Fish Passage Design Aids Wildlife Crossing in Washington State – State of the Practice

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Abstract

Since 1991, the Washington State Department of Transportation (WSDOT) has partnered with the Washington Department of Fish and Wildlife (WDFW) to help sustain & restore aquatic ecosystems by improving fish passage & natural stream functions at road crossings through a statewide program for Washington highways. In the past 22 years, WSDOT has transitioned its program from culvert retrofits to total replacement of fish passage barrier culverts.

Historically, WSDOT's culvert projects & retrofits were designed for fish use using the hydraulic method based on the swimming abilities of fish. The collaboration with WDFW has led WSDOT to utilize the "stream simulation" design approach, where feasible, to correct a fish passage barrier. The principle of stream simulation is that if fish can move through a natural channel, they can also move through a man-made crossing that simulates the stream channel.

WSDOT has placed motion triggered wildlife cameras near our stream simulation designed culverts around the state and discovered that these newer fish passage structures were very attractive to wildlife, especially deer. Highlighted in this paper are two stream simulation designed culverts on the east & west side of Washington state and also featured is the first WSDOT combination habitat connectivity & fish passage project constructed in this past year in the south central part of the state. Our observations from hundreds of camera images are that a combination of dry bank, adequate illumination, shallow water & lower stream velocities through stream simulation structures provide attractive conditions for wildlife to pass through.

FISH PASSAGE PROGRAM

Since 1991, WSDOT has completed 270 barrier removal projects restoring access to 904 miles of potential upstream habitat for fish. As of July 2013, WSDOT and WDFW have inventoried 6,527 crossings over natural drainages and 1,927 have been identified as barriers. Out of the 1,927 barriers, around 1,500 are barriers with significant upstream habitat that will be prioritized for future correction. A significant reach of upstream habitat is defined as a section of stream having at least 200 meters of habitat without a natural barrier. Stand-alone fish passage barrier projects are prioritized by WSDOT & WDFW to target sequential correction of barriers that have the largest gains in fish habitat and the greatest production benefits for fish.

FISHWAYS

In addition to culverts, WSDOT owns & maintains 160 fishways (Figure 1) statewide. During the 1990's, many WSDOT fish passage barriers were retrofitted with fishways, as an interim fish passage repair. Fishways, commonly called fish ladders, are structures built to facilitate passage of fish through, over, or around an instream barrier. Most fishways enable fish to pass around the barriers by swimming and leaping up a series of relatively low steps.

Fishways were considered a low-cost solution to fish passage barrier correction, compared to the cost of culvert replacements and bridge installation. However, the high costs associated with regular inspection and maintenance of structures over time, and the potential for these structures to fail and become fish passage barriers, has made fishways a less-desirable option for fish passage barrier correction. Additional limitations of fishways include limited or no passage for some life stages of fish and no provision for terrestrial wildlife passage.

FIGURE 1- A steel culvert was assessed as a barrier due to slope & water velocity at Cement Creek. This culvert was retrofitted with a pool -and- chute fishway for $200,000 in 2002 (milepost 8.8 on SR 401 in the southwest corner of WA).

Regular inspections and maintenance are essential in the continued successful operation of fishways. Maintenance of the fishways includes removal of organic debris and sediments, repair of broken or missing baffles and other similar activities to ensure fish passage.

For some fishways, maintenance alone can no longer provide unimpeded fish passage indefinitely. Eventually, baffles, log and concrete control structures, deteriorate, or other parts of the fishways need to be replaced. When the fishways were originally designed, it was recognized that they were intended to provide a relatively short-term, inexpensive fish passage solution. Over the years, fishways provided fish passage, particularly in situations where culvert replacement with a larger culvert or a bridge would have been very difficult or prohibitively expensive. When fishways reach their lifespan and no longer provide fish passage, they are put on the barrier list to be evaluated by biologists and engineers for a solution. Based on the totality of experience with fishways, WSDOT is moving towards total replacement of fish passage barriers in the future rather than building more engineered fishways.

