Oregon Department of Forestry: Compliance With Fish Passage and Peak Flow Requirements at Stream Crossings Final Study Results

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COMMITTEES AND COORDINATORS

This study has oversight by external and internal review committees. The committees' main functions were to review and provide feedback on the study design and reports. This input was utilized by the Oregon Department of Forestry (ODF) in carrying out the study and completing the report. The committees met throughout the development of the project and will continue to meet annually.

<u>Internal Review Committee</u>

John Buckman	Protection Unit Forester, Pendleton
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Rex Storm	Association of Oregon Loggers
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INTRODUCTION

Oregon statutes (ORS 498.351 and ORS 509.605) and current forest practices rules require that new or reconstructed stream crossings on Type F streams must be installed to provide fish passage. Crossings must also be designed with the capacity for a 50-year design peak flow. During the summer of 1998, the Oregon Department of Forestry (ODF) implemented a pilot study to test the field protocol for monitoring compliance with forest practices rules regarding stream crossings on fish-bearing (Type F) streams. The main goals of the stream-crossing pilot project were:

- To refine study design and field methods, and
- To provide preliminary results regarding compliance with juvenile fish passage and peak flow regulations.

The pilot study was completed in 1998 and the study design and field protocol were subsequently modified to improve sampling methods and repeatability. A pilot study report was prepared in March 2000 on the results of this pilot project. The final study was carried out from 1999 to 2000, when 98 additional sites were randomly selected and monitored with the modified protocol to evaluate compliance with forest practice fish passage and peak flow rules.

The emphasis on fish passage, especially juvenile fish passage, has grown in importance in recent years as the number of salmonid species listed as threatened or endangered under the Endangered Species Act has grown. ODF issued its first memorandum about constructing road crossings on Type F streams with an emphasis on juvenile fish passage in January 1995 (Mills and Stone, 1995). Since that time, the ODF fish passage guidelines have been expanded and improved three times (Robison, 1995; OWEB, 1997; OWEB, 1999). Other states in the Pacific Northwest have issued guidelines during the same period (IDL, 1998; WDFW, 1999). Traditionally, a stream crossing design was considered successful when it maximized the speed and efficiency of water passage with the smallest possible culvert. Changing from this to designing culverts that provide the low-velocity environment needed to allow upstream movement of juvenile fish is a dramatic shift in the approach to the engineering of stream crossings. The installations monitored as part of this project were all installed in 1998, less than four years after the juvenile fish passage requirements were enacted. There is a steep learning curve for all involved with such a change, from engineers to the backhoe operators, that is reflected in the monitoring results.

<u>Limitations of the Study</u>

The results presented in this paper are based on data from 98 different stream crossings collected in 1999 and 2000. All of these crossing were constructed using the 1997 guidelines (OWEB 1997) that have since been replaced by an updated 1999 version (OWEB 1999). While some of the alternatives in the guidelines remained relatively unchanged in the current version, specifications on other alternatives changed significantly. Thus, findings from this report will be most applicable to the 1997 guidelines and will have limited applicability to some of the guidelines currently in use. Also, since the large majority of projects evaluated in this study occurred on industrial forestlands (78%), the findings are also most applicable to stream crossings on industrial forestlands. Nonetheless, the findings reported here will provide valuable insights that will assist landowners, operators, and the ODF in having greater success in implementation of fish-friendly stream-crossing strategies.

Furthermore, this report presents estimates of how many of the monitored sites are likely to pass both juvenile and adult fish. There are three basic methods one could use to assess fish passage at stream crossings: 1) direct observation of successful fish passage; 2) detailed velocity profiles and other measures of the stream crossings compared to fish swimming abilities; and 3) measures of surrogates indicative of velocity and other conditions (surrogates of #2) at the stream crossings. Due to the complexity and high expense involved in utilizing the first two options, the third option for assessing fish passage was utilized in this study. The limitation of this approach, however, is that data collected at the sites permit evaluation of only the most restrictive condition (juvenile fish passage likely year-round). Therefore, it is important to keep in mind that sites found "not likely to pass fish" might pass some larger juvenile (>2 inches) and adult fish under conditions when fish movement is likely to occur.

Other Monitoring Projects

This stream-crossing study compliments a comprehensive Best Management Practices Compliance Monitoring Project (BMPCMP) designed to evaluate harvest units, high risk sites, roads, skid trails, wetlands, and riparian areas. Please refer to the BMPCMP final study report regarding these other compliance topics (Dent and Robben, 2002). The ODF forest practices monitoring program has conducted other water quality, riparian, and landslide studies which focus on the effectiveness of the rules in providing resource protection. Please refer to the forest practices monitoring strategy and ODF forest practices monitoring web page for more information on these studies (Dent, 1998a).

BACKGROUND INFORMATION

Juvenile Fish Passage Through Culverts

The goal of fish passage through culverts requires a change in thinking with regards to stream-crossing installations. To begin with, the image that comes to mind when pondering fish passage is usually that of an adult salmon leaping through frothy white water as it makes its way upstream to native spawning grounds. Less thought of, but perhaps equally important, is the upstream movement of juvenile anadromous fish as well as resident fish. These younger fish have been observed to make upstream migrations and are thought to do so for a number of reasons, such as or including: to avoid predation, to seek appropriate habitat for given life stages (e.g. cooler temperatures, lower velocities), or to seek less populated areas with better opportunity for food and cover (Bustard and Narver, 1975; Cederholm and Scarlett, 1981; Everest, 1973; Fausch and Young, 1995; Gowan et al., 1994; Hartman and Brown,1987; Reiser and Bjornn, 1979; Shrivell, 1994). There is evidence that juvenile fish that are able to reach more favorable habitat conditions are larger in size and have better survival rates (Bustard and Narver, 1975; Skeesick, 1970).

Installation of road systems without regard to fish passage can potentially modify access to, and the distribution of, fish habitat by truncating the available habitat. Therefore, ODF requires that stream crossings are designed and installed to pass fish. Consistent with Oregon Department of Fish and Wildlife (ODFW) guidelines, fish passage requirements for stream crossings are based on physical abilities of fish with the intent to accommodate the basic requirements for reproduction, habitat and refuge of the "weakest fish," usually juvenile fish as small as two inches in length. Fish swimming abilities vary by age and species, as do timings of upstream migration. These issues should be considered when designing culverts for fish passage (OWEB, 1999).

Historically, culverts were installed to pass water as quickly as possible and minimize the likelihood that material would be retained in the culvert. However, to accommodate juvenile fish passage, culverts must be installed so that velocities through the pipe are not accelerated compared to the natural channel. Sometimes this involves retaining material in the culvert. Unlike their older counterparts, juvenile fish have greater limitations in terms of the ability to jump and then swim upstream against fast flowing water for any extended period of time (Bell, 1986). In addition to the physical limitations, fish appear to be reluctant to pass through culverts, possibly due to the change in light and hydraulic conditions (Bates, 1995). Fish seem to conserve energy when navigating through culverts rather than utilizing their full athletic potential (Behlke et al., 1989).

Therefore, juvenile fish require very low gradient culverts ($\leq$ 0.5%), resulting in low velocity water (less than two feet per second), that can be accessed without jumping into the culvert. Another strategy is to provide areas where the young fish can retreat from fast flowing water and rest before moving upstream again. Such an area is referred to as a "velocity refuge." Velocity refuges can be created within a culvert with structures such as baffles or with sediment retention to simulate a natural streambed. Such designs allow for slightly higher gradient culvert installations and therefore can be used in some of the higher gradient forest streams (up to 8 or 12%). These embedded strategies (i.e. contiguous sediment retained in the culvert) reduce culvert capacity for the 50-year flow and thus must be oversized to compensate for the loss in cross-sectional area. Juvenile fish passage can also be achieved with installations that keep the native streambed intact (i.e. open-bottom arches, bridges, or fords).

Designing culverts to pass juvenile fish is a relatively new approach to stream-crossing installations. While the Oregon statute requiring fish passage was first adopted in 1955, it wasn't until 1994 that the ODF revised the rules to specifically require both adult and juvenile fish passage. The first detailed guidance on how to design stream crossings to pass juvenile fish was available from ODF in June 1995 (Robison, 1995). The Washington Department of Fish and Wildlife published detailed guidelines in 1999 (WDFW, 1999). A memorandum of understanding (MOU) was signed in 1997 between Oregon Department of Transportation (ODOT), Oregon Department of Fish and Wildlife (ODF&W), Oregon Department of Agriculture (ODA), Division of State Lands (DSL), Federal Highway Administration (FHA), and the Oregon Department of Forestry (ODF) (ODOT, 1997). The MOU demonstrates agreement between these agencies to use the same criteria and guidelines when designing or consulting on projects that may affect juvenile and adult fish passage.

Providing juvenile fish passage requires innovative engineering approaches that bridge the biological needs and the infrastructure needs. The design specifications are based on laboratory and field research. While the science is fairly clear that juvenile fish do indeed move upstream, less clear is how successful the stream crossing solutions are at providing juvenile fish passage, and on how the fish-friendly crossings will endure over time. Nonetheless, forest landowners are motivated to install and upgrade existing installations to pass juvenile fish using the best available technology. Eighty-one percent of all fish passage improvement projects reported to the governor's office occurred on private industrial and state forestland in 1999 (Maleki and Riggors, 1999).

Peak Flow Design

Designing stream crossings to pass a given volume of water is based on the probability of peak flow occurrence. The probability (or likelihood) that a given stream flow will occur each year can be calculated if there is a gaging record of sufficient length. The probability is referred to as the return interval (e.g. 100-year flow). For example, a stream flow with a 50-year return interval has a 2% chance (1 in 50) of occurring *any* year while a 100-yr return flow has a 1% chance (1 in 100) of occurring any year. So while it is not likely, it is possible that a 100-year event may occur twice in one year or in two consecutive years. The actual volume of water (stream flow) that results from the 50-year flow varies from basin to basin and generally decreases with decreasing basin size in western Oregon. Return interval predictions are more accurate when the gage record covers a long period of time. At a minimum, the period of record should be at least as long as the desired return interval prediction, in this case 50 years.

