Emergency Relief Program

Resilience Case Study – Arizona

Resilience to Changing Hydrology in the Beaver Dam Wash Bridge

The Beaver Dam Wash is a seasonal stream that drains a watershed of over 600 square miles in Arizona, Utah, and Nevada. The area is characterized by high bluffs, erodible soil, and deep river channels, which makes it susceptible to flooding. In 2004-2005, the region experienced an unusually warm winter. Heavy rains swept through the area in early winter. In February 2005, 3.0 inches of rain fell, 2.2 inches above average, making it the fifth-wettest February on record in the region. The rains fell on an above-average snowpack in the surrounding mountains, which was 50% larger than normal. The rain and subsequent mild temperatures quickly melted the snowpack, causing major floods on the Beaver Dam Wash. The flooding damaged residences, businesses, and infrastructure in communities within Mohave County, Arizona.

The flood washed out the southern approach to the Beaver Dam Wash Bridge that carries County Road 91. The waters also scoured the piers; uprooted trees, causing further damage; and almost overtopped the bridge. Erosion and the uprooted trees shifted the channel path upstream, which put the bridge in the main channel of the stream and exposed it to greater potential damage.

The Beaver Dam Wash Bridge is a critical link in the community of Beaver Dam. It serves homes, a gas station, a convenience store, a railroad maintenance yard, and a firehouse on either side of the bridge. Students living south of the bridge reach an elementary school and a high school located on the north side. Immediately following the storm, Mohave County constructed a temporary access road to the bridge as an emergency repair under the Federal Highway Administration (FHWA) Emergency Relief (ER) program.

The bridge was re-opened but was placed under weight restriction and remained at risk of failure from future storms. Mohave County concluded that the bridge repair required resilience upgrades for three reasons. First, the Beaver Dam Wash basin is prone to flooding and hazardous erosion of the banks. Second, the February 2005 flood compromised the bridge's structural integrity. Third, the flood realigned the stream in a manner that put the bridge at even greater risk in a future flood event.

Resilience Features

To address the damage and structural vulnerability of the bridge, Mohave County developed and evaluated three bridge repair and replacement alternatives:

1. Repair existing 330-ft bridge
2. Replace existing bridge with a new 330-ft bridge
3. Replace bridge with a new 400-ft bridge

Both replacement options included longer spans to enable debris to pass more efficiently. Repairing the existing bridge (Option 1) was ruled out because the structural integrity could not be restored.

Figure 1: Damage to the Beaver Dam Wash Bridge following heavy floods in January 2005. Source: Mohave County

Project Snapshot

Location: Mohave County, Arizona

Date of ER Event: January 2005

Nature of Event: Heavy rains and flooding

Assets Impacted: County Road 91 Bridge over Beaver Dam Wash

Cost of Resilience Improvements: $6.5 million

Type of Improvement: Replacement to current standards

Lead agency: Mohave County Public Works

Other agencies involved: Arizona Department of Transportation; Federal Highway Administration, Arizona Division; U.S. Army Corps of Engineers

U.S. Department of Transportation
Federal Highway Administration

FHWA-HIF-23-023

Mohave County also considered five different erosion/scour protection alternatives, to be used in combination with one of the bridge replacement options:

A. Soil cement-lined training dikes. Soil cement is a strong, durable mixture of natural soil with a small amount of cement and water. A training dike is an embankment that directs a river's flow through a bridge opening.

B. Dumped riprap-lined training dikes. Riprap is a layer of large stones or boulders used to stabilize slopes in flood-prone areas.

C. Gabion-lined training dikes. A gabion is a wire cage filled with riprap and placed on a slope for erosion control.

D. Gabion-lined training dikes, supplemented with a long gabion-lined levee protecting the eroded south bank.

E. Gabion-lined training dikes, supplemented with wing dams along the eroded south bank. Wing dams extend partway into a river channel to slow the flow of water near the banks.

Mohave County evaluated each alternative based on cost, public safety, hydraulic performance, debris and scour vulnerability, environmental impact, right-of-way/easement acquisitions, and operation and maintenance considerations.

For the 330-ft replacement (Option 2), Erosion Protection Options A, B, and C were eliminated; it was determined they would not prevent future flanking of the south bank protection, leaving the south bank and south bridge approach vulnerable to erosion during a flood.

For the 400-ft bridge (Option 3), Options D and E were eliminated. The longer bridge span would relocate the southern approach away from the stream, eliminating the need for the extra bank protection in Options D and E.