MODERN FISH PASSAGE DESIGN

When a fish passage barrier is identified and scheduled for correction, WSDOT works with WDFW to choose the best alternative for correcting the fish passage problem. Older strictly hydraulic designs intended to suit the swimming abilities of targeted fish populations are now outdated, and, in many instances, permitting agencies won't allow them to be used. The hydraulic design method can be complex and it requires detailed engineering calculations. WDFW developed a 2nd alternative known as the "no slope" culvert design method in the 1990's. The no slope method relies on a simple stream width measurement as the design parameter. The thought is that the natural stream channel develops over time to accommodate a wide range of flows. This channel width is the substitute for the hydraulic analysis. The culvert has a width equal to or greater than the average channel bed width and the culvert is set at a zero percent slope which allows the natural movement of bed load to form a stable bed inside the culvert. There are drawbacks with the no slope method as it does not work for streams with a slope.

WDFW started a new approach to stream design around 1999 called "stream simulation" and formalized this method in their "Design of Road Culverts for Fish Passage (2003 edition). The premise for stream simulation is that if fish can migrate through a natural channel, they can also migrate through a man-made culvert and channel that simulates the natural channel. Stream simulation structures carry a stream with all the appearance of a natural streambed and span an area wider than the existing stream channel and sloped to a similar gradient (Figure 2). This design method attempts to mimic the natural conditions that occurred prior to the culvert's placement in the stream.

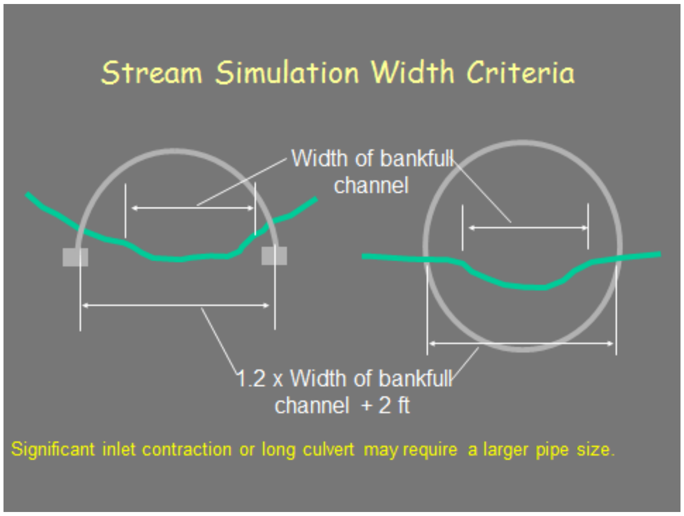

FIGURE 2- Stream Simulation Width Criteria (courtesy of the Washington Department of Fish &Wildlife)

Stream simulation provides for larger stream widths that promote sediment and woody debris passage through the structure during high flow events (Figure 3). Additionally, stream simulation designed crossing structures allow small and medium sized animals to travel through the crossing structure because the streambed margins are usually dry or the water is shallow enough that the animals will wade the stream. The latest stream simulation design guidance and its history can be found in the 2013 edition of WDFW's *Water Crossing Design Guidelines*.

FIGURE 3- A 0.7 m (2.2 ft) round culvert was replaced with stream simulation designed 3.6 m (11.8 ft) span x 1.8 m (6 ft) rise bottomless concrete box at an Unnamed Tributary to Squamish Harbor on SR 104 at milepost 12.30 near the Hood Canal Bridge.

WSDOT is currently required by a U.S. District Court Permanent Injunction of March 29, 2013 to use bridges or stream simulation designs in fixing approximately 840 plus fish passage barriers in Western Washington over the next 17 years. The injunction requires that "fish passage shall be achieved by (a) avoiding the necessity for the roadway to cross the stream, (b) use of a full span bridge, (c) use of the "stream simulation" methodology described in *Design of Road Culverts for Fish Passage* (WDFW, 2003) or *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings* (U.S. Forest Service, May 2008), which the parties to this proceeding have agreed represents best science currently available for designing culverts that provide fish passage.."

CAMERAS DOCUMENT WILDLIFE PASSAGE

Quantification of wildlife use of WSDOT stream simulation designed culverts and bridges began in April 2010 when motion-triggered cameras were deployed at both ends of the Mosquito Creek box culvert (Kintsch & Cramer 2011). A 1.2 m (4 ft) round culvert was replaced with a stream simulation designed culvert that is 4.9 m (16 ft) wide at Mosquito Creek on US 101at milepost 76.48 southeast of Aberdeen, WA. This new fish friendly culvert provides 3.5 km (2.2 mi) of upstream habitat for fish and habitat connectivity for wildlife (Figure 4).

The Mosquito Creek culvert was designed by WSDOT and constructed during the late summer and early fall of 2009. The engineer's estimate for construction was $868,331 and the low winning bid was $728,349. The total cost of the project with design and permitting was $1,428,863. The cost of the box culvert, itself, was $92,000 in the low bid.

FIGURE 4- A round culvert was replaced with stream simulation designed 4.9 m (16 ft) span x 2.9 m (9.5 ft) rise bottomless concrete box culvert at Mosquito Creek on US 101.

In 138 days of camera monitoring, 60 black-tailed deer and 18 raccoon crossings were documented. Many of the crossings involved a doe with two fawns (Figure 5).

FIGURE 5- A doe & two fawns utilizing the Mosquito Creek culvert on US 101 in 2011.

WDFW evaluates all stand-alone fish passage barrier correction projects completed by WSDOT immediately after construction and for one year following construction to verify they are working properly and providing fish passage. If the stream is functioning as a natural stream inside the new culvert or bridge during both evaluations, it is assumed that fish can pass through (whether they are present or not) and the site is taken off the fish passage barrier list.

WDFW personnel conduct adult spawner surveys pre and post project for WSDOT. Typically, the surveys are conducted 500 meters below and above the project. If salmonids are not detected upstream of the fish passage project in the first year after construction, surveys may be performed in subsequent years. Not all potential habitat may be utilized by salmonids following a fish passage project. There are other factors that may influence fish production including surface water diversions, pollution, hydropower, unfavorable ocean conditions, predation, harvest, habitat degradation and upstream/downstream barriers.

Spawner surveys were conducted at Mosquito Creek pre-project in 2006 & 2007 and one adult coho salmon was seen downstream and one adult coho upstream. Post project surveys were completed in 2009 & 2010 with upstream observations of 4 adult coho salmon and 2 salmon redds (egg nests) in 2009 and 3 adult coho salmon and 2 salmon redds in 2010 (Figure 6).

FIGURE 6- A large salmon (possibly coho) triggers the wildlife camera in January of 2011 at Mosquito Creek.

At Deadman Creek on U.S. 2 north of Spokane, a 2.4 m (8 ft.) box culvert (Figure 7) was replaced with a stream simulation designed steel plate arched culvert as part of a larger transportation project during the late summer and fall of 2010. The new culvert opened up approximately 92 km (57 mi) of potential upstream habitat for resident cutthroat trout.

FIGURE 7- This concrete box culvert at Deadman Creek on US 2 was considered a barrier due to excessive water velocity during high flows.

The new culvert has a 9.1 m (30 ft) horizontal opening and a 4.6 m (15 ft) vertical opening, and is 34.1 m (112 ft) long (Figure 8). There is no cost information for this culvert as it was part of a much larger $42.8 million dollar transportation project built just north of Spokane, WA.

FIGURE 8- The new Deadman Creek culvert just north of Spokane, WA at milepost 296. One of the wildlife cameras is in the green utility box in the right of the photo.