Most streams do not have any gaging records from which to predict the 50-year return interval; this is especially true for small headwater streams. Therefore, the Department of Forestry has established a method that landowners can use to estimate the 50-year flow and design their crossings (e.g. culvert size, bridge span) accordingly. The model uses drainage area and precipitation intensity to predict stream flow. Stream flow is determined by locating the planned stream crossing on a stream flow intensity map. The maps display the 50-year peak flows in cubic feet per second, per square mile (cfs/mi^2) overlain on a map of Oregon. To calculate the stream flow at a particular crossing, the landowner multiplies the basin area in square miles by the peak flow shown for that specific area. These maps are available in the ODF fish passage guidelines (OWEB, 1999), or can be obtained from the ODF in a digital format. Small-scale maps specific to western Oregon can also be purchased by placing an order with the ODF Forest Practices section in Salem. Landowners may use a different peak flow estimation model upon approval of the state forester.

Forest Practices Rules: Fish Passage and Peak Flows

The forest practices rules require that stream-crossing installations pass a peak flow that at least corresponds to the 50-year return interval. The resulting installation must preclude ponding of water higher than the top of the culvert (OAR 629-625-0320 2a) and allow migration of adult and juvenile fish upstream and downstream during conditions when fish movement in the stream normally occurs (OAR 629-625-0320 2b). Culverts must also be maintained to pass juvenile and adult fish (629-625-600 8). If the stream crossing is on a wide flood plain, the crossing capacity can be reduced to avoid excessive fill. Under such a scenario, the installation must be at least as wide as the active channel, no soil fill is placed in the floodplain other than the culvert cover, and the downstream end of all fill should be armored with rock to protect the fill from eroding when a flood flow occurs. Guidance is available for design of overflow dips that can handle the excess floodwater at such crossings, and minimize erosion of the road prism and fill.

ODF Guidelines on Fish Passage

The landowner is responsible for complying with the fish passage rules described above for all stream crossings on Type F streams and the peak flow rules for all streams regardless of fish presence. However, the rule does not explicitly define how the landowner will install the crossings to provide for juvenile fish passage or the 50-year stream flow. In January 1995, the first ODF memorandum regarding construction of crossings on Type F stream was issued (Mills and Stone, 1995). This was followed by interim fish passage guidance dated June 16, 1995 (Robison, 1995). In cooperation with Oregon Department of Fish and Wildlife, a third guideline version was developed to aid the operator and/or landowner in choosing an appropriate strategy for the particular stream they are working in (OWEB, 1997). The 1997 guidelines describe eight different fish passage alternatives that can be applied and the precise specifications for those installations (e.g. resulting culvert gradient) as well as what type of channel the installation is appropriate for (e.g. channel gradient, valley fill) (Table 1). Methods are also described for determining the structure size needed to pass a 50-year design flow. Finally, the guidelines provide a template for what a landowner should include in a written plan submitted to the department for a stream-crossing installation. All 98 sites monitored and analyzed in this report were installed using the 1997 guidelines.

The stream-crossing guidelines were updated again in 1999 (OWEB, 1999), which consolidated alternatives 4 and 5 into one alternative. Also, alternatives 2 and 3 were combined into one alternative for a total of six alternatives rather than eight. Recommendations at the end of this report will pertain to the 1999 version of guidelines where applicable.

STUDY DESIGN

Key Monitoring Questions

The key questions that this study will address are further explored in the Evaluation section of this paper and include the following:

1. What percent of stream crossings are in compliance with the written plans?
   - Did the written plan have sufficient information to determine which alternative was being used?
   - Did the planned installation meet the guidelines?
   - Did the landowner/operator install the crossing as described in the written plan?
2. What percent of stream crossings have a high likelihood to pass juvenile fish?
3. What percent of stream crossings have been installed in accordance with ODF guidelines?
4. What percent of stream crossings have been installed with adequate capacity for a 50-year flow?

Stream-Crossing Site Selection

The study was designed to use a random sample of stream crossings that were installed in 1998. A query of the Forest Activities Computerized Tracking System (FACTS) database identified road construction sites that met the following initial criteria:

- new road construction or re-construction
- the construction took place in 1998
- the operation took place within 100 feet of waters of the state

The stream-crossing site selection process resulted in a random selection of 98 stream crossings monitored during 1999 and 2000.

Table 1: Summary of ODF stream-crossing installation options as described in the 1997 guidelines for passing juvenile and adult fish. Current guidelines have been revised as of June 1999 (OWEB, 1999), and vary somewhat from what is described here.

Alternative	Design Option	Key Specifications That Allow Juvenile Fish Passage ∗	Appropriate Stream Characteristics
1 ∗∗	Non-stream simulation culvert	Culvert installed with ≤ 0.5% gradient to achieve low velocities.	Streams ≤ 0.5% gradient.
2 ♣	Culvert with outlet backwatering	Culvert placed at/below stream grade with downstream control structure(s) that back up water throughout the culvert.	Streams ≤ 5% with well defined channel. Can also mitigate existing problem culverts with outlet structures.
3 ∗∗	Partially buried culvert (non-stream simulation)	Sink culvert at inlet to lower resulting gradient to ≤ 0.5%. Difference between stream grade and resulting culvert grade is less than 2%. Depth of sinking ≤ 2 feet. Caution against creating an inlet drop.	Use on streams < 2.5% with deep valley fill. No bedrock at inlet, if inlet must be sunk to achieve resulting culvert gradient.
4 ∇	Culvert partially buried at inlet and outlet (stream simulation)	Resulting culvert grade = stream grade (but ≤ 4%). Culvert width = to channel width. May need to manually seed culvert with rock to initiate sediment deposition. Oversize to pass 50-year flow.	Streams ≤ 4%. Deep valley fill to sink culvert in. Mobile gravel and cobble substrate to build up in culvert. If fines dominate the natural streambed, this alternative may not work.
5 ∇	Culvert partially buried at both ends but deeper at inlet (stream simulation)	Resulting culvert grade is 1.5% < stream grade and ≤ 7%. Sink at least 1 foot. If resulting culvert grade > 4%, seed culvert. Oversize culvert to pass 50-year flow.	Streams ≤ 9%. Deep valley fill and mobile cobble and gravel streambed. If fines dominate the natural streambed, this alternative may not work.
6 ♣	Baffled culvert	Culvert with flow obstructions inside the culvert to increase depth or roughness. Oversize culvert to pass 50-year flow.	Streams up to 12%. Valley fill not a factor.
7 °	Open-bottom arch	Culvert placed on footings with a natural streambed below.	Only used in bedrock streams and shallow valley fill to insure stable footings
8 °	Bridge	Structure spans the channel and is placed on piers and/or abutments located in or near the stream.	Need to place footings on bedrock.

∗ = All designs require no jump at the outlet of crossing structures.
∗∗ = Design relies on low gradient (< 0.5%), and resulting low velocity to pass fish.
♣ = Design creates low enough velocities to pass juvenile fish with structures either downstream or within the culvert.
∇ = Design relies on sediment retention to pass juvenile fish. Sediment retention must be adequate to simulate a natural streambed condition which provides velocity refuge for fish.
° = Design relies on maintaining natural streambed to pass fish.

Field Methodology
The stream-crossing field protocol was designed to assess if structures were installed in compliance with written plans and consistent with the appropriate technical guidelines regarding juvenile fish passage. At each crossing, the following parameters were measured:

- Structure type and dimensions
- Culvert gradient
- Outlet: design, depth of countersinking, and outlet drop (if any)
- Outlet mitigation: design, dimensions, and condition
- Inlet: design and depth of countersinking
- Overflow dip: design, dimensions, and condition
- Footing condition for bridges and open-bottom arches
- Sediment size and pattern in streambed simulation culverts
- Baffle dimensions and design
- Road fill depth and armoring
- Valley and channel characteristics
- Cross-sectional area under bridges
- GPS points and photos were taken of every culvert

The measurements were taken using a combination of an engineer's level, stadia rod, logger's tape, clinometer, and hip chain. Categorical data were collected on design specifications. A Trimble Geoexplorer global positioning station (GPS) was used at each crossing to establish location. For a more detailed understanding, see Appendix A for the field protocol.

Site and Study Descriptions
All of the stream-crossing sites were on fish bearing streams and were located throughout Oregon (Figure 1). 78% of the sites were under industrial ownership, 13% on non-industrial and 9% on a mixture of state, city, county, and/or non-profit. 16% of the sites were bridges, 4% were open arches, 33% were pipe arches, 43% were round culverts and 4% were fords. 17% were large streams, 42% were medium streams, and 40% were small streams (does not total 100% due to rounding). Bankfull stream widths ranged from 1.5 to 44 feet, with the majority (54%) falling between 6 and 10 feet (Figure 2).