Figure 2: Damaged house and flooded bank on Beaver Dam Wash from 2005 flood. Source: Mohave County

Figure 3: Construction of the new Beaver Dam Wash Bridge. Source: Mohave County

The analysis found that the 400-ft bridge would be hydraulically superior as it would lower backwater elevations, decrease flow velocities, lower scour potential, and pass debris more efficiently. Modern hydraulic modeling techniques, which were unavailable when the original bridge was constructed in the 1950s, confirmed that a 330-ft bridge would be inadequate to meet the expected flood volumes. Mohave County also determined that the gabion-lined training dikes—Option C—were the better erosion control alternative, because the flexibility of the slope mattress gabion would allow it to self-heal following damaging events. Mohave County ultimately selected Option 3C: a 400-ft replacement bridge with gabion-lined training dikes. The selected alternative was the least costly of the options that were not otherwise eliminated.

The new bridge and training dikes were completed in June 2010. In December 2010, almost immediately after the new bridge was opened to traffic, the Beaver Dam Wash basin experienced another historic flooding event. Several consecutive storms brought more than 20 inches of rain in one week (eight times the typical precipitation for the time of year), causing significant flooding that threatened the communities of Beaver Dam and Littlefield. South of the bridge, the wash overtopped the north and south banks, damaging several homes and a golf course. An overtopped cottonwood tree impacted the south training dike, damaging the riprap and causing a 250-foot breach of the dike embankment. However, the bridge and roadway did not sustain significant damage. The training dikes and longer bridge allowed floodwaters and debris to pass with no damage to the new bridge's hydraulic or structural capacity, and the bridge remained open during the flooding. The damaged dike was reconstructed after the flood with soil cement. The north dike, though relatively undamaged, was also fortified using driven steel rails to stabilize the riprap and overlayed with an additional 12 to 24 inches of riprap.

Challenges and Lessons Learned

According to the project team, the resilience improvements were well received by the community of Beaver Dam in large part due to Mohave County's emphasis on community relations. Mohave County placed staff in Beaver Dam 24/7 in the weeks following the initial 2005 flood to ensure that the response and recovery efforts went according to plan.

Additionally, Mohave County, the Arizona DOT, and the FHWA Arizona Division Office cooperated to support this project. The team at Mohave County ensured that meetings included all the agencies involved to achieve buy-in.

The primary technical challenge in this project was understanding the hydraulics of the stream. Not only did the 2005 flood change the hydrology of the stream, but the best information available dated from the 1950s when much less was known about hydraulic engineering. As a result, the project team had to go through several rounds of study and design to determine how far upstream to place the bank protection measures. Elements of the initial erosion protection measures proved ineffective against the 2010 flood, requiring steel rails and additional riprap as reinforcement. This underscores the importance of accurate modeling of area hydraulics and future changes in precipitation patterns for resilience projects. Since the December 2010 floods, Mohave County has placed an increased emphasis on aligning hydraulic function of bridges and the upstream channel, as any failure of the upstream channel may cause premature compromise of the bridge structure.

Figure 4: New Beaver Dam Wash Bridge. Source: Mohave County

The project encountered several environmental challenges. First, the north training dike required filling in 0.63 acres of waters of the United States including 0.29 acres of wetlands. As a result, the Mohave County had to obtain a permit from the U.S. Army Corps of Engineers (USACE) to complete the project. Mohave County mitigated the loss of wetlands by acquiring adjacent privately-owned wetlands and establishing a conservation easement. The USACE did not issue the permit until Mohave County had fully acquired the private wetlands, which delayed construction and left the bridge vulnerable to another flood while it was structurally compromised. Mohave County recommends that other agencies in similar situations anticipate any necessary property acquisition to ensure it does not hold up the process.

Figure 5: Gabion-lined training dikes upstream of the replacement Beaver Dam Wash Bridge. Source: Mohave County

Another environmental challenge occurred when Mohave County constructed temporary crossings of the wash to provide access for construction equipment, which made it impossible for fish to travel through the construction area naturally. Mohave County installed block seines—weighted nets that spanned the channel—upstream of the crossings to intercept fish. A fisheries biologist was onsite for the duration of the construction to collect fish from the seine and relocate them downstream.

Key Takeaways

The Beaver Dam Wash Bridge is integral to the surrounding area's access to services and other regions. After a major flood in 2005, the new hydraulics of the wash and compromised structural integrity of the bridge left it vulnerable to future events. Mohave County elected to construct a new bridge and install gabion-lined training dikes to reduce the risk of damage from floodwaters and associated debris in the future. The project team navigated hydraulic, engineering, and environmental challenges to construct a more resilient bridge that has proven capable of withstanding a major flooding event.

Contact Information

Ammon Heier, Area Engineer and Emergency Relief Coordinator
Federal Highway Administration, Arizona Division
602-382-8983
Ammon.Heier@dot.gov