As construction was nearing completion, White-tailed Deer began using the structure, and, at the end of ten months of monitoring, 1,241 White-tailed Deer crossings had been documented, an average of more than 4 deer crossings per day. An image of a moose was captured by the cameras as well (Figure 9).

FIGURE 9- A moose traversing the stream simulation designed culvert at US 2 Deadman Creek near Spokane, WA

BRIDGE FOR FISH & WILDLIFE

Terrestrial wildlife have not been purposefully considered in the design of stream simulation fish passage projects until recently by WSDOT. Recognizing the economies of fixing two environmental deficiencies simultaneously, WSDOT developed an innovative combination fish passage and wildlife connectivity project (Figure 10) near Goldendale, WA. A culvert that was undersized relative to modern standards was located at Butler Creek on US 97 at milepost 21.35. It was identified as a fish passage barrier due to slope and excessive water velocities during high flows. The creek provides habitat for steelhead and resident trout with 16 km (10 mi) of fish habitat upstream of the barrier culvert. To the north and south of this culvert is a 12.8 km (8 mi) stretch of highway between mileposts 15 to 23 that has seen an increasing number of deer-vehicle collisions: 616 deer carcasses were removed in a ten-year period from 2002 to 2011. This stretch of highway has one of the highest deer-vehicle collision rates in Eastern Washington.

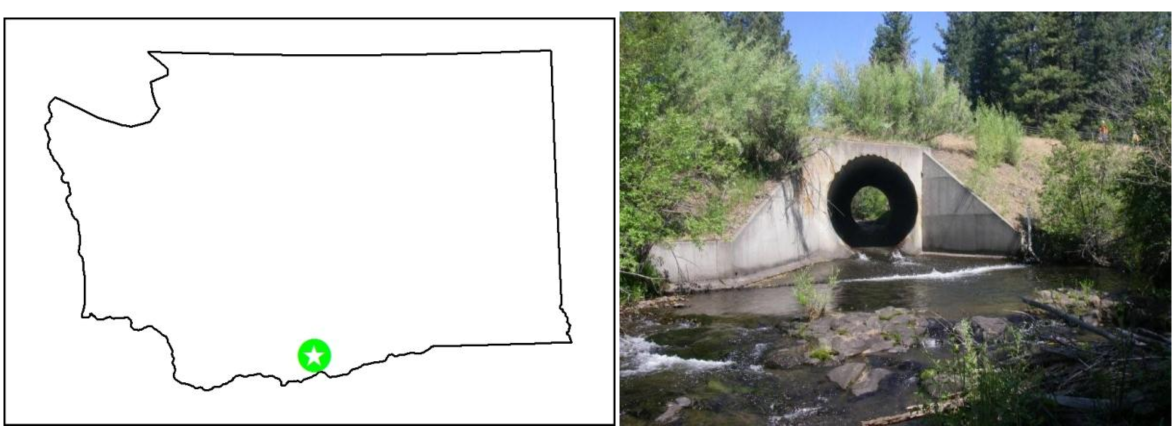

FIGURE 10- This undersized 3.2 m (10.5 ft) round culvert in Klickitat County was be replaced in 2012 with a 19.8 m (65 ft) bridge with a 3 m (10 ft) wildlife bench incorporated into the channel design at milepost 21.35.

WSDOT conducted a reach analysis (Schanz, 2010) at Butler Creek to examine the hydrologic and geomorphic factors that should be considered when the culvert was replaced. It was determined that a 9.1 m (30 ft) channel width would meet the WDFW Stream Simulation design criteria plus an additional 3 m (10 ft) for a wildlife bench. The final cross section under the bridge was 13.1 m (43 ft) in total with an active channel width of 8.2 m (27 ft) and a wildlife bench width of 3 m (10 ft).

