

Case Study 14. Rocky Creek Vented Box Culvert Ford

Location

West Central Arkansas. Ouachita National Forest; Oden Ranger District. Rocky Creek crossing on Forest Road 887 (Muddy Gibbs Road).

Crossing Description

This is a concrete vented ford on a perennial stream that provides habitat for several fish and mussel species. The structure consists of three 6- by 3-foot concrete box culverts, with a splash apron extending downstream of the roadway (figure A86). Six-inch curbs focus water into the center culvert for low-flow passage for weak-swimming fish, and boulders embedded in the concrete provide resting areas for them .



Figure A86. Looking upstream at the concrete vented ford and splash apron.

Setting

Ouachita Mountain Section (M231-A), elevation 740 feet. Parallel ridges and valleys on sandstone and shale are drained by a trellis-patterned drainage network (McDougal et al 2001). Drainage density is high and there are frequent bedrock outcrops. Predominant vegetation includes shortleaf pine, red and white oak, hickory, dogwood, and willow.

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Why Was This Structure Selected?

This structure design was chosen to achieve the following objectives.

- Provide safe and reliable vehicle access during most flows without the expense of a bridge.
- Avoid plugging by woody debris during floods. (Previous structures were a constant maintenance headache because of plugging. Just before the crossing was reconstructed, the area had experienced a major ice storm, and trees falling into streams were plugging culverts and causing them to fail.)
- Provide passage for several endemic aquatic species. (The site is part of a research project into what kind of structures local fish can pass.)

Crossing Site History

In 1964, an unvented ford was installed at this site with 39-inch gabions supporting the downstream edge of a gravel roadbed. The gabion structure was frequently damaged when high flows outflanked the approaches. By 1979, two 24-inch pipes had been placed under the roadbed, and the road was surfaced with concrete (figure A87). The pipes plugged frequently, and many repairs were needed. In 2000, when the existing structure was built, there were several generations of concrete to be removed along with the gabions and pipes.



Figure A87. The previous crossing on road 887 at Rocky Creek was a gabion-culvert structure that was frequently damaged during high flows.

Road Management**Objectives**

The Muddy Gibbs road is a school bus route maintained by the county, and is designed for passenger vehicle use. Average daily traffic is 20 to 30 vehicles.

Stream Environment

Hydrology: Rocky Creek is a perennial stream draining about 1,700 acres of timbered land above the ford. Although rain occurs throughout the year, the two main rainy seasons are winter and spring. Average precipitation is 48 to 56 inches per year. Floods occur during sustained intense rainfall on already saturated soils or during summer thunderstorms. High flows generally do not last more than several hours.

Channel Description: Rocky Creek at the site is moderately entrenched between terraces about 5 to 6 feet above the streambed. Stream substrate is small boulders and large cobbles, with some larger boulders and bedrock outcrops. Channel slope is approximately 2.5 percent, bankfull width is about 15 to 20 feet, and depth at bankfull is 2 feet. The flood plain is narrow, about 2 feet wide. Banks are rocky and well-vegetated upstream of the structure (figure A88). Downstream, banks are scoured and the stream is wider, but the effects of the crossing on channel stability appear to be restricted to the immediate vicinity of the crossing.



Figure A88. Looking downstream at the crossing on Rocky Creek.

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Aquatic Organisms: Two State endemic fish species are found in this watershed: the orangebelly darter and the Caddo madtom. A threatened mussel that occurs downstream depends on several of the native species—including darters—to disperse. Several species of turtles and crayfish; Ouachita dusky; spotted, tiger, and marbled salamanders; as well as frogs and toads also use the stream. A study done for the Ouachita National Forest showed that traditional concrete pipe vented fords (see case study 11) are associated with significant reductions in the number of fish species and individual fishes upstream as compared to downstream of the fords (Gagen and Rajput 2002). Passage is required not only for spawning but also for thermal refuge, as fish seek out deep pools with cooler water in the heat of the summer. Aquatic species must also be able to recolonize areas after local extinctions due to droughts. The need for fish passage was one of the primary drivers for this replacement structure.

