lower than the tops of the streambanks.

5.3.3 Crossing History

The previous structure was a two-cell reinforced-concrete box culvert with a total span of 22 feet and a rise of 8 feet. As Figures 5.25 and 5.26 show, the old culvert was almost entirely filled with soil due to channel aggradation and its deck was collapsed.

Figure 5.25: Old Structure Filled with Sediment

Figure 5.26: Partially Collapsed Culvert Deck

Figure 5.27: Sediment Deposited on Top of Rock Riprap on Downstream Side of Structure

5.3.4 Road and Traffic

The 24-foot-wide county road is surfaced with compacted sand and gravel. The road is used mainly by farm vehicles and heavy trucks servicing oil and gas wells. The average daily traffic count is less than 25. The crossing is not on a school-bus route.

5.3.5 Stream Characteristics

The drainage area of Mule Creek at the crossing is 10.8 mi^2. The land use is a roughly equal mix of cropland and rangeland. The streamflow is ephemeral. Table 5.3 shows estimated streamflow characteristics. The bed and banks are composed of silt and sand. The bankfull channel is 20 to 25 feet wide and 4 to 5 feet deep.

Table 5.3: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)
90%	0
75%	0
50%	0
25%	0
10%	0

Recurrence interval (years)	Flow (cfs)
2	394
5	1,120
10	1,840
50	4,100
100	5,360

5.3.6 Governmental Permits and Regulatory Issues

This project was issued a Section 404 Nationwide Permit 14 from USACE and a Stream Obstructions permit from Kansas DWR. The Section 404 permit included special provisions added by KDWPT. A separate Action Permit from KDWPT was not needed. The crossing is located in an area that does not participate in the National Flood Insurance Program.

5.3.7 Project Cost

This ford was constructed at a cost of $60,000. This cost does not include engineering services.

5.3.8 Maintenance Requirements and Performance to Date

This vented ford has performed well in its first year of operation. No debris removal or roadway resurfacing has been required. However, some riprap on one downstream bank has washed away and will need to be replaced with larger rock at some point.

5.3.9 Project Owner

Kiowa County owns the ford. Jay Schmidt, the Kiowa County Road and Bridge Supervisor, is the main point of contact.

5.3.10 Project Designer

This project was designed by Kirkham Michael Consulting Engineers in Ellsworth, Kansas.

5.3.11 Summary

This minor crossing of an ephemeral stream is an appropriate location for a vented ford. The structure provides year-round passage for the heavy trucks that service local oil and gas wells. The large embedded culverts allow for some degree of aquatic organism passage.

5.4 Case Study 4. Vented Ford in Phillips County

5.4.1 Location

The vented ford is located on West 1200th Road, 0.65 miles south of West Day Dream Road, at a crossing of Bow Creek, approximately 17.6 miles SW of Phillipsburg (39.5725, -99.5528).

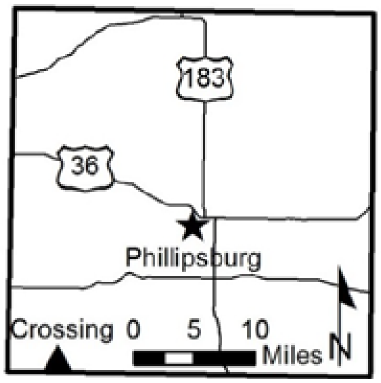

Figure 5.28: Location of Crossing in Phillips County


Figure 5.29: View of Structure from Upstream

Figure 5.30: View of Structure from Downstream

Figure 5.31: View of Ford from West 1200th Road

Figure 5.32: Downstream Channel Viewed from Deck of Structure


Figure 5.33: Timber Build-Up on the Upstream Face of Structure


Figure 5.34: Downstream Face of Structure


Figure 5.35: Upstream Channel

Figure 5.36: Downstream Channel

5.4.2 Crossing Description

The vented ford, constructed in 2007, is a reinforced-concrete structure with three 36-inch diameter corrugated-steel vent pipes. The structure is 20 feet wide. The horizontal center section is 15 feet long and the two approach sections are each 20 feet long. The driving surface is 1 to 2 feet lower than the tops of the streambanks. The left bank is 1 to 2 feet higher than the bridge deck. Three 36-inch corrugated-metal vent pipes are installed on a 30° skew to match the channel alignment. The pipes are spaced 2 feet apart, edge to edge, with crowns 12 inches below the driving surface. The bottoms of the pipes are perched approximately 18 inches above the channel bottom. At low flows, the crossing acts as a barrier to aquatic organisms.

5.4.3 Crossing History

The previous structure was a 50-foot-span bridge with a steel-truss frame and a 16-foot wide deck. Before the vented ford was constructed, the crossing was out of service because the bridge had collapsed into the stream.