WSDOT biologists worked with WSDOT design engineers to purposely construct a 19.8 m (65 ft) bridge span (Figure 11) with a new stream channel underneath that includes a 3 m (10 ft) wildlife bench and at least 2.7 m (9 ft) of height (rise) for deer and other wildlife. The average height of the bridge after construction from the center of the stream to the bottom of the bridge is 3.9 m (13 ft). The inclusion of barrier fencing, jump-downs, and wildlife guards followed recommendations in the Wildlife-Vehicle Collision Reduction Study – Report to Congress from the Federal Highway Administration.

FIGURE 11- The new 19.8 m (65 ft) bridge constructed in 2012 at US 97 Butler Creek near Goldendale, WA

Wildlife fencing that is about 2.4 km (1.5 mi) in length and that is 2.4 m (8 ft) tall was constructed between natural barriers to encourage and/or funnel the animals under the new bridge and prevent their wandering on the highway (Figure 12). Six escape jump-downs were built into the fencing so that animals that somehow get trapped on the highway can utilize a jump-down to escape the highway (Figure 13). The bridge was operational in the fall of 2012 but the fencing and jump-downs were not completed until August of 2013. The engineer’s estimate was $2,105,341 and the low winning bid was $2, 113,354. The total project cost is $3.4 million.

FIGURE 12- Wildlife guards (similar to a double-width cattle guard) were placed at three nearby access roads flanked by 2.4 m (8 ft) tall fencing. This deer avoided the highway with the wildlife guard and fencing in place.

FIGURE 13- One of six jump-down structures to facilitate escape for deer trapped in the right-of-way of US 97 at Butler Creek.

This creative project will undoubtedly solve an aquatic and wildlife connectivity problem with a single action (Figures 14, 15, 16).

FIGURE 14- Six deer crossing under the new bridge at US 97 Butler Creek near Goldendale, WA

FIGURE 15- A great blue heron walking the streambed under the new US 97 Butler Creek bridge.

FIGURE 16- A doe and two fawns utilizing the wildlife bench under the new bridge at US 97 Butler Creek at milepost 21.35.

Four motion triggered wildlife cameras have been placed upstream and downstream and the preliminary data is promising. A total of 101 deer crossings were observed between June 1, 2013 and September 30, 2013 for an average of 1.1 deer per day. A Great Blue Heron and a ground squirrel crossed under the bridge 5 times during this time period as well. Additional cameras have been placed at one of the jump-downs and near a road crossing with a wildlife guard. We are looking forward to reporting on our remote camera results and more in the future.

SUMMARY

WSDOT has a dedicated program in place to replace its fish passage barrier culverts. In the past 12 years the agency has moved from retrofits and hydraulic design methods for fish passage to a newer method of design called stream simulation. An added benefit to constructing stream simulation culverts and bridges is increased wildlife connectivity through stream corridors.

WSDOT's observations from hundreds of motion triggered wildlife photos in the past 3 years are that wildlife passage, as well as fish passage, can be provided by larger stream simulation culverts and bridges. We believe a continuous and dry bank through the culvert is not necessary for passage to be attractive and functional to some species. The pictures we've gathered show examples of deer and raccoon walking the stream despite a dry bank alternative being available. Areas of shallow water and low water velocity are almost certainly more important to functionality than a continuous dry bank. However, the combination of dry bank, adequate illumination, shallow water and lower stream velocities through stream simulation structures provide attractive conditions for many animals to traverse through. If vertical clearance is adequate (generally > 2.4 m (8 ft)), medium sized animals such as deer will use them for safe passage under a highway. Birds are also known to fly through them. We found no evidence to suggest that the center of the channel must remain in the middle of the bridge or culvert to provide passage. It's possible that some small mammals, like deer mice and voles, benefit from a continuous dry bank. However, our cameras seldom will trigger on mammals smaller than a raccoon so that is difficult to confirm at this time.

Engineers and designers should consider the WDFW stream simulation method when designing a stream crossing. WSDOT has discovered that by constructing a culvert a little wider than the stream and adding a little additional height, you can maintain wildlife passage through riparian corridors.

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