A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on the National Forests of Alaska

(A supplement to the Alaska Region's June 2, 2002 briefing paper titled Fish Passage on Alaska's National Forests)

U. S. Forest Service, Alaska Region
(September 27, 2002)

This is a general technical review of the process undertaken by the USDA Forest Service, Region 10 interagency fish passage task force, to address the issue of fish blockage at road crossings.

This review will answer the following question:

1. Why is it important to provide fish passage at road crossings?
2. What is a "blockage" of fish movement at road culverts?
3. How were existing road culverts evaluated to determine if they blocked fish?
4. How are new and reinstalled culverts being designed to ensure fish passage?
5. What additional information is needed to better address fish passage issues?

Providing for fish passage at stream and road intersections is an important consideration when constructing or reconstructing forest roads. Improperly located, installed or maintained stream crossing structures, primarily culverts, can restrict fish movement, thereby adversely affecting fish populations. These structures may present a variety of obstacles to fish migration. The most common obstacles are culvert outlet vertical barriers, debris blockages, and excessive water velocities.

Why provide fish passage?

Fish residing in the streams of Alaska's national forests require unhampered access up and down the stream for various reasons. Adult anadromous fish returning from the ocean require access to spawning habitat while juvenile anadromous fish often move during their freshwater life stage in response to seasonal differences in available food and shelter. Resident (non-anadromous) fish, which spent their entire lives in freshwater, also move within the stream seeking food, shelter and access to spawning habitat.

Barriers to fish movements may not need to be complete barriers to fish to drastically affect fish populations.

- Even if stronger swimming adult fish can obtain passage, juvenile fish may not be able to, and habitat important to them on a seasonal basis will not then be available.
- Under-utilization of available habitat may be the result if passage is provided only to the stronger individuals of a population or if passage is only possible at high or low stream flows.
- Barriers to spawning migrations may cause fish to deplete their stored energy prior to spawning or delay spawning later than optimal for egg survival.
- Failure to provide fish passage at roads can reduce the genetic diversity of stranded resident fish populations or their complete loss after extreme flood or drought.

The requirement and direction to provide fish passage at road crossings can be found in several documents.

- Section 33, Code of Federal Regulations 323.3(B), Clean Water Act states: "the design, construction and maintenance of the road crossing shall not disrupt the migration or other movement of those species of aquatic life inhabiting the waterbody"
- The Southeast Alaska Area Guide (USDA, 1977) states: "Fish passage must be assured at all locations where roads cross streams."
- Tongass Land Management Plan (1997) states: "Maintain, restore or improve the opportunities for fish migration…"

Supplemental Memorandum of Understanding between ADF&G and the USFS (1998) agreed to: “Protect fish habitat and provide efficient fish passage. ”

What is a fish passage blockage?

A culvert is determined to be a blockage to fish passage if it fails to allow passage of a designated species and life stage at or below a designated stream flow.

The designated species, or design fish, for anadromous streams is juvenile coho salmon, 55 mm in length, while for non-anadromous or resident fish streams, Dolly Varden char, rainbow trout and cutthroat trout are the design species.

The Tongass Forest Plan states that passage in Class I streams may be delayed for up to four days due to high water velocity during the mean annual flood, which is the stream flow that statistically recurs about once every two years. The State of Alaska requests instead that the Forest Service only allow fish to be delayed for up to two days, one day before and one day after mean annual flood flows. This upper limit stream flow, or design flow, is unique for each stream and is estimated at 40% of the mean annual flood flow. Although our information is limited, it appears that flows in most streams will not exceed this level more than 2% of the time, generally during storm events when fish would be less likely to move under natural conditions. The Clean Water Act does not contain a provision to delay migration due to high stream flows.

How are existing culverts evaluated?

The basic challenge of evaluating fish passage capability at culverts is to determine and compare fish swimming performance and culvert hydraulic conditions across a range of stream flows. Analytical software, entitled “FishXing”, has been developed by the Forest Service to assist with these calculations. This software is designed to allow the user to input various criteria important to fish passage and estimate the effects on the fish’s ability to move through the culvert at different stream flows. Some of the input variables are fish swimming ability, culvert dimensions, roughness within the culvert and various streambed and culvert elevations. This software is available on-line from: http://www.stream.fs.fed.us/fishxing.

To improve assessment efficiency, a juvenile fish passage evaluation criteria matrix was developed by a group of interagency, interdisciplinary professionals (table 1). The matrix increases assessment efficiency by creating a course sieve that quickly separates out the culverts that have conditions that can be assumed to meet standards from those that do not. It is then only necessary to do the more time intensive FishXing analysis on the culverts with less obvious fish passage conditions. The evaluation matrix stratifies culverts by type and establishes criteria thresholds for culvert gradient, stream constriction, debris blockage, and vertical barrier at culvert outlet (perch) specific to each stratified culvert type. Each culvert is placed into one of the three threshold categories. The categories are: **GREEN**: conditions that have a high certainty of meeting juvenile fish passage at all desired stream flows; **RED**: conditions that have a high certainty of not providing juvenile fish passage at all desired stream flows and **GRAY**: conditions are such that additional and more detailed analysis is required to determine their juvenile fish passage ability. This additional analysis includes use of the FishXing analytical model.

Table 1. Fish passage evaluation criteria (see note below).

	Structure	Green	Grey	Red
1	Bottomless pipe arch or countersunk pipe arch, substrate 100% coverage and invert depth greater than 20% of culvert rise.	Installed at channel grade (+/- 1%), culvert span to bedwidth ratio of 0.9 to 1.0, no blockage.	Installed at channel grade (+/- 1%), culvert span to bedwidth ratio of 0.5 to 0.9, less than or equal to 10% blockage.	Not installed at channel grade (+/- 1%), culvert span to bedwidth ratio less than 0.5, greater than 10% blockage.
2	Countersunk pipe arches (1x3 corrugation and larger). Substrate less than 100% coverage or invert depth less than 20% of culvert rise.	Grade less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75.	Grade between 0.5 to 2.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 2.0%, greater than 4" perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
3	Circular CMP 48 inch span and smaller, spiral corrugations, regardless of substrate coverage.	Culvert gradient less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Culvert gradient 0.5 to 1.0%, perch less than 4 inches, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Culvert gradient greater than 1.0%, perch greater than 4 inches, blockage greater than 10%, span to bedwidth ratio less than 0.5.
4	Circular CMPs with annular corrugations larger than 1x3 and 1x3 spiral corrugations (>48" span), substrate less than 100% coverage or invert depth less than 20% culvert rise.	Grade less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75.	Grade between 0.5 to 2.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 2.0%, greater than 4" perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
5	Circular CMPs with 1x3 or smaller annular corrugations (all spans) and 1x3 spiral corrugations (>48" span), 100% substrate coverage and substrate depth greater than 20% of culvert rise.	Grade less than 1%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Grade 1.0 to 3.0%, perch less than 4 inches, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Culvert gradient greater than 3.0%, perch greater than 4 inches, blockage greater than 10%, culvert span to bedwidth ratio less than 0.5.
6	Circular CMPs with 2x6 annular corrugations (all spans), 100% substrate coverage and substrate depth greater than 20% of culvert rise.	Grade less than 2.0%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Grade 2.0 to 4.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 4.0%, greater than 4 inch perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
7	Baffled or multiple structure installations		All	
8	Log stringer or modular bridge	No encroachment on bedwidth.	Encroachment on bedwidth (either streambank).	Structural collapse.

Note: These criteria are not design criteria, but rather indicate whether the structure is likely to provide fish passage this moment in time.

How are new culverts designed to ensure fish passage?

To provide fish passage in new road crossing structures, principles of stream simulation are often used in structure design. As the name implies, stream simulation attempts to design the stream crossing structure so that it will replicate the form and function of the stream channel. Under these conditions the bottom of the structure has a natural substrate and fish can move freely through the structure under the same hydraulic conditions experienced in the natural stream channel. Some of the design considerations used to maintain the natural stream process include the following:

- Equip the culvert with bedload retaining baffles and backfill the culvert with appropriately sized rock that will be retained even during major storm events.
- Bury the inlet and outlet of the culvert to help retain the natural stream gravels and flow velocities.
- Install the culvert at the same gradient as the stream to prevent erosion at the upper and lower ends.
- Backwater the culvert outlet to facilitate fish passage.
- Match the culvert width to the average "bankfull" width of the stream.

What are the information needs?

Assessing and designing culverts to provide efficient fish passage is a complex process. Since actual fish passage is difficult to measure, the assessment of fish passage through culverts in varied stream conditions has been dependent on models. These models are based upon many assumptions pertaining to stream hydrology, culvert hydraulics, fish swimming performance and timing of fish movement. The validity of the results are only as good as the assumptions they are built on. Much more information is needed to validate these assumptions. The following list identifies some of the most important information needs:

- Additional quantitative information on the stream flow characteristics in small watersheds.
- Additional quantitative information on the movement patterns of juvenile coho, cutthroat trout and Dolly Varden char as related to season, stream flow and size of fish.
- Additional information about the locations and character of fish habitats
- Validation of the Juvenile Fish Passage Evaluation Criteria Matrix.
- Additional quantitative data on the burst and sustained swimming speeds of juvenile coho salmon, cutthroat trout and Dolly Varden char.

- Validation of mathematical predictions of fish swimming capability in natural field conditions.

In summary, some road stream crossing structures, such as culverts, can block the natural movement patterns of fish and cause reductions in fish production. By using the appropriate design fish and the appropriate culvert design standards, we can maintain the long-term survival and sustained production of fish that are important to subsistence, commercial and recreational users, while continuing to provide opportunities for road construction and access.

Reference

Readers are encouraged to refer to this brief list of references for more detailed discussions of fish passage at road crossings.

USDA Forest Service, 2000. FSH 2090.21_30, Section 34, Fish Passage at Road Crossings. 21 p.

Behlke, C.E., D.L. Kane, R.F. McLean and M.D. Travis, 1991. Fundamentals of Culvert Design for Passage of Weak-Swimming Fish. Final Report prepared for State of Alaska, Department of Transportation and Public Facilities. FHWA-AK-RD-90-10. 159 p.

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Kahler, T.H. and T.P.Quinn, 1998. Juvenile and Resident Salmonid Movement and Passage Through Culverts. Final Research Report for the Washington State Transportation Commission. Research Project T9903, Task 96. 38 p.

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USDA Forest Service, 1977. Southeast Alaska Area Guide. 289 p.

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