5.4.4 Road and Traffic

West 1200th Road is a 16- to 18-foot-wide dirt road owned and maintained by Phillips County. It carries passenger and farm vehicles and oil-field trucks. The average daily traffic is less than 10 vehicles. It is not used by school buses or postal vehicles.

5.4.5 Stream Characteristics

Bow Creek, a tributary to the North Fork Solomon River, is an intermittent stream. The contributing drainage area at the crossing is 279 mi^2. The land use in the watershed is primarily pasture with some cropland. Table 5.4 shows the estimated streamflow characteristics at the crossing. The channel width is approximately 30 feet. The bed is composed of silt and sand, and the banks are mostly silt. The stream carries large quantities of woody debris at high flows.

Table 5.4: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)	Recurrence interval (years)	Flow (cfs)
90%	0	2	779
75%	1	5	2,470
50%	2	10	4,380
25%	4	50	11,200
10%	8	100	15,400

5.4.6 Governmental Permits and Regulatory Issues

This project was issued a Section 404 Nationwide Permit 14 from USACE and a Stream Obstructions permit from Kansas DWR in 2007. If proposed today, some design changes would be needed to comply with current regulatory requirements. The total waterway area would need to be much larger and the conduits would need to be embedded in the stream to facilitate aquatic organism passage. This crossing is located in an area that does not participate in the National Flood Insurance Program.

5.4.7 Project Cost

The cost of engineering design and project materials was $34,500. This cost does not include labor for construction. The ford was constructed by county employees.

5.4.8 Maintenance Requirements and Performance to Date

Since its completion in 2007, the crossing has required only simple routine maintenance after high-flow events. A two-man crew with a backhoe can remove any trapped woody debris in about an hour. Phillips County is pleased with the crossing's performance to date.

5.4.9 Project Owner

The vented ford is owned and maintained by Phillips County. Rick Capps, the Road and Bridge Supervisor, is the main point of contact.

5.4.10 Project Designer

Penco Engineering, P.A., in Plainville, Kansas, designed the vented ford.

5.4.11 Summary

The construction of this economical structure enabled Phillips County to reopen the crossing to traffic, which has greatly benefited local residents. Although properly permitted by USACE and Kansas DWR in 2007, the vented ford inhibits aquatic organism passage at low flows. It is hoped that at some future date this ford will be replaced with a more fish-friendly structure.

5.5 Case Study 5. Proposed Vented Ford in Osborne County

5.5.1 Location

The proposed vented ford will be located on West 120th Drive at a new crossing of Twin Creek. This location is 0.6 miles east of S. 70th Avenue, approximately 5.5 miles SE of Osborne, Kansas (39.3944, -98.6090).

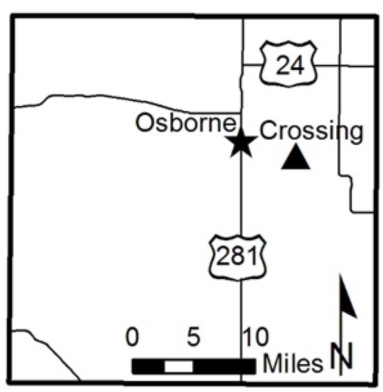

Figure 5.37: Location of Crossing in Osborne County

Figure 5.38: Old Steel-Truss Bridge, Which was Closed in June 2015

Figure 5.39: Left Abutment Retrofitted with Steel Sheet-Pile

Figure 5.40: Right Abutment with Original Wood Planks

5.5.2 Crossing Description

The existing steel-truss bridge on West 120th Drive has been closed since June 2015 due to structural and functional deficiencies and the expense of required periodic inspections. The bridge is too narrow for many modern farm vehicles and its abutments are failing. This structure, built in 1905, is a 54-foot-span steel-truss bridge with a roadway width of 16 feet. The bridge deck is 12 to 14 feet above the channel bottom. Osborne County had planned to remove the old bridge and replace it with a vented ford until a Section 404 permit review by USACE found that the bridge could be historically significant. After consultation with the Kansas State Historic Preservation Office (SHPO), the bridge's historical significance was confirmed. A study by USACE, SHPO, and Osborne County examined whether the bridge could be preserved, restored, or relocated. These options were found to be impractical.

Osborne County is now considering realigning the roadway so that it crosses Twin Creek 400 feet upstream of the old bridge. The current plan is to abandon the existing roadway and remove the old bridge. The new roadway will have two 12-foot lanes within a realigned right-of-way. The proposed replacement structure is a ford with an 84-inch diameter corrugated-metal vent embedded to a depth of 1 foot. The new crossing would accommodate large farm vehicles.