Structure Details

Structure: The structure consists of three 6- by 3-foot concrete box culverts set at streambed elevation (figure A89). A 10-foot long splash apron protects the structure against scour during overtopping flows, and a 6-inch curb at the apron's downstream edge is intended to prevent formation of a plunge there by creating a reverse eddy. Curbs under the roadway backwater flows in the side culverts and concentrate water toward the center box (figure A90) for low flow fish passage. The curbs help to retain some bed material in the floor of the culverts, which is also expected to help aquatic species passage through the culvert. Four- to 6-inch boulders embedded in the concrete floor further assist fish passage by providing resting areas.



Figure A90. Looking upstream at the splash apron and backwater curbs.

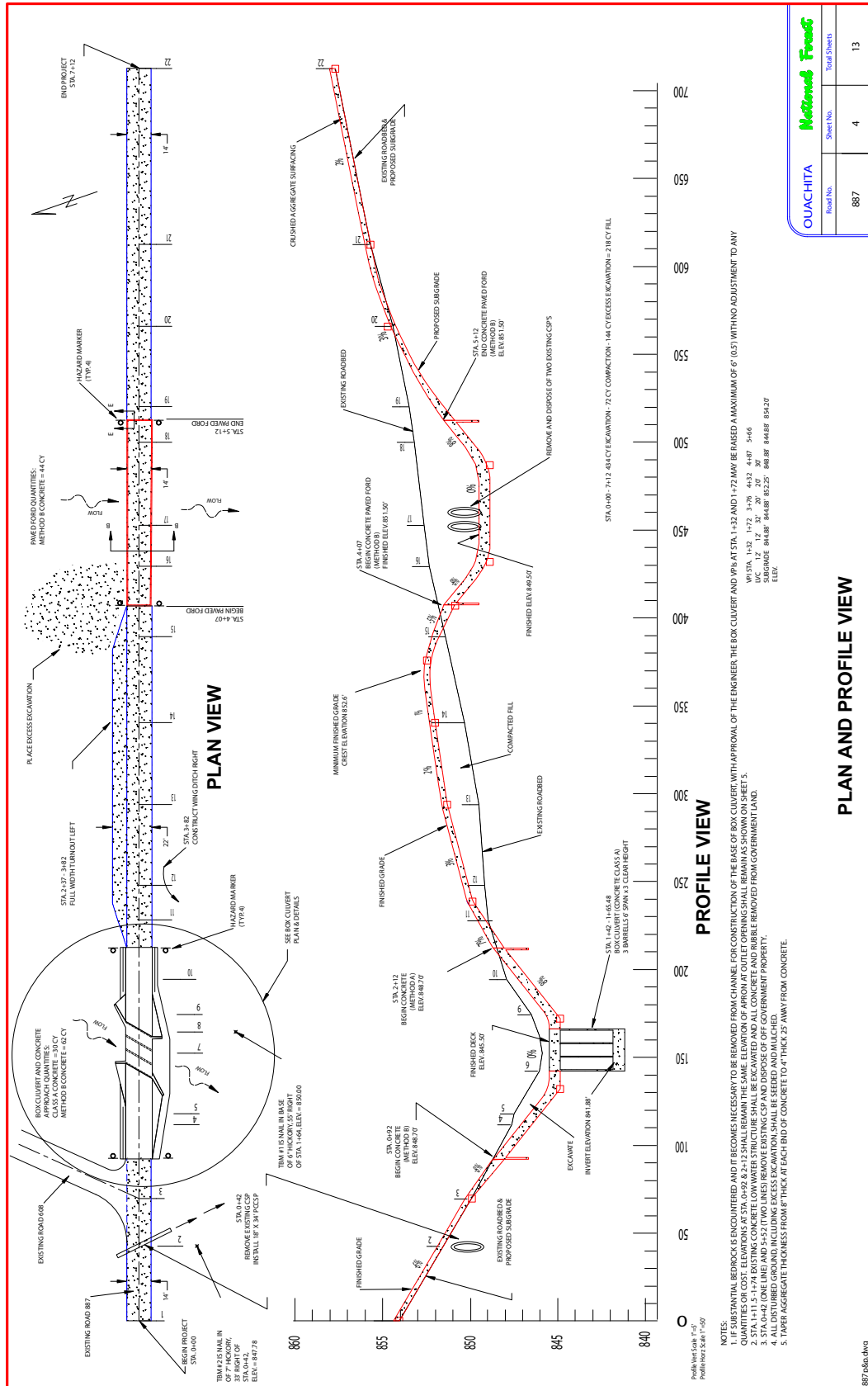
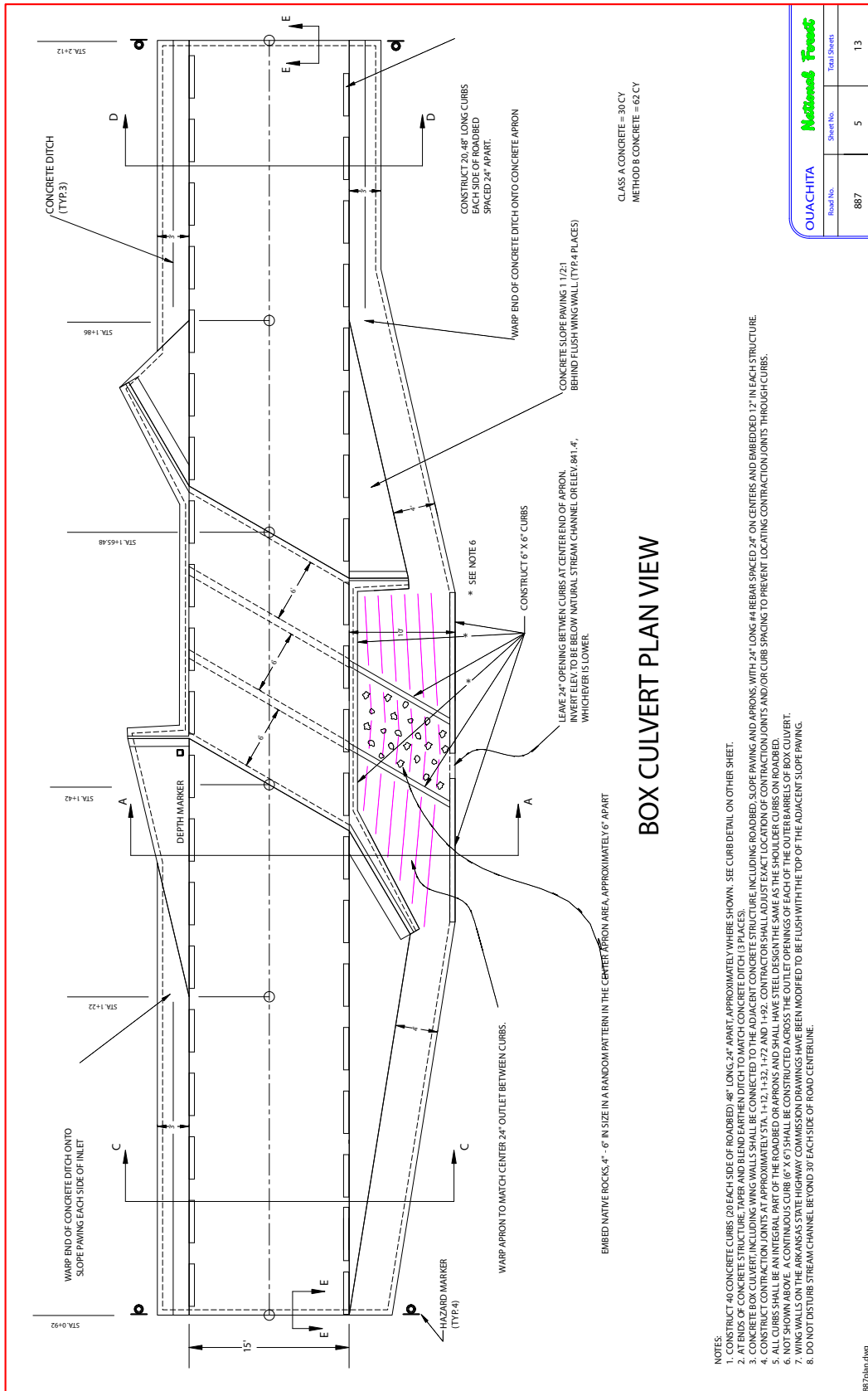