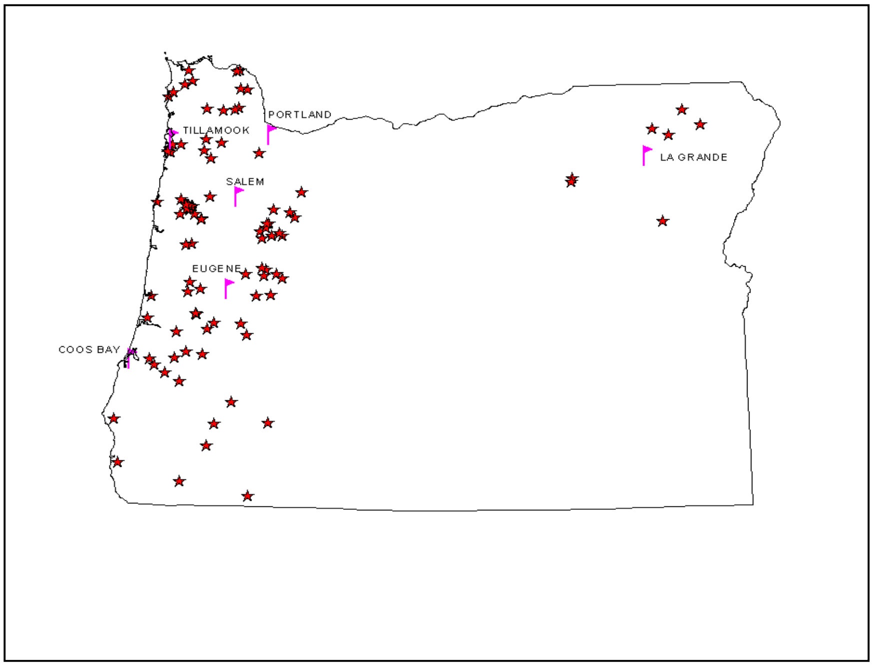


Figure 1: Location of 98 monitoring sites across Oregon visited in 1999 and 2000.

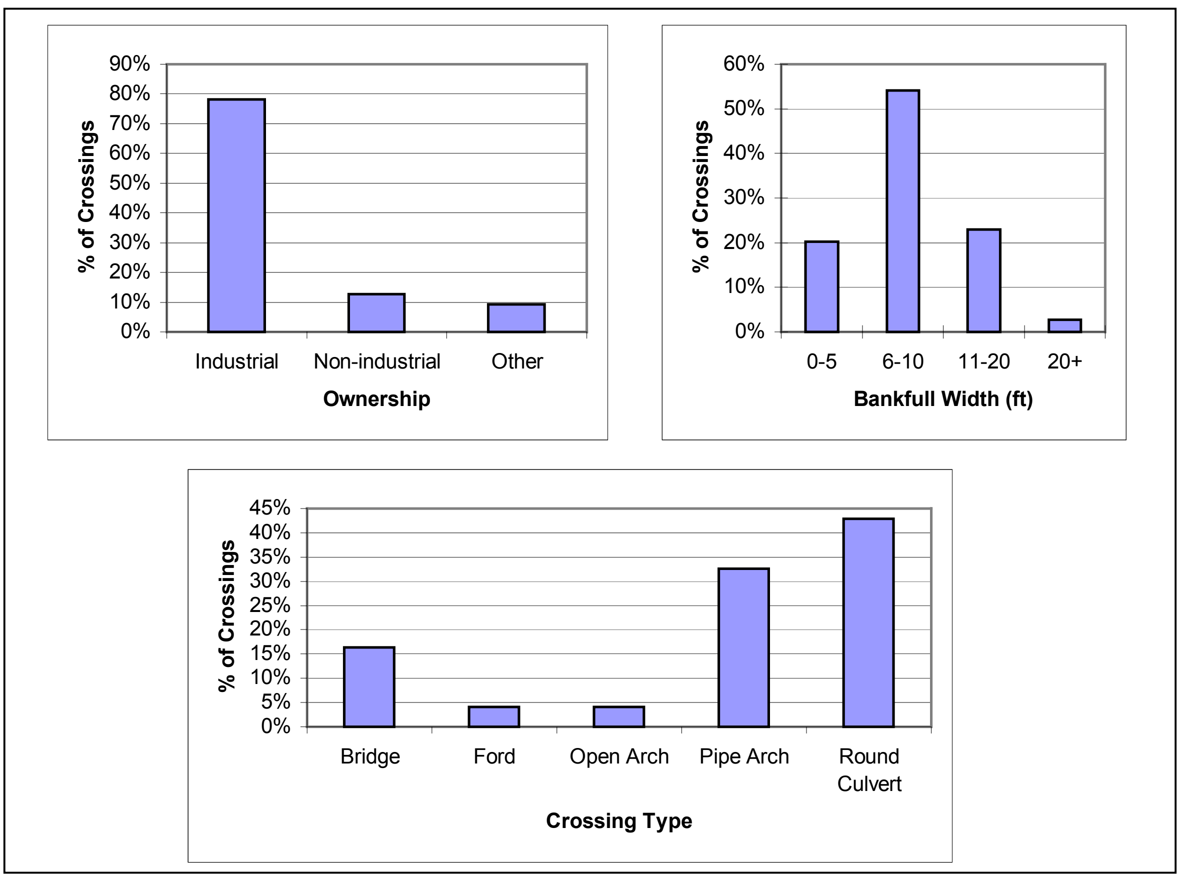


Figure 2: Stream-crossing site characteristics.

EVALUATION OF STREAM CROSSINGS

Compliance with written plans, likelihood to pass juvenile fish, proper implementation of guidelines, and the 50-year stream flow capacity are the four separate issues evaluated below.

Written Plan

What percent of stream crossings are in compliance with the written plans? To fully evaluate this key question, there are three elements to consider with regards to written plans and written plan compliance:

1. *Did the written plan have sufficient information to determine which alternative was being used?* The June 1997 ODF stream-crossing guidelines describe eight alternatives a landowner can use to provide for juvenile fish passage at stream crossings. The written plans were evaluated to determine if sufficient information was included in order to identify which alternative was being implemented.

2. *Did the planned installation meet the guidelines?* This was evaluated by comparing the planned operation as described in the written plan with the criteria in the guidelines. This question investigates if potential installation problems began in the planning phase (see Appendices B and C for evaluation methods and data).

3. *Did the landowner/operator install the crossing as described in the written plan?* This is the most direct compliance question since this is ultimately what a landowner must do. To answer this question, field data from the installed crossing were compared against the specifications in the written plan (see Appendices B and C for evaluation methods and data).

Likelihood to Pass Juvenile Fish

What percent of stream crossings have a high likelihood to pass juvenile fish? Rather than making direct observations of fish passage or taking detailed water velocity measurements, this study assumed that if a crossing met one of the following five criteria, it would pass juvenile and adult fish:

1. Bridges and open-bottom arches,
2. Bare culverts at $\leq$ 0.5% gradient with no outlet drop and a minimum water depth throughout the pipe,
3. Sediment retention (‘stream-simulation’ or ‘contiguous rock’) culvert strategies with no outlet drop,
4. Culverts with baffles or weirs (engineered designs) and no outlet drop, or
5. Culverts with backwatering from outlet mitigation structures.

While the current fish passage guidelines require any one of these criteria be met to ensure that fish passage is provided, this does not mean that not meeting any one of these criteria equates to no fish passage occurring. The current guidance is designed to provide for conditions that will allow the weakest age group of the weakest fish to pass through a stream crossing. Some level of fish passage still may be occurring through a stream crossing if the criteria are not met, it just won’t be at the level considered “likely to pass juvenile fish” under current guidelines.

Implementation of the Guidelines

What percent of stream crossings have been installed in accordance with ODF guidelines? The field data and written plan data from installed crossings were compared against the guideline specifications for the particular alternative (see Appendices B and C for evaluation methods and data). Data were analyzed to determine if installations met the specific criteria regarding stream and valley characteristics, culvert gradient, outlet jumps, outlet mitigation, culvert dimensions, and sediment retention.

50-Year Stream Flow Design

What percent of stream crossings have been installed with adequate capacity for a 50-year flow? Those crossings that did not have adequate capacity are evaluated to determine the specific reason(s). Capacity losses due to sediment retention and baffles were subtracted from the capacity calculations. Measurement and prediction errors were applied to the peak flow analyses.

> *Capacity Losses*. Use of sediment retention strategies and baffled culverts decrease the volume of water that can pass through a culvert. The depth of sediment and height of baffles were measured in the field. These measurements were used to calculate the effective stream flow capacity as a result of the reduced cross-sectional area.
>
> *Measurement and Prediction Errors*: The field measures were repeated on a subset of sites to determine measurement error. Based on these comparisons, the ability to estimate the 50-year capacity on an existing culvert was plus or minus 7% (p-value = .05). An additional 10% error exists in the ability to predict the actual 50-year peak flow volume. This additional error is a function of some level of subjectivity that is involved in (1) locating the site on a map, (2) estimating the watershed area, and (3) the relatively low precision of the ODF 50-year peak flow maps.

RESULTS

The results are presented in the four categories as described above: Written Plans, Likelihood to Pass Juvenile Fish, Implementation of Guidelines, and Peakflow Capacity. Stream crossings were evaluated by comparing data collected in the field by ODF personnel to written plan data and to the 1997 ODF fish passage guidelines. For more details about the evaluation process and results, see the Evaluation section of this paper.

Written Plans

Did the written plan contain the necessary information to determine which of the eight installation alternatives was being used? Eighty-six out of 98 written plans (88%) contained the necessary information to determine which alternative was being used. It is important that written plans reflect this information for both administrative and monitoring purposes. When the alternative is not clearly stated, determining if the guidelines were properly implemented and if the installation goals were achieved is problematic.

Did the planned installation meet the guidelines? Only 36 out of the 98 installations (37%) had enough information in the written plan to determine if the installation specifications for the alternative described in the plan met the specifications in the guidelines. Of these 36 installations, 80% met the guidelines. Of the 62 installations that did not have adequate data included in the plan to evaluate against the guidelines, 47 complied with the guidelines in the field (76%).

Was the written plan properly implemented? Excluding the four sites that were fords, 72 of the 94 sites (77%) were implemented as described in the written plans (Figure 3). One recurring problem was that written plans proposed to install culverts at a steeper grade than recommended in the guidelines for the particular alternative. A culvert installed at too steep of a grade is less likely to pass fish, either because water velocities are too high or because a natural streambed can not be established. Channel gradient can be a difficult parameter to measure, and this shows in the poor correlation between ODF and written plan values (Figure 4). To improve confidence in ODF measurement of channel gradient above that for the 1998 pilot study, the protocol was modified for this study to require clinometer measurements of gradient to be shot at a level rod. The methods used to measure channel gradient prior to installation likely varied widely and were generally not described in the written plans.