5.5.3 Road and Traffic

West 120th Drive is owned by Penn Township and is constructed of native soil. The proposed realigned roadway would be 24 feet wide. The road and crossing would be a through route for farm and passenger vehicles but would not be used by school buses or postal vehicles. The new crossing is expected to have an average daily traffic count of 10 vehicles or less.

5.5.4 Stream Characteristics

Twin Creek is an intermittent-to-perennial stream with a drainage area of 61 mi^2 at the crossing. Estimated streamflow characteristics at the crossing are shown in Table 5.5. The land use in the watershed is mostly agricultural. The streambed and banks are composed mainly of silt. At the proposed location for the new ford, the streambank height is 12 to 14 feet. The stream's low-bench and high-bank widths are approximately 15 and 30 feet.

Table 5.5: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)	Recurrence interval (years)	Flow (cfs)
90%	0	2	824
75%	0	5	2,280
50%	1	10	3,780
25%	3	50	8,660
10%	7	100	11,400

5.5.5 Governmental Permits and Regulatory Issues

Osborne County has been issued a Section 404 Nationwide Permit 14 by USACE and a Stream Obstructions permit by Kansas DWR for this project. No issues with threatened or endangered species were identified. Osborne County does not participate in the National Flood Insurance Program.

In the Section 404 permit review, USACE found the old bridge eligible for listing in the National Register of Historic Places, and Kansas SHPO concurred with this determination. Because restoring or relocating the old bridge was impractical, Osborne County worked with USACE and SHPO to develop a mitigation plan. Two other steel-truss bridges in Osborne County will be left in place and nominated to the National Register of Historic Places. Osborne County will be allowed to remove or repair seven other steel-truss bridges, including the closed bridge on W. 120th Drive.

5.5.6 Project Cost and Funding

As of May 2016, Osborne County had obtained the necessary permits to remove the closed bridge on West 120th Drive, realign the roadway, and install a low-water crossing. Complications related to right-of-way acquisition have delayed the project. KDOT's Kansas Local Bridge Improvement Program will provide funding to remove the old bridge.

5.5.7 Project Owner

Osborne County will own and maintain the new crossing. Bo French, the current Road and Bridge Supervisor, and Larry Patee, the former Road and Bridge Supervisor, are the contacts for the project.

5.5.8 Project Designer

Penco Engineering, P.A., in Plainville, Kansas, designed the proposed vented ford.

5.5.9 Summary

This case study offers some useful lessons in dealing with unexpected regulatory issues. The historic bridge issue discovered during the Section 404 permit review complicated and delayed this project. To obtain the required Section 404 permit for the bridge removal and replacement, Osborne County worked with the USACE and SHPO to develop an acceptable mitigation plan. Public input was an essential part of the process. USACE and Osborne County solicited and considered public comments in deciding which two historic bridges would be preserved. Osborne County Public Works believes that earlier communication with USACE, Kansas SHPO, and surrounding landowners during the project planning phase could have saved considerable time and expense.

5.6 Case Study 6. Low-Water Box Culvert in Shawnee County

5.6.1 Location

The low-water box culvert is located on NW 46th Street, 0.50 miles west of Capper Road, at a crossing of a tributary to Cross Creek. This structure is located in the Kansas River floodplain, approximately 1.1 miles southwest of Rossville, Kansas (39.1296, -95.9707).

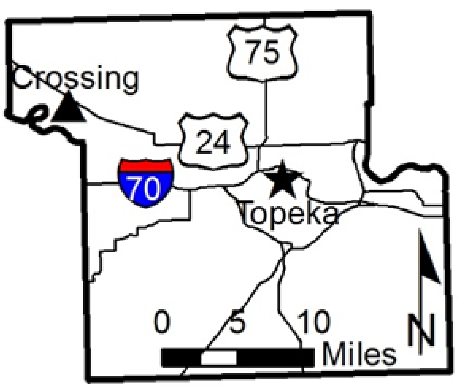

Figure 5.41: Location of Crossing in Shawnee County

Figure 5.42: View of Structure from Upstream

Figure 5.43: View of Structure from Downstream

Figure 5.44: Upstream Wingwall with Riprap Stabilization Covered in Silt

Figure 5.45: Downstream Wingwall with Riprap Stabilization

Figure 5.46: Channel Directly Upstream of the Culvert

Figure 5.47: Channel Directly Downstream of the Culvert

5.6.2 Crossing Description

The two-cell box culvert has total span of 20 feet and a rise of 6 feet. The culvert is 67 feet long. The extra length allows for 4-foot-wide shoulders on the roadway over the structure and eliminates the need for guardrails. In addition to their high cost, guardrails tend to trap debris and may become damaged during an overtopping event. Guardrails on narrow bridges can also hinder or prevent the passage of large farm vehicles and machinery. The box culvert is aligned with the channel at a 32° angle from perpendicular to the roadway.

5.6.3 Crossing History

The previous structure was a 16-foot-long simple-span bridge. The deck, backwalls, and piling were made of timber. The roadway was 19 feet wide with guardrails that required frequent maintenance due to damage from debris and collisions with farm equipment. The area of the waterway opening was 86 ft^2, which is significantly smaller than the new structure's 120-ft^2 waterway area.

5.6.4 Road and Traffic

NW 46^{th} Street is owned and maintained by Rossville Township. The road is surfaced with compacted gravel over native soil. NW 46^{th} Street is 24 feet wide in the vicinity of this new crossing and 15 to 16 feet wide elsewhere. The crossing is located in an area of the Kansas River floodplain with fertile cropland and few residents. The road is used by farm and passenger vehicles. The old bridge had an average daily traffic count of 10 vehicles. Since the new low-water culvert was completed, the average daily traffic count has increased to nearly 50 vehicles. The new wider crossing accommodates farm vehicles that could not traverse the old bridge. Those large slow-moving vehicles now travel on NW 46^{th} Street rather than Highway 24, which has improved traffic safety on that section of Highway 24.

5.6.5 Stream Characteristics

This tributary of Cross Creek is an agricultural drainage channel on a straight alignment. The streamflow is intermittent. Backwater from high flow in the Kansas River can occasionally fill the tributary. Table 5.6 shows estimated streamflow characteristics. The drainage area at the crossing is 2.8 mi^2. The watershed is composed entirely of cropland within the Kansas River floodplain.

The stream is approximately 7 feet deep with a bankfull width of 25 to 30 feet. The channel bed and bank soils composed of silt. This tributary experiences backwater from the Kansas River during periods of high flow in the river. The combination of streamflow from the watershed and occasional prolonged backwater form the river supports a healthy habitat for many types of aquatic and terrestrial species.

Table 5.6: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)
90%	0
75%	0
50%	0
25%	1
10%	2

Recurrence interval (years)	Flow (cfs)
2	536
5	1,130
10	1,640
50	3,030
100	3,740

5.6.6 Governmental Permits and Regulatory Issues

Shawnee County Public Works was issued a Section 303 Nationwide Permit 14 and a Stream Obstructions permit from Kansas DWR for this project. There were no issues with threatened or endangered species or historical resources. This crossing is located within the regulatory floodplain of the Kansas River (Zone AE). A CLOMR/LOMR was not required.

5.6.7 Structure Details

The 67-foot-long box culvert has approximately 1 foot of fill on top of concrete box for the road surface. Approach grades for the roadway are minimal. The culvert openings are aligned with the channel. The culvert has flared wing walls that support the roadway embankment and protect the structure from scour.

Riprap is placed on the left bank of the channel on the upstream and downstream sides of the culvert for erosion protection. The concrete floor of the culvert was embedded to a depth of 1 foot and buried with 1 foot of native streambed soil to promote aquatic organism passage.

Construction of began in October 2013 and was completed in November 2013. Weather conditions were ideal and the channel was completely dry during construction. The contractor used 32 of the 53 calendar days allowed for road closure.

5.6.8 Project Cost

The construction cost was $150,000. The total project cost, including design, inspection, staking, and some minor right-of-way acquisition, was approximately $195,000.

5.6.9 Maintenance Requirements and Performance to Date

The structure has not required routine maintenance since it was built in 2013. During a period of high flow in the Kansas River in 2014, the crossing was submerged and some of the roadway was damaged by erosion and silt deposition. Rossville Township re-surfaced and smoothed NW 46th Street after this flood. Otherwise the crossing has performed very well, with no significant erosion or sediment deposition around or within the culvert.

5.6.10 Project Owner

Shawnee County Public Works owns and maintains the crossing. The main contact for the project is Mike Welch, P.E., at Shawnee County Public Works.

5.6.11 Project Designer

The project was designed by Finney and Turnipseed Transportation and Civil Engineering, L.L.C., in Topeka, Kansas.

5.6.12 Summary

This low-water culvert is subject to flooding from watershed runoff, Kansas River backwater, or both in combination. The culvert's extra length eliminated the need for guardrails. This new structure has opened NW 46th Street to large farm vehicles, which has improved traffic safety on nearby Highway 24.

5.7 Case Study 7. Low-Water Bottomless Culvert in Johnson County

5.7.1 Location

Two bottomless culverts are located on 175th Street in an unincorporated area of Johnson County, Kansas. The east structure is located approximately 300 feet west of Mission Road on Camp Branch Tributary A. The west structure is located approximately 1600 feet west of Mission Road on Camp Branch Creek. This case study focuses on the west structure on Camp Branch Creek (38.8111, -94.6369).

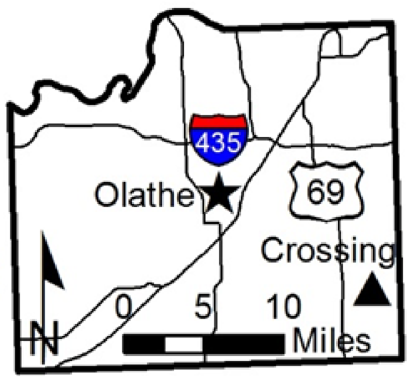

Figure 5.48: Location of Crossing in Johnson County

Figure 5.49: View of Structure from Upstream

Figure 5.50: View of Structure from Downstream

Figure 5.51: View of Crossing from 175th

Figure 5.52: West Abutment from Downstream Side

Figure 5.53: East Abutment from Downstream Side, Showing Exposure of Stem Wall

Figure 5.54: Upstream Channel Viewed from Structure

Figure 5.55: Downstream Channel Viewed from Structure

Figure 5.56: Downstream Face and East Abutment

Figure 5.57: Downstream Face and West Abutment

5.7.2 Crossing Description – West Structure over Camp Branch

Constructed in 2010, this precast bottomless culvert has a span of 20 feet and a rise of approximately 6 feet above the streambed. The structure is supported on spread footings keyed into shale approximately 3 feet below the streambed. The driving surface is 21 feet 4 inches wide. The total length of the concrete driving surface, including the paved approaches, is 124 feet.

5.7.3 Crossing History – West Structure over Camp Branch

The previous structure was a vented ford in Figures 5.58 and 5.59. The vented ford was too often impassable due to overtopping and also impeded aquatic organism passage.

Figure 5.58: Upstream Face of Old Vented Ford

Figure 5.59: Downstream Face of Old Vented Ford

5.7.4 Road and Traffic – West Structure over Camp Branch

This section of 175th Street is a gravel-surfaced road owned and maintained by Johnson County. The road and crossings are heavily used by local residents, school buses, and postal and commercial vehicles. The average daily traffic count of approximately 300 (in 2016) is extremely high for a gravel road with two low-water crossings. The traffic volume will soon increase further as nearby residential subdivisions are completed.

5.7.5 Stream Characteristics

Camp Branch Creek is an intermittent stream with channel bottom with loose cobbles over bedrock. The channel banks are composed of silt with rock outcroppings. The bankfull channel is approximately 45 feet wide and 7 feet deep on average. The drainage area at this crossing is 6.8 mi^2. The land-use in the watershed is a mix of low-density residential properties, cropland, pasture, and woods. Table 5.7 shows estimated streamflow characteristics at the crossing.

Table 5.7: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)	Recurrence Interval (years)	Flow (cfs)
90%	0	2	1,210
75%	0	5	2,420
50%	1	10	3,430
25%	4	50	6,150
10%	10	100	7,530

5.7.6 Governmental Permits and Regulatory Issues

The replacement of the vented ford with the bottomless culvert did not require a Section 404 permit from USACE because no additional fill was placed in regulated waters. Johnson County was issued a Stream Obstructions permit by Kansas DWR. There were no issues with threatened or endangered species or historic resources. The crossing is located in a FEMA Zone AE with a regulatory floodway. A Flood Plain Development Permit was issued by the Johnson County Planning, Development, and Codes Department. The new structure met the no-rise condition, so a CLOMR and LOMR was not needed.

5.7.7 Project Cost and Funding

Multiple options were evaluated to determine the most reasonable and economical solution for this location. The county received a $65,000 grant from the U.S. Fish and Wildlife Service to replace the two old vented fords with two new fish-friendly bottomless structures. The total construction cost in 2010 for both remove-and-replace projects was approximately $127,000.

5.7.8 Maintenance Requirements and Performance to Date

The crossing has performed well and required only some routine debris clearing after high flows. The new bottomless culvert traps much less debris than the old vented ford.

5.7.9 Project Owner

Johnson County owns and maintains the crossing. Ayman Issawi, P.E., of Johnson County Public Works and Infrastructure is the main point of contact for this project.

5.7.10 Project Designer

Johnson County Public Works designed the crossing with help from the U.S. Fish and Wildlife Service.

5.7.11 Summary

This project is unusual in several ways. It is located in a rapidly developing area of Johnson County. The traffic volume is already very high and will increase markedly over the next few years. The low-water bottomless culverts are a temporary solution. At some point, 175th Street will be reconstructed to city standards and the current structures will be replaced with standard bridges. In the meantime, the replacement of the old vented fords with the bottomless culverts has resulted in safer driving conditions and better traffic flow on this busy road.

5.8 Case Study 8. Low-Water Bridge in Sumner County

5.8.1 Location

This structure is located on S. Chicaskia Road at Bluff Creek, 0.5 miles north of the Kansas-Oklahoma border. The crossing is approximately 1.3 miles east and 1.7 miles south of Caldwell, Kansas (37.0063, -97.5824).

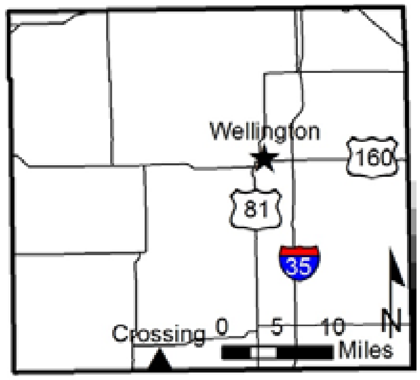

Figure 5.60: Location of Crossing in Sumner County

Figure 5.61: View of Bridge from Upstream

Figure 5.62: View of Bridge from Downstream

Figure 5.63: View of Bridge from Road

Figure 5.64: View of Upstream Channel from Bridge

Figure 5.65: View of Downstream Channel from Bridge

Figure 5.66: View of Downstream Bridge Face in Comparison to Streambank Height

Figure 5.67: View of Upstream Bridge Face in Comparison to Streambank Height

Figure 5.68: North Approach Viewed from Bridge

Figure 5.69: South Approach Viewed from Bridge

Figure 5.70: Debris-Trapping Piers on the Upstream Side of Bridge

5.8.2 Crossing Description

Constructed in 2007, this low-water bridge is 24 feet wide and 102 feet long. The steel structure has four 25-foot spans. Steel pipe piling supports the piers and abutments, as well as the approaches. The bridge deck consists of 8.5 inches of cast-in-place concrete over steel decking on W12x50 steel girders. The three piers extend 8 feet upstream of the bridge face. The pier extensions capture some large timber debris before it reaches the upstream face of the bridge.

The approaches are constructed of compacted rock, native soil, and some asphalt on grades of 9% and 6%. The approaches are protected from erosion by wing walls of steel sheet piling driven to 3 feet below the streambed level.

5.8.3 Crossing History

The previous structure was a vented ford with five 72-inch corrugated-steel vent pipes. The ford's driving surface was approximately 10 feet above the streambed. The vents often became clogged with timber during high flows, which led to frequent flooding of the roadway and finally a complete wash-out of the south approach.

Figure 5.71: Downstream Side of Old Structure with Washed-Out South Approach

Figure 5.72: Washed-Out South Approach to Old Structure

Figure 5.73: Old Structure Viewed from Washed-Out Approach

5.8.4 Road and Traffic

S. Chikaskia Road, constructed of compacted native soil, is owned and maintained by Caldwell Township. The road carries a very low volume of farm and passenger vehicles. It is not used by school buses. The average daily traffic count is less than 15 vehicles.

5.8.5 Stream Characteristics

Bluff Creek is a large perennial stream that is prone to lateral migration. The drainage area at the crossing is 442 mi^2. The streambed is composed of clay, silt, and gravel. The heavily vegetated banks are composed of clay and silt. The bankfull channel is 13 to 15 feet deep and 110 to 130 feet wide in the vicinity of the crossing. Table 5.8 shows the estimated streamflow characteristics at the crossing.

Table 5.8: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)
90%	4
75%	10
50%	23
25%	53
10%	132

Recurrence interval (years)	Flow (cfs)
2	5,890
5	12,500
10	18,500
50	36,000
100	45,200

5.8.6 Governmental Permits and Regulatory Issues

Sumner County was issued a Section 404 Nationwide Permit 14 from USACE and a Stream Obstructions permit from Kansas DWR for this project. There were no issues with threatened or endangered species or historic resources. The County was allowed to install a temporary crossing during construction. This crossing is located in a FEMA-mapped floodplain (Zone A/AE). This project reduced flood levels upstream of the crossing.

5.8.7 Project Cost

The cost of the materials for the bridge, not including the wing walls, was approximately $70,000. Sumner County removed the old crossing and built the new bridge with county forces in approximately 1 month.

5.8.8 Maintenance Requirements and Performance to Date

Sumner County reports that the debris-trapping pier extensions have performed as intended. Timber debris issues have been manageable and have never required closure of the bridge. After high flows, county employees use an excavator with a jaw attachment to remove trapped debris and place it on the side of the channel downstream of the bridge, where it is later burned. Debris removal typically takes 1 to 3 hours.

5.8.9 Project Owner

Sumner County owns and maintains the bridge. Melvin Matlock, the Road and Bridge Director, and Nita Simonton, the Supervisory Engineer, are the main project contacts.

5.8.10 Project Designer

The Sumner County Engineering Department designed the crossing with assistance from CFS Engineers in Topeka, Kansas.

5.8.11 Summary

This inexpensive low-water bridge was constructed in 1 month by county employees. Bluff Creek carries a heavy debris load at high flows. The bridge traps much less timber debris than the old vented ford and does not impede aquatic organism passage. The approaches are well protected from wash-out by steel sheet-piling that extends far into the banks.

5.9 Case Study 9. Low-Water Bridge in Geary County

5.9.1 Location

The crossing is located on Pressee Road at McDowell Creek, 0.5 miles east of McDowell Creek Road. This location is approximately 4 miles SE of Ogden, Kansas (39.0699, -96.6479).

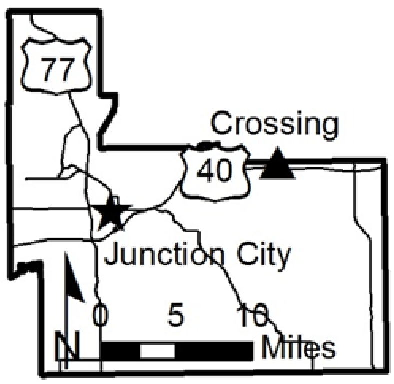

Figure 5.74: Location of Crossing in Geary County

Figure 5.75: View of Structure from Upstream


Figure 5.76: View of Structure from Downstream


Figure 5.77: View of Structure from Pressee Road


Figure 5.78: Upstream Right Bank

Figure 5.79: Scouring Behind the Upstream Right-Bank Wing Wall

Figure 5.80: Downstream Right Bank

Figure 5.81: Upstream Left Bank


Figure 5.82: Upstream Channel Viewed from Bridge Deck


Figure 5.83: Downstream Channel Viewed from Bridge Deck


Figure 5.84: Left Bank Downstream of Bridge, Looking Toward Bridge

Figure 5.85: Right Bank Downstream of Bridge, Looking Toward Bridge

5.9.2 Crossing Description

This single-span low-water bridge was constructed in 2015. The bridge deck is 46 feet long, 14.5 feet wide, and 2 feet thick. The precast concrete bridge deck rests on concrete abutments supported by steel H-piles. The bridge deck is approximately 7 feet lower than the tops of the channel banks. The bridge was placed below the channel banks to reduce its length for economy.

5.9.3 Crossing History

The previous structure was a 79-foot-long steel-truss bridge with a 16-foot-wide deck. The old bridge was closed in January 2014 when county inspectors noticed several broken deck planks. The deck of the old bridge was approximately 14 feet higher than the deck of the new bridge.

5.9.4 Road and Traffic

Pressee Road is a dead-end gravel road that provides the only access for three agricultural parcels with no residences. The bridge is exclusively used for agricultural access. The average daily traffic count is less than one vehicle.

5.9.5 Stream Characteristics

McDowell Creek has a drainage area of 65.7 mi^2 at Pressee Road. Table 5.9 shows estimated streamflow characteristics at this location. The watershed is three-fourths pasture with some cropland and woodlands. The streambanks are heavily vegetated with some minor evidence of lateral migration. The channel is 80 to 100 feet wide between the tops of the banks.

Table 5.9: Estimated Streamflow Characteristics at the Crossing

% of time flow is equaled or exceeded	Flow (cfs)
90%	0
75%	2
50%	8
25%	27
10%	76

Recurrence interval (years)	Flow (cfs)
2	4,740
5	9,810
10	14,300
50	26,700
100	33,000

5.9.6 Governmental Permits and Regulatory Issues

This project was issued a Section 404 Nationwide Permit 14 by USACE and a Stream Obstructions General Permit was issued by Kansas DWR. The DWR Permit required the structure to pass the 2-year discharge without overtopping. Because the crossing is located in a FEMA Zone A floodplain, the structure could not increase the 100-year flood level by more than 1 foot. The permit reviews found no issues with threatened or endangered species or historical resources.

5.9.7 Structure Details

This single-span bridge is constructed of precast concrete. Each abutment is constructed of cast-in-place concrete on four HP10x42 steel piles driven to shale. Construction plans indicate that all piles were to be driven to a depth of 16.5 feet. A geotechnical investigation was performed to estimate the necessary depths for the piles. The abutments are protected by 24-inch light-series stone riprap along the upstream wing walls. The channel banks on both sides of the bridge are protected with 24-inch riprap. Because the bridge deck is approximately 7 feet below the tops of the channel banks, it was necessary to excavate nearly 4,000 cubic yards of soil to achieve acceptable approach grades. The unpaved approaches are stabilized with shot-rock and aggregate.

5.9.8 Project Cost and Funding

The total bridge cost was $251,375. This cost includes engineering, surveying, and construction management. Geary County received $120,000 for this project from KDOT's Kansas Local Bridge Improvement Program.

5.9.9 Maintenance Requirements and Performance to Date

Since the new bridge was completed in March 2015, the approaches have needed to be resurfaced with aggregate four times. After the first flood event caused minor scouring around the wing walls, the county placed 24-inch rock riprap around the upstream wing walls for protection.

Clearing debris and reapplying aggregate takes a two-man crew 1 to 3 hours. Large timber debris is removed and placed downstream using a back-hoe with an extended arm and hydraulic thumb.

5.9.10 Project Owner

Geary County owns and maintains the crossing. Dennis Cox, Geary County Public Works Director, is the main point of contact.

5.9.11 Project Designer

The bridge was designed by Kaw Valley Engineering, Inc., in Junction City, Kansas.

5.9.12 Summary

This sturdy and economical bridge carries heavy trucks and machinery across a large stream. The new structure was constructed at a much lower elevation than the old bridge to reduce its length. Since its deck is considerably lower than the tops of the channel banks, the bridge is overtopped frequently and requires removal of trapped woody debris and repair of the unpaved approaches. Paving the approaches with concrete would reduce the needed repairs after high flows, but the expense might not be justifiable for this little-used crossing. The precast deck structure allowed the bridge to be constructed in only 3 weeks.

References

Arneson, L. A., Zevenbergen, L. W., Lagasse, P. F., & Clopper, P. E. (2012). *Evaluating scour at bridges, Fifth edition* (Report No. FHWA-HIF-12-003, Hydraulic Engineering Circular No. 18). Washington, DC: Federal Highway Administration.

Clarkin, K., Keller, G., Warhol, T., & Hixson, S. (2006). *Low-water crossings: Geomorphic, biological, and engineering design considerations* (Report No. 0625 1808P). San Dimas, CA: U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center.

Federal Highway Administration (FHWA). (2012). *Manual on uniform traffic control devices (2009 Edition with Revisions 1 and 2)*. Washington, DC: Author.

Lagasse, P. F., Clopper, P. E., Pagán-Ortiz, J. E., Zevenbergen, L. W., Arneson, L. A., Schall, J. D., & Girard, L. G. (2009). *Bridge scour and stream instability countermeasures: Experience, selection and design guidance, Volumes 1 and 2, Third edition* (Report No. FHWA-NHI-09-112, Hydraulic Engineering Circular No. 23). Washington, DC: Federal Highway Administration.

McDonald, T., & Anderson-Wilk, M. (2003). *Low water stream crossings in Iowa: A selection and design guide*. Ames, IA: Center for Transportation Research and Education, Iowa State University.

Motayed, A. K., Chang, F. M., & Mukherjee, D. K. (1982a). *Design and construction of low water stream crossings* (Report No. FHWA/RD-82/163). Washington, DC: Federal Highway Administration.

Motayed, A. K., Chang, F. M., & Mukherjee, D. K. (1982b). *Design guide: Low water stream crossings* (Report No. FHWA/RD-82/164). Washington, DC: Federal Highway Administration.

National Weather Service (NWS). (2010). *Floods: The awesome power* (Report No. NOAA/PA 200467). Silver Spring, MD: Author.

Perry, C. A., Wolock, D. M., & Artman, J. C. (2004). *Estimates of flow duration, mean flow, and peak-discharge frequency values for Kansas stream locations* (Scientific Investigations Report 2004–5033). Reston, VA: U.S. Geological Survey.

Rasmussen, P. P., & Perry, C. A. (2000). *Estimation of peak streamflows for unregulated rural streams in Kansas* (Water-Resources Investigations Report 00–4079). Reston, VA: U.S. Geological Survey.

Russell, E. R., Mulinazzi, T., & Kornala, V. K. (2005). *Handbook of traffic control practices for low volume rural roads* (Report No. K-TRAN: KSU/KU-05-5). Topeka, KS: Kansas Department of Transportation.

Schall, J. D., Thompson, P. L., Zerges, S. M., Kilgore, R. T., & Morris, J. L. (2012). *Hydraulic design of highway culverts, Third edition* (Report No. FHWA-HIF-12-026, Hydraulic Design Series Number 5). Washington, DC: Federal Highway Administration.

United States Army Corps of Engineers (USACE). (2011). *Low-water crossings: Lessons learned* (Public Works Technical Bulletin 200-1-115). Washington, DC: Author.

United States Army Corps of Engineers (USACE), Kansas City District. (2012). *General guidelines for stream crossings, Regional condition 1*. Kansas City, MO: Author.

United States Geological Survey (USGS). (n.d.). *StreamStats state applications*. Retrieved from https://water.usgs.gov/osw/streamstats/ssonline.html.

Young, C. B., McEnroe, B. M., Gamarra, R., Luo, Y., & Lurtz, M. (2014). *Estimating the discharge for ordinary high water levels in Kansas* (Report No. K-TRAN: KU-13-1). Topeka, KS: Kansas Department of Transportation.


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