Figure A89a—Plan and profile drawings of the concrete box culvert vented ford at Rocky Creek. A full size drawing may be found on the CD included in the back of this publication.



OUACHITA		Wildland Forest	
Road No.	887	Sheet No.	5
		Total Sheets	
		13	

Figure A89b—Plan drawing of the concrete box culvert vented ford at Rocky Creek. A full size drawing may be found on the CD included in the back of this publication.

This structure was designed to fit the landform. It comes close to matching channel width and the boxes slightly exceed bankfull depth. Although the forest has not monitored flows, they believe the structure overtops several times per year for no longer than several hours at a time.

Bank Stabilization and approaches: The driving surface and approaches are concrete. The structure is protected during overflow by concrete armored wings with ditches both above and below the crossing (figure A90). The approaches slope at 8 percent into the ford and the ditches on the downstream side empty onto the concrete apron below the structure, protecting the streambed from scour by high velocity ditch flows.

There is an overflow channel about 300 feet from the main channel that receives flow during most floods and takes some of the stress off the main structure. Before the replacement, water from the overflow channel would run down the road to the ford. Figure A89 (profile view) shows how the road alignment was modified to prevent diversion and protect both the road and water quality. The two pipes in the overflow channel were replaced by a concrete slab ford at stream grade that cannot plug and that greatly increases the volume of flow the overflow channel can accommodate.



Figure A91. Looking downstream from ford. Note local channel widening.

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Figure A91 looks downstream of the main crossing showing the locally widened channel. Although the channel is rocky and quite stable, flows that overtopped and spread out over and around the previous structure likely caused the bank erosion there. The road's skew relative to the channel may have contributed too.

Cost: Constructed in 2000 for approximately \$70,000.

Safety: Like most of the low-water crossings on roads maintained by the county, this crossing is not signed. Interrupted curbs on the roadway edges provide vehicle protection during overflow conditions, figure A92).

Flood and Maintenance History

The box culvert vented ford has sustained numerous overtopping floods without requiring any maintenance.

Summary and Recommendations

The splash apron, curbs, concrete fillslope armoring, and ditches are working well to keep this structure and the roadway stable. There is no channel bed scour, and the bank scour visible in figure A91 appears to be very limited. The boxes are high enough to prevent plugging so far (5 years after construction). Traffic interruptions are brief enough to be tolerable even on this school bus route.

Fish are often observed in the crossing when it is wet. This particular crossing has been the subject of two fish passage studies but the stream is susceptible to drying and is quite remote so that fish passage detection has been difficult. Nonetheless, 4 of the 8 to 13 species found above and below the crossing have been documented as passing the structure: grass pickerel, central stoneroller, orangebelly darter, and green sunfish. There is a thin veneer of fines on the floor of the box and many embedded boulders (figure A92), but the bed lacks areas with different water velocities and depths, and may not provide passage for the non-fish species present in the stream.



Figure A92. The floor of the central box has a thin veneer of sediment at low flow.