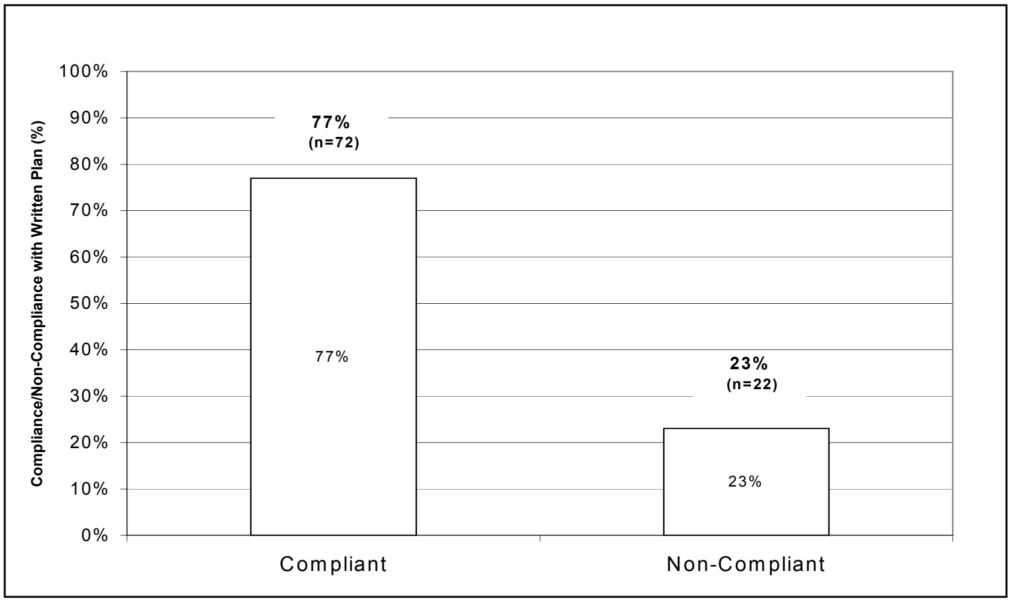


Figure 3: Compliance of installed crossings with specifications described in the written plan.

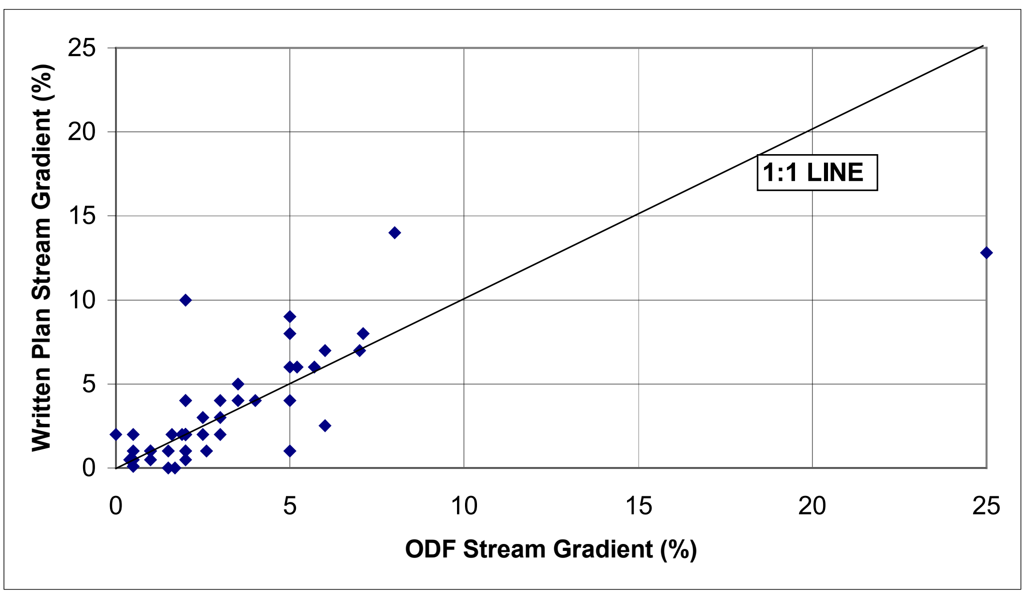


Figure 4: Channel gradient as recorded in the written plan versus that measured by ODF.

Likelihood to Pass Juvenile Fish

What percent of stream crossings have a high likelihood to pass juvenile fish?
Excluding the four sites with fords not evaluated for fish passage, 67 of 94 sites (71%) are considered likely to pass juvenile and adult fish during all design flows based on the assumptions described in the evaluation of stream-crossings section of this report. For passage during all but low design flows, the number increases to 70 (74%). The three sites that were judged to provide passage at all but low design flows met all the criteria for fish passage except the minimum water depth criteria. At these installations, the residual pool depth below the crossing was eight inches or greater; thus it was assumed that juvenile fish passage would occur if a minimum depth were maintained through the culvert.

Figure 5 shows the percent of sites likely to provide fish passage broken out by ODF alternative. The ODF alternatives are sorted from highest to lowest success. The four sites where fords were constructed were not evaluated for fish passage and thus are not included in Figure 5. The bridge and open-bottom arch designs provided the highest levels of success (100%). At the other end of the spectrum were the baffled and "unknown" designs with only 25% and 33% success in providing fish passage, respectively. These success rates look at the overall implementation of the guidelines as opposed to their effectiveness.

When considering passage success at greater than low flows, the success percentage for alternative 1 increases from 55% to 68%. The relative rankings of the different alternatives in terms of percent providing fish passage, however, remains unchanged.

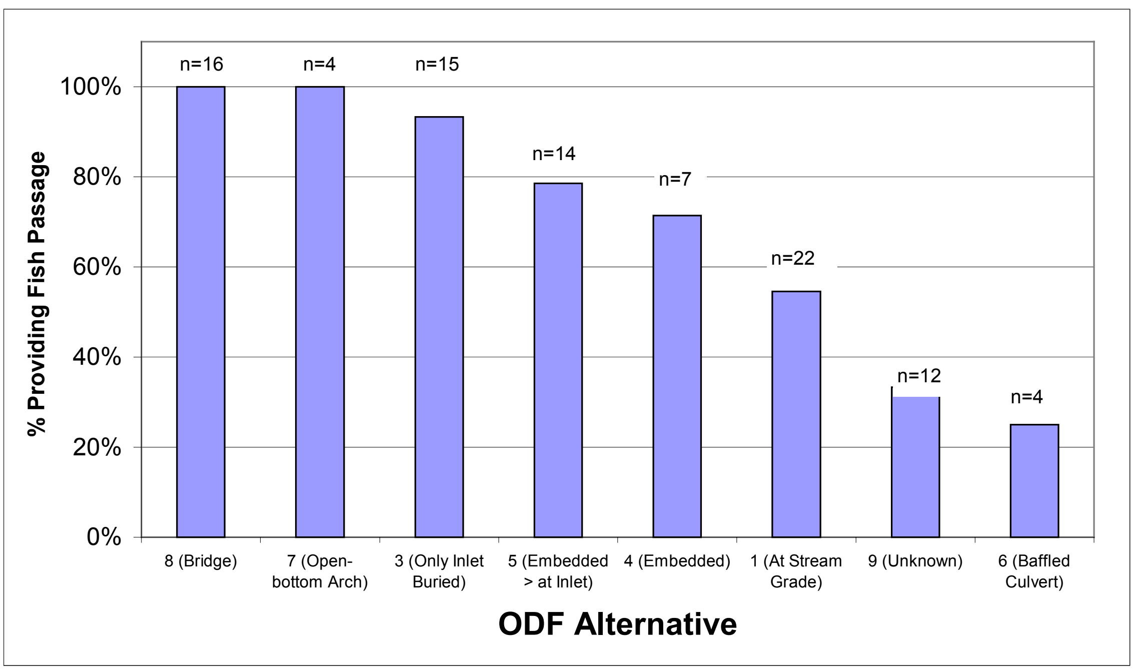


Figure 5: Percent of sites providing fish passage. It should be noted that some projects were not implemented according to the guidelines. When evaluating the effectiveness of the different alternatives using only those projects that were implemented according to the guidelines, some of the alternatives demonstrated higher rates of success than what is depicted here (see Figures 6-10).

While none of the installations used alternative 2 (culvert with backwatering at the outlet), 12 installations did construct a downstream weir to maintain backwatering in the structure. Four of these were embedded installations (alternatives 4 and 5), four were bare culvert installations (alternatives 1 and 3), two were weir/baffle culvert designs (alternative 6), and two were 'other.' With the exception of one of the baffle/weir installations, none of the weirs were successful in backwatering. However, two of the alternative 3 and two of the alternative 4 installations with downstream weirs did maintain a simulated streambed through the structure. It could not be determined to what extent the weirs influenced the retention of sediment, although it is possible that the weirs did play a role.

Implementation of Guidelines

What percent of stream crossings have been installed in accordance with ODF guidelines? To assess implementation of guidelines, field data collected at each site were compared against applicable guideline criteria. For example, if the written plan indicated alternative 1 was being used, field data on culvert gradient and outlet drop were measured against the 0.5% culvert gradient requirement and zero measurable outlet drop requirement. However, the planned alternative could not be determined on 12 sites. Overall, 74% of the sites installed culverts in accordance with the guidelines (excluding the "unknown" and ford alternatives).

Common reasons for sites not meeting the guidelines were the installation of culverts at too steep a gradient for the chosen alternative and the selection of an alternative that was inappropriate for the channel gradient (Figures 6-10). Outlet drops were another reason for not meeting the guidelines.