Recognizing that a natural streambed is preferable where aquatic species passage is a goal, the forest is moving to embed more recent box culverts below streambed elevation (see Long Creek vented ford, below). Current practice is to embed the floor below the best estimate of final channel grade, keep the deck as low as possible so that overflows are not much wider than in the natural channel, and provide openings equivalent to the full channel width.

Richard Standage, forest fisheries biologist, and Jim Getchell, engineer, both of the Ouachita National Forest, provided information and photos about the Rocky Creek and Long Creek vented fords.

Similar Structures at Other Locations

Forest Road 512 crosses Long Creek about 30 miles southwest of the Rocky Creek crossing described above. The stream types and road issues and constraints are similar. Figure A93 shows a ford similar to the old unvented ford at the Long Creek crossing. The new 2004 replacement has five 4-foot-high box culverts that were allowed to self-embed to a planned depth of 1 to 2 feet (figures A94 and A95). The crossing's total open width is now just under bankfull width.

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Figure A93. Unvented ford similar to the one replaced at FR 512 crossing on Long Creek, Ouachita National Forest.



Figure A94. Looking upstream at the embedded box culverts that replaced the unvented ford in 2004.

BLASTING AND BEDROCK NOTES

1. It is anticipated that BEDROCK WILL BE ENCOUNTERED and blasting will be necessary to achieve the required elevations, grades and templates. After bedrock is encountered, the elevation of the box culvert may be raised a maximum of 12" with the approval of the Engineer after consultation with the Forest Service Fisheries Biologist. APPROVAL IS NOT GUARANTEED. The elevation of the floor of the box culvert is critical to fish passage and approval to raise the elevation will be based on the recommendation of the Fisheries Biologist. A request for approval will not be considered until after the existing structure has been removed and bedrock has been exposed at the box culvert site. Approval will require a field visit by the Fisheries Biologist and may take up to 3 days to schedule inspection. Contractor is urged to keep the engineer informed of his excavation schedule to facilitate the presence of the Fisheries Biologist. Contractor is also urged to consider the impacts of bedrock removal before submitting his bid!
2. Where bedrock is encountered, the fill depth of all footings may be decreased, with the approval of the engineer if 12" long, #4 rebar pins are placed 6" into bedrock, every 12" along footing length to anchor footings to the bedrock. Under no conditions will the thickness of the box floor be reduced.
3. Upstream of the box culvert, the entire width of the channel, shall be graded from the inlet end of the box culvert, 30' upstream on a uniform slope. If bedrock is encountered blasting may be necessary to ensure that there are no abrupt drops in grade between inlet and 30' upstream. If bedrock is encountered, the slope will not be smooth, but left in a roughened condition over the 30' distance upstream.
4. Downstream of the box culvert there shall be as little disturbance of the channel as possible. If bedrock is encountered, this may include an abrupt change in elevation that may vary with block drainage of the box culvert. This is acceptable and preferable! Contractor shall not disturb more than 20' downstream of outlet of box culvert and less if possible. Point labeled R2, on cross section above, is over 30' downstream, it is exposed bedrock, it is planned to be higher than the floor of the box culvert, and it shall not be disturbed.
5. If approval is granted to raise the elevation of the box culvert, the clear height of 4' in the box shall not be shortened. The elevations of the VPI at Stations 2+18 and 3+00 shall also be raised the same amount. However, the elevation of the ends of the concrete approaches at Stations 1+78 and 3+32 shall remain the same.

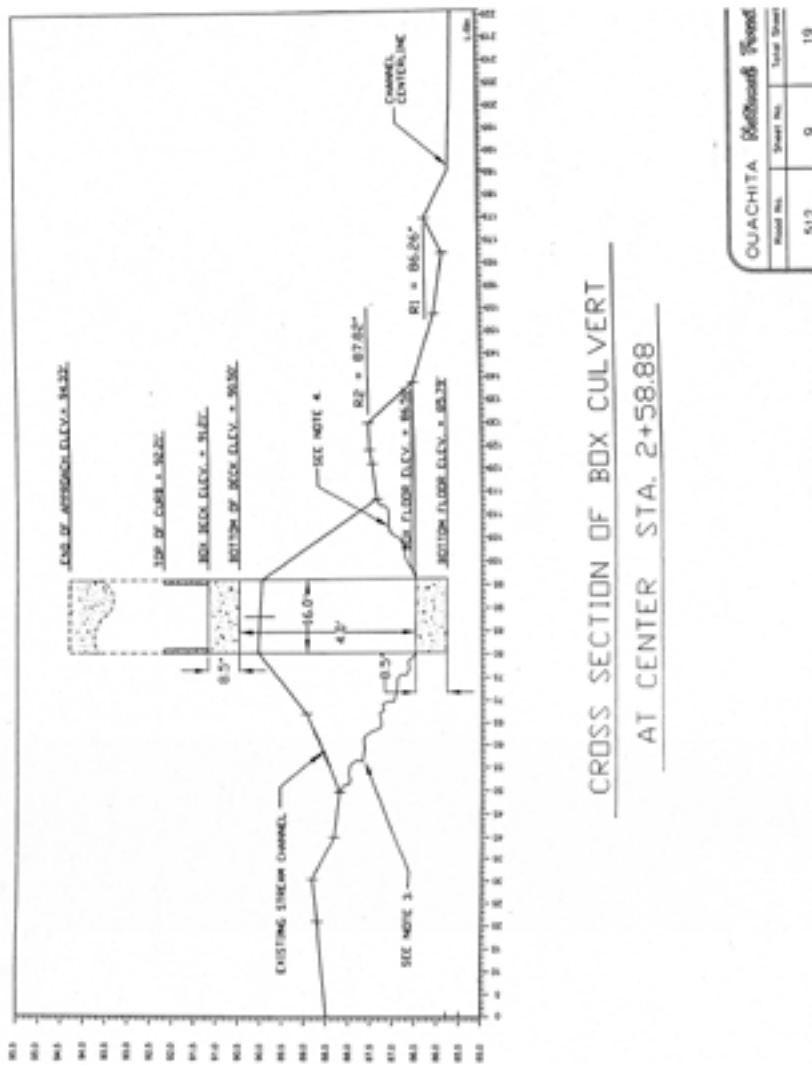


Figure A95 □
 tinuous across the channel. A full size drawing may be found on the CD included in the back of this publication.

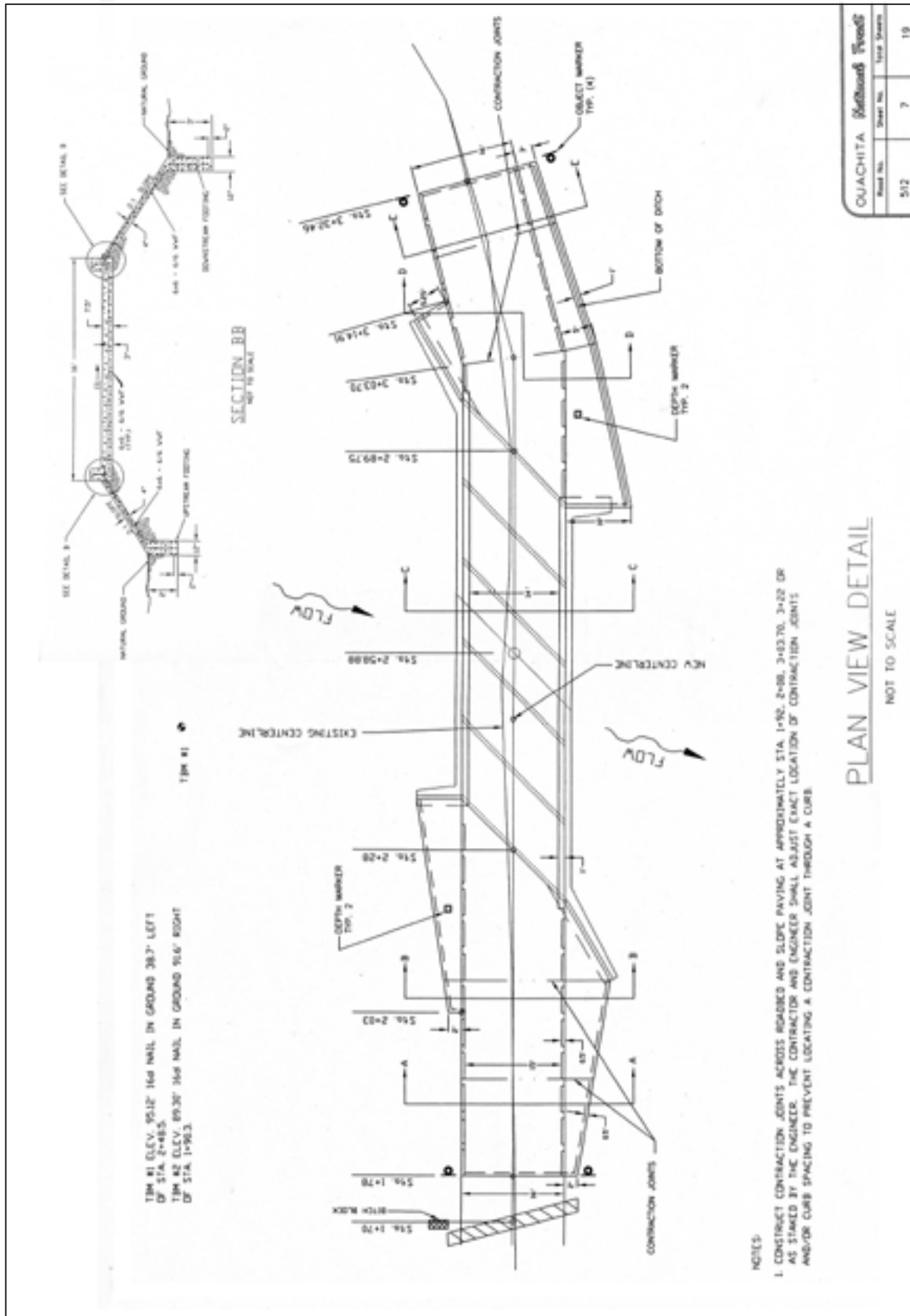


Figure A96—Plan view contract drawing and cross section detail of structure near the channel centerline. A full size drawing may be found on the CD included in the back of this publication.

Figure A95a is a contract drawing showing the longitudinal profile of the stream. The plan was to allow the embedded boxes to fill in with streambed material naturally over time. However, a large storm during construction overtopped the structure and completely plugged the boxes with construction-generated material and natural bedload. The structure was partially cleaned out, leaving substrate at grade and the streambed has maintained itself. In gravel-bed streams, not filling the embedded culverts during construction could produce a headcut. However, in this case there was no headcutting risk because bedrock is intermittently exposed along and across the channel above and below the crossing.

Given the near-surface bedrock, open-bottom arches might appear to be feasible in these streams; however, they are rarely used, not only because bedrock locations are unpredictable with available technology, but also because the intent is to keep the deck as low as possible to give woody debris the best chance of going over the structure rather than plugging it. Also, even with the occasional need to blast to embed the boxes (as was done here), boxes are generally cheaper. They are strong, reliable structures that survive the worst of storms.

The cost of the replacement in 2004 was \$110,000. Note that the curbs on this ford are continuous. Since the ford is the low spot on the road, it retains water on its surface and the curbs do not allow it to drain. In future, the forest plans to add drainholes in the road surface.