Figures 6-10 plot the culvert and channel slope (in percent) for each installation, broken out by the specific alternative. The area within the figures outlined in bold delineate those sites that were installed according to the slope specifications given in the guidance for that particular alternative, taking into account a 0.5% measurement error. For sites using alternatives 3, 4, or 5, those installations that stayed within the guidelines for the culvert and stream slope specifications had substantially greater success that those that did not. For these three alternatives, 92% (23 of 25) of the installations that fell within the slope guidelines had a high likelihood of passing fish, compared to only 60% (6 of 10) of those installations outside of the slope guidelines.

A correlation between greater fish passage success and following the slope guidelines was not apparent for those installations using alternatives 1 and 6 (Figures 6 and 10). For sites using alternative 1, 40% (2 of 5) of the installations that fell within the slope guidelines had a high likelihood of passing fish, compared to 60% (10 of 17) of those installations outside of the slope guidelines.[1] For sites using alternative 6, none of the installations fell within the slope guidelines. The success or failure of alternative 6 sites in achieving fish passage appears to be related more to either the elevation of the outlet, culvert size (diameter/width), and/or inadequate armoring around the outlet. The baffle/weir culvert design (alternative 6) requires significantly more expertise and

[1] It is worth noting that a number of the installations under alternative 1 were actually installed according to the slope guidelines for alternative 3 (stream slope $\leq$2.5% and culvert slope $\leq$0.5%). These sites evaluated as alternative 3 installations have a success rate in terms of providing fish passage of 75%.

engineering experience than alternatives 1, 3, 4, or 5; thus it is not unexpected that culvert and stream slope alone would not be a good indicator of success or failure of this design.

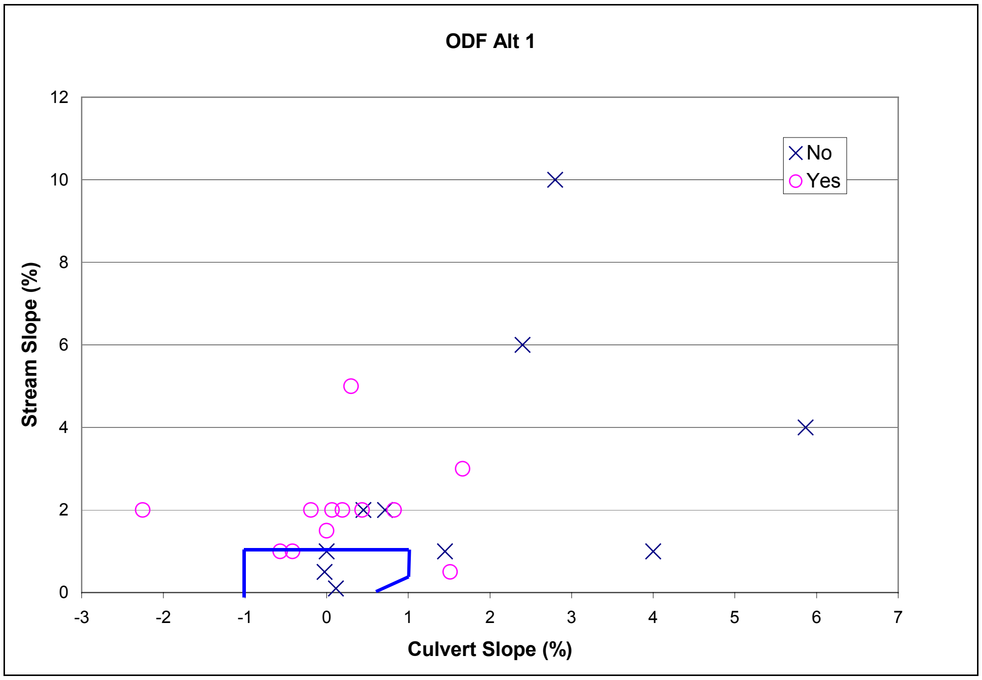


Figure 6: Stream and culvert slope plotted for installations using alternative 1. The "yes" or "no" delineations refer to whether or not the installation is likely to pass fish. The area outlined in bold defines those sites that met the slope specifications in the guidelines.

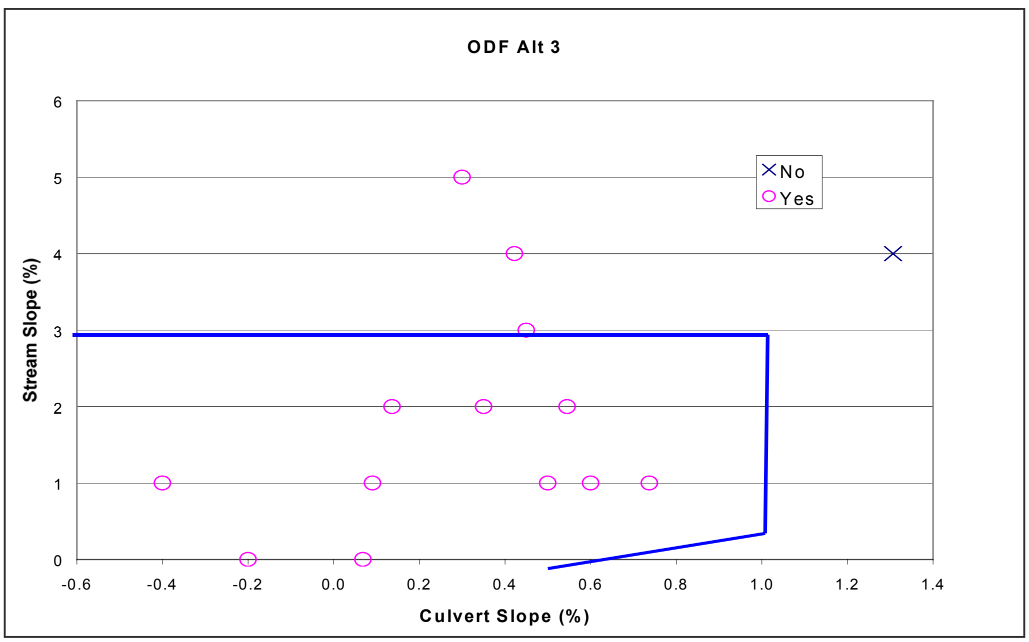


Figure 7: Stream and culvert slope plotted for installations using alternative 3. The "yes" or "no" delineations refer to whether or not the installation is likely to pass fish. The area outlined in bold defines those sites that met the slope specifications in the guidelines.

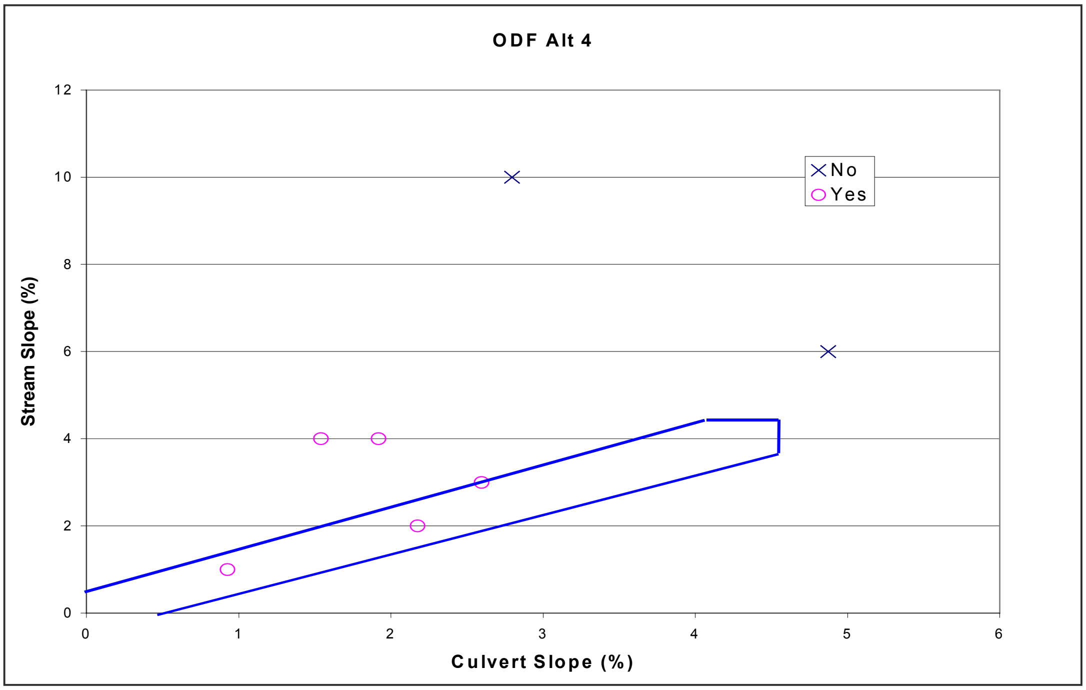


Figure 8: Stream and culvert slope plotted for installations using alternative 4. The "yes" and "no" delineations refer to whether or not the installation is likely to pass fish. The area outlined in bold defines those sites that met the slope specifications in the guidelines.

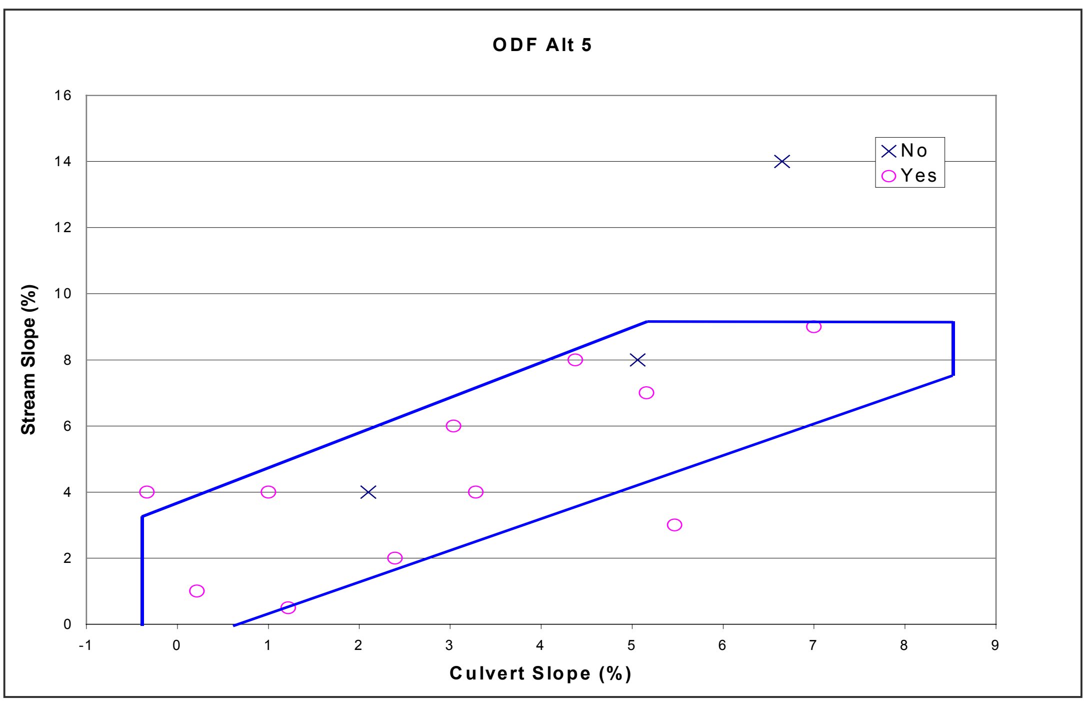


Figure 9: Stream and culvert slope plotted for installations using alternative 5. The "yes" and "no" delineations refer to whether or not the installation is likely to pass fish. The area outlined in bold defines those sites that met the slope specifications in the guidelines.

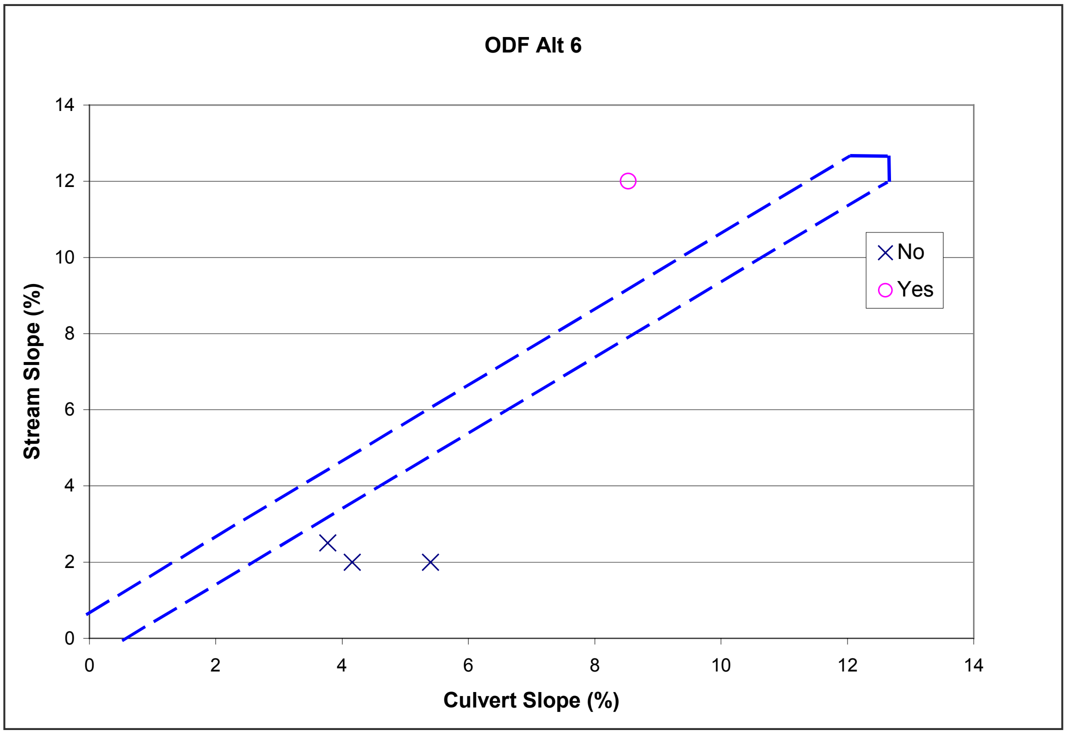


Figure 10: Stream and culvert slope plotted for installations using alternative 6. The "yes" and "no" delineations refer to whether or not the installation is likely to pass fish. The area outlined in bold defines those sites that met the slope specifications that are implied in the guidelines, but not explicitly required.

Did particular ODF guideline fish passage alternatives have greater success? The low sample size for some of the individual alternatives (for example, alternative 6 had a sample size of four) make it problematic for drawing statewide comprehensive conclusions about which alternative is achieving more success than another is. It is evident, however, that among those sites monitored in this study, certain alternatives had a substantially different level of success than others in providing for fish passage (Figure 5). Bridges and open-bottom arches both had a 100% success rate, bare culverts buried at the inlet (alternative 3) had a 93% success rate, and the embedded designs averaged a 76% success rate. Culverts placed flat, baffled designs, and where the alternative was unknown had the lowest success rates (55%, 25%, and 33%, respectively).

The ultimate success of any of the alternatives is based on whether or not it provides for fish passage. When installed consistent with the guidance, alternatives 3, 4, 5, 7, and 8 (described on p.7) were observed to have success rates of 92-100%, while other alternatives were observed to have a success rate of only 40% or less. This would argue that alternatives 3, 4, 5, 7, and 8 are effective designs so long as they are implemented according to the guidelines. The effectiveness of alternatives 1 and 6 require further investigation to better understand why they had less success. It is worth noting that two of the five alternative 1 installations that were within the slope guidelines were not likely to pass fish because of a lack of backwatering. Had adequate backwatering been maintained, either through the use of weirs or by burying the culvert to an adequate depth, the success rate for this alternative would have increased from 40% to 80%.

Another way to evaluate success is whether the installation resulted in fish passage as intended by the design. For example, alternatives 1 and 3 have the specific goal of maintaining backwater throughout the culvert, while for alternatives 4 and 5, the goal is to maintain a simulated streambed throughout the culvert. There were many sites that were 'successful' in providing passage but not necessarily in the way intended by design (i.e. they maintained sediment retention when the intended design was backwatering, and vice versa).

Figure 11 shows how fish passage was achieved with those sites using alternative 1. For 27% of the sites, the installation successfully maintained backwatering as designed. Another 14% of the sites provided fish passage as well, but because of streambed simulation and not backwatering as intended. The remaining installations (59%) did not provide passage through either streambed simulation or backwatering.

Figure 12 shows a similar graph for sites using alternative 3. Forty-seven percent provided fish passage as intended using the backwatering technique, while another 33% were successful due to streambed simulation. Twenty percent of these sites did not provide for fish passage.

Figure 13 and Figure 14 show that 57% and 58% of alternative 4 and 5 sites provided fish passage due to streambed simulation, respectively. Another 14% of both alternatives provided fish passage through backwatering. The remaining 29% and 28% of the alternative 4 and 5 sites did not provide passage through either streambed simulation or backwatering, respectively.

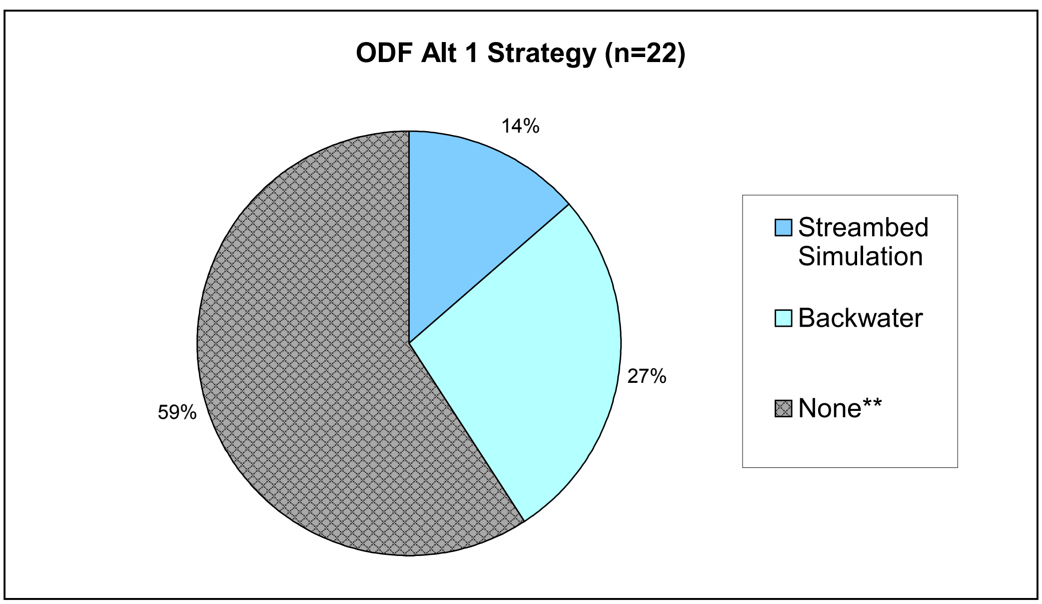


Figure 11: The percentage of installations using alternative 1 that had a simulated streambed, were backwatered, or had neither condition present ("none"). **Three of the installations included in the "none" category were judged to provide passage "at times when fish passage is likely to occur" due to the fact that the stream depth below the installation was too shallow for juvenile passage.

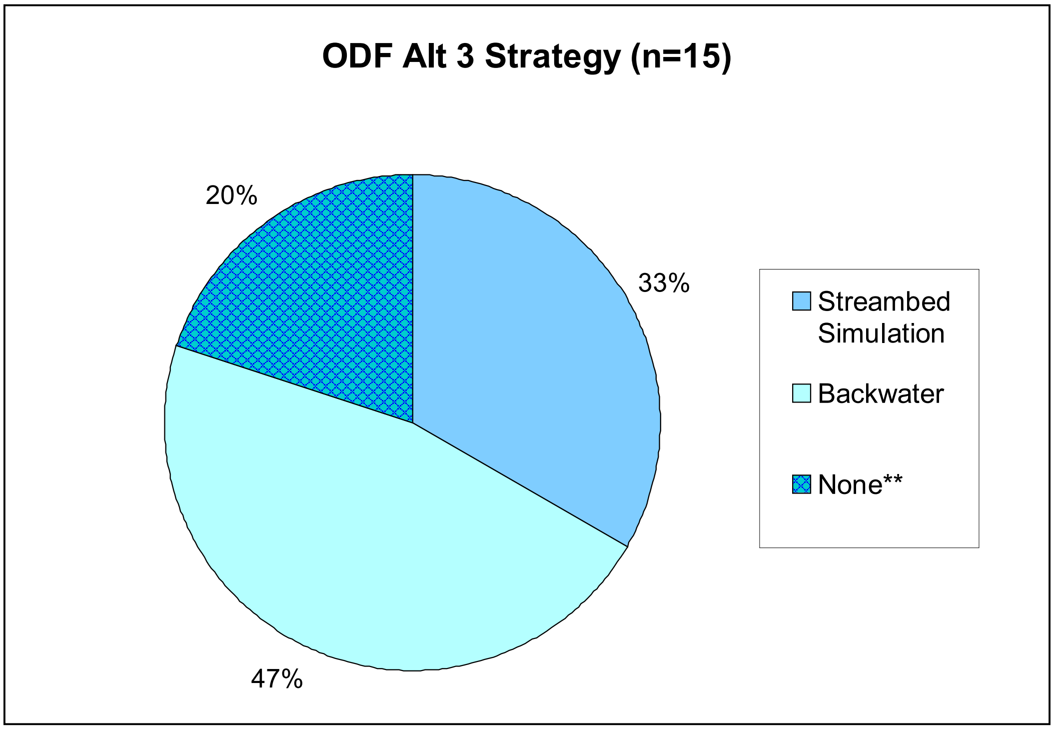


Figure 12: The percentage of installations using alternative 3 that had a simulated streambed, were backwatered, or had neither condition present ("none"). **Two of the installations included in the "none" category were judged to provide passage "at times when fish passage is likely to occur" due to the fact that the stream depth below the installation was too shallow for juvenile passage.

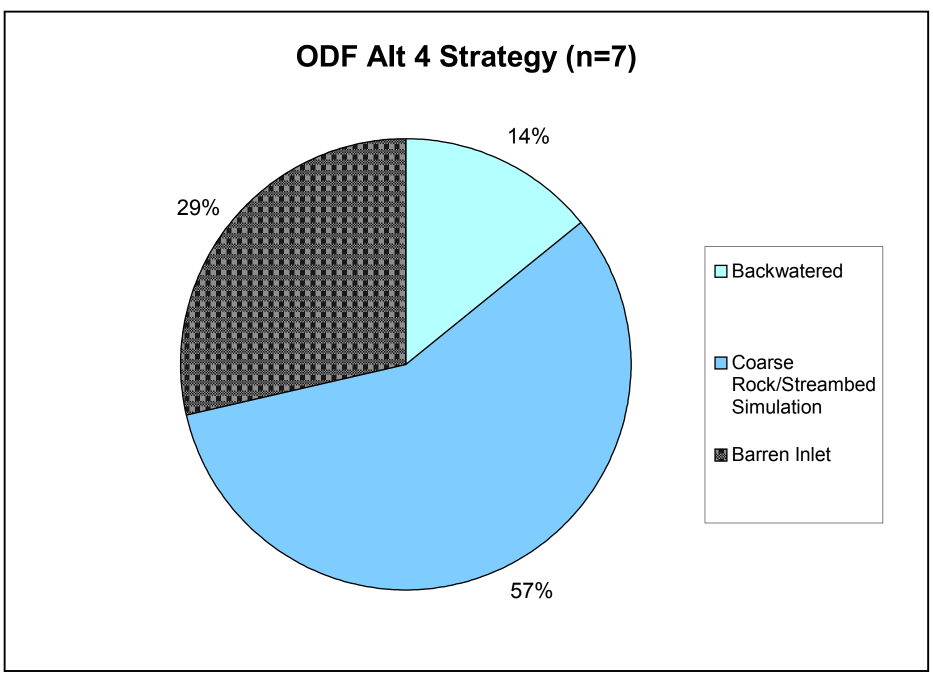


Figure 13: The percentage of installations using alternative 4 that had a simulated streambed, were backwatered, or had some other condition present.

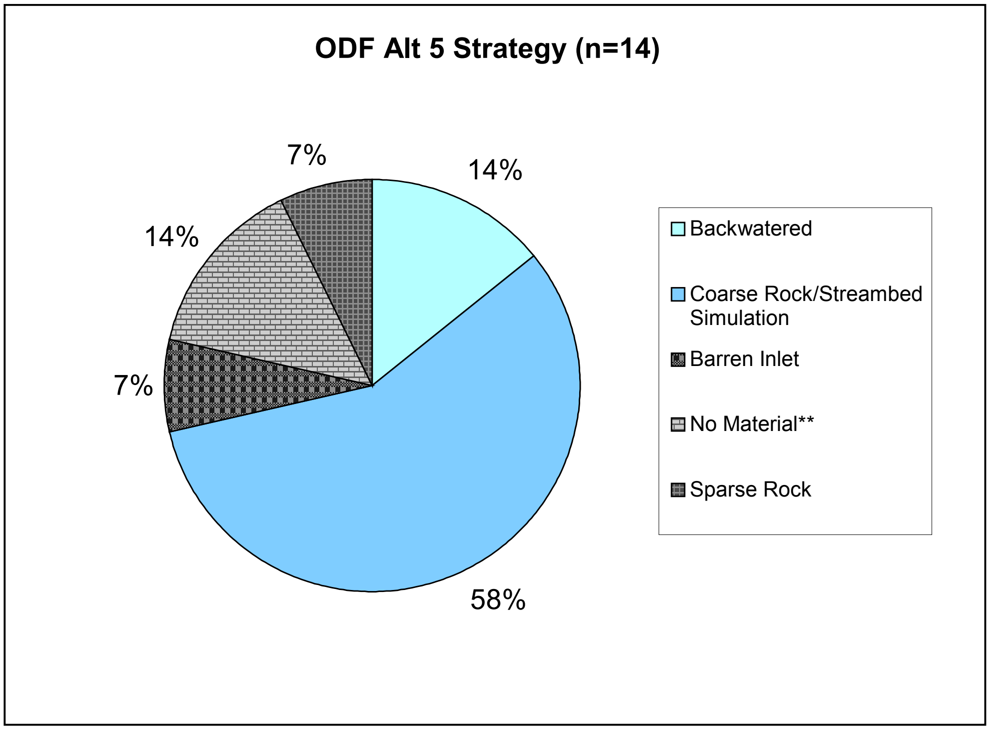


Figure 14: The percentage of installations using alternative 5 that had a simulated streambed, were backwatered, or had some other condition present. **One of the installations included in the "No Material" category was judged to provide passage "at times when fish passage is likely to occur" due to the fact that the stream depth below the installation was too shallow for juvenile passage (i.e., the data was collected at a time when fish passage was unlikely to occur).

50-year Stream Flow Design

Will the installed structure pass a 50-year peak flow? The 50-year flow calculations provided in the written plans commonly exceed the ODF calculated 50-year flow (Figure 15). Ninety-five percent (93 out of 98) of the sites passed the ODF calculated 50-year flow. Two out of the five with insufficient capacity did not provide either the 50-year peak stream flow calculations or the culvert capacity calculations in the written plan. Another two out of the five did not provide culvert capacity calculations (they did provide the 50-year peak stream flow calculations). All five of the sites with insufficient capacity installed a different-sized structure than what was described in the written plan.

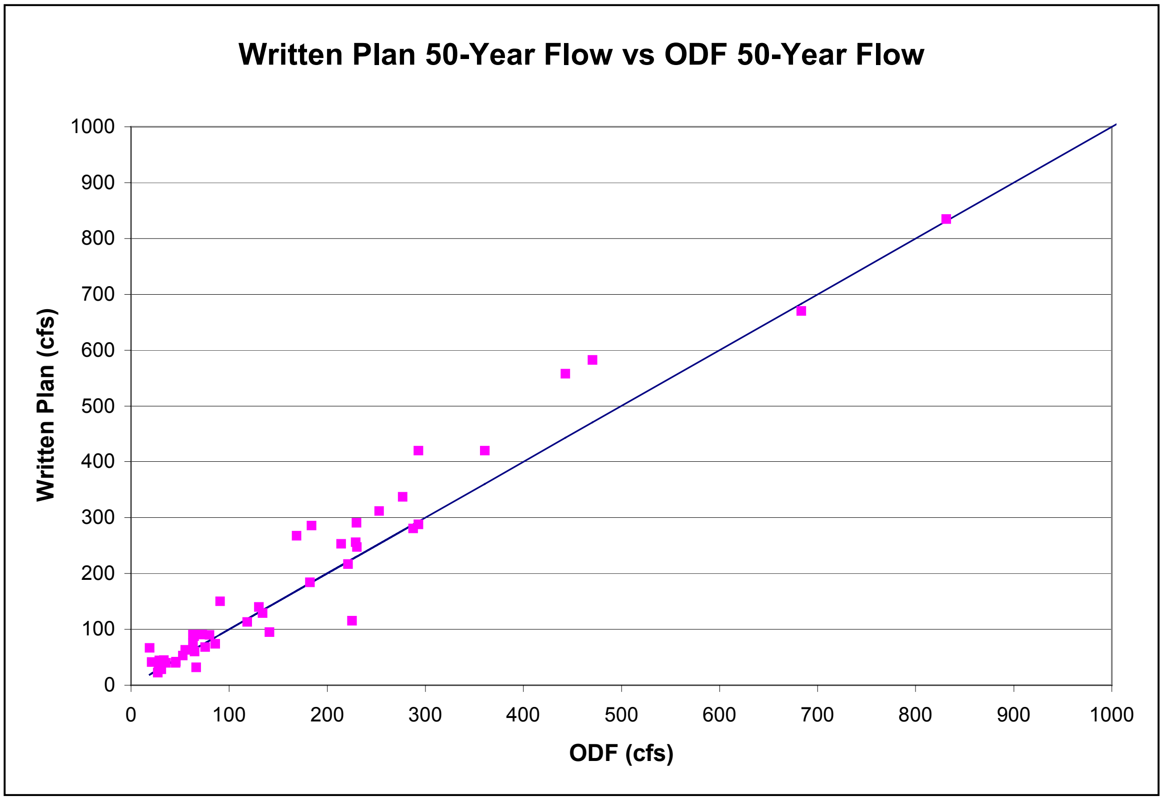


Figure 15: Written plan 50-year flow calculation vs. ODF 50-year flow estimate. Points that fall on the 1:1 line are sites where the two calculations were the same.

SUMMARY AND DISCUSSION

Written Plans

The results indicate that 76% of the installations were implemented as described in their written plans. Also, only 37% of the installations contained enough information in the written plans to determine if the plans had sufficient details for a complete evaluation against the guidelines. When comparing the results in the field, having adequate detail to evaluate the written plan for compliance with the guidelines did not appear to be a significant indicator of whether or not the installation met the guidelines. Of the 36 installations that had adequate details in the written plans, 80% met the guidelines. Of the 62 installations that did not have adequate details in the plan, 76% met the guidelines in the field. This would suggest that written plans that do not include all the information recommended in the guidelines do not automatically equate to a lower level of compliance or a rule violation. It may be that for some installations the designer and the FPF have a good idea of what the intention is, but the designer may not have provided enough detail for a 3rd party to determine what was intended.

An important factor appears to be whether or not the written plan had enough detail to simply understand which alternative was being used. For those written plans where it was not possible to determine the intended alternative, only 33% had a high likelihood of passing fish. All other installations had a combined rate of 77% with a high likelihood of passing fish. While it could be argued that it's always a good idea to provide a high level of detail in the written plan, having, at a minimum, the detail needed to determine the intended alternative substantially increased the likelihood that the installation was successful in providing for fish passage.

Juvenile Fish Passage and Implementation of the Guidelines

It is important to note that this monitoring project assessed structures with a relatively high level of detail and scrutiny. ODF considered the installation strategy and its appropriateness for the stream channel (e.g. gradient and valley type) as a measure of successful implementation of the guidelines. The likelihood of fish passage was also based on a set of assumptions about the hydraulic conditions provided by the stream-crossing alternative designs. The assumptions about hydraulic conditions, for example, resulted in the determination that if a bare culvert was not placed at a zero grade (slope $\leq$ 0.5%) *and* had backwatering at least six inches in depth through the entire culvert, it was assumed "not likely to pass fish." Therefore, the findings in this report will not be directly comparable to findings of fish-passage adequacy in other assessment efforts that utilize a lower level of detail and scrutiny.

At 77% of the sites, culverts were installed in accordance with the guidelines (excluding unknown alternatives and fords). The most common reasons for sites not meeting the guidelines were installing culverts at too steep a gradient for the chosen alternative and selecting an alternative that was inappropriate for the channel gradient (see Figures 6-10). Additional issues included outlet drops, culvert length, and installing culverts at gradients less than the channel gradient.

Based on the conditions assumed to provide fish passage, 71-74% of all the sites had a high likelihood to pass juvenile fish, depending on whether all design flows or all flows except low design flows were considered. Bridges and open arches had the highest success rate (100%), followed by alternative 3 (93%), and then by alternatives 4 and 5 (76%). Alternatives 1 and 6 had the lowest success rate for fish passage, at 55% and 25% respectively. The most common reason for the lack of success was not installing the stream crossing according to the guidelines, or using an alternative that was not appropriate for the stream-crossing location.

Findings from this study highlight a few important points:

- *The contemporary nature of juvenile fish passage regulations*. The guidelines that recommended eight juvenile fish passage alternatives were first released in 1995 and have twice been modified. At the time of installation for the stream-crossings monitoring in this study, the landowner, operators, and department personnel were still on a steep learning curve on how to achieve the standards described therein. The guidelines require rigorous design plans and careful assessments of channel characteristics for successful implementation.

- *More detail is needed in written plans*. While the sample size for some alternatives is relatively low, these results highlight the need for written plans to contain a minimum level of detail. More detail (chosen alternative, culvert grade, channel grade, valley fill depth, etc.) is needed for department personnel be able to determine the intended alternative, as well as to judge consistency between the written plan and the guidelines. With the exception of alternatives 1 and 6, the results from this study show that when the implementation of an alternative complies with the guidelines, it has a substantially higher likelihood of being successful in providing for fish passage.

- *There is a continued need for additional training and better communication of the guidelines to the landowner and operator*. The results from installations using alternative 1 imply that failure in providing for fish passage can result from operators using an alternative that is not appropriate for the site-specific conditions. It also appears that more scrutiny should be applied to those installations using alternative 6, as they require significantly more expertise and engineering experience. These and other findings suggest a need for better communication of the guidelines to the landowner and/or operator to ensure that there is at least a basic understanding of the different alternatives and where they should be applied. One method of providing better communication is more training on the guidelines for landowners, operators and ODF personnel. Training should focus on guideline criteria, identification of strategies appropriate for various channel types, and methods and tools for measuring stream-crossing parameters. The goal here is to ensure that both landowners and ODF personnel are better aware and have an adequate understanding of the guidelines so that they are followed.

50-year Stream Flow Design

Ninety-five percent (93 of 98) of the installations were estimated to pass the ODF-calculated 50-year flow. Differences between ODF and landowner calculations were mostly attributable to discrepancies in acreage estimations. Two out of the five with insufficient capacity did not provide either the 50-year peak stream flow calculations or the culvert capacity calculations in the written plan. Another two out of the five did not provide culvert capacity calculations (they did provide the 50-year peak stream flow calculations). All five of the sites with insufficient capacity installed a different-sized structure than what was described in the written plan. If the culvert size described in the written plan had been used on these five sites, four of them would have ended up meeting the 50-year flow capacity. These results suggest that more complete 50-year flow calculations in the written plan may result in more success at meeting the 50-year flow capacity, along with not changing the size of the structure without first checking the flow capacity.

RECOMMENDATIONS

Monitoring

ODF should develop, or coordinate with other agencies or organizations to develop, methods to monitor the effectiveness of the alternative designs to pass juvenile fish. Current guidelines apply scientific knowledge about biological needs to culvert design. The assumptions are that (1) current guidelines accommodate juvenile fish physical limitations and that (2) passage can be provided if the physical needs (e.g. stream velocity, jumping heights, water depths) of the juvenile fish are met. These assumptions need to be tested and verified in the field.

ODF should develop methods to monitor maintenance issues associated with these fish-friendly stream crossings. The guidelines propose designs to pass juvenile and adult fish and the 50-year flow, but still in question are how long they will last and what kind of maintenance program is required to assure fish passage and capacity for the design flow over time. Monitoring is needed to determine the durability, longevity, and maintenance issues with fish-friendly culverts.

<u>Policy</u>

There is no indication at this point that the Forest Practices policies need to be significantly changed. The FPA requires that juvenile fish passage be provided on all fish-bearing streams. The ODF guidance was revised in 1999 (OWEB 1999) and it represents the most current knowledge on juvenile fish needs and the ability to provide stream-crossing conditions that meet those needs. With the exception of alternatives 1 and 6, it appears that when the guidelines are implemented correctly, the success rate for creating conditions that are believed to provide a high likelihood of fish passage is high. Alternatives 1 and 6 should be revised to improve their effectiveness. The following six recommendations are aimed at improving guidance effectiveness and program delivery:

1. *Update the two bare culvert alternatives in the current guidance (OWEB 1999) by combining them into one alternative.* The results of this study show that alternative 3 has a high success rate for providing fish passage. Alternative 1 also has a high success rate as long as a minimum water depth can be maintained through the culvert. Also, weirs constructed to maintain backwatering have not been shown to be an effective method. The "culvert placed essentially flat" and the "culvert with backwatering at the outlet" (OWEB 1999) should be combined and updated to reflect the findings from this study. The updated alternative might be described as follows:

   "Culvert Placed at Zero Grade"—

   - Specifications: For stream slopes up to 2.5% with moderate to deep valley fill. The outlet should be buried at least six inches, and the inlet should be buried to a depth equal to or greater than six inches so that the culvert is placed flat (≤0.5%). To minimize channel constriction, the effective culvert width should be similar to bankfull width.
   - Rationale: Requiring the outlet to be buried a minimum of six inches will ensure that the minimum water depth needed for juvenile fish passage will be maintained. Requiring the inlet to be buried adequately so that the culvert is flat will maintain the lower velocities through the culvert that are necessary for juvenile passage. Sizing the culvert similar to bankfull width will minimize risks associated with constricting the channel. An excessive inlet or outlet constriction can create a velocity barrier for juveniles. An excessive outlet constriction can also cause the downcutting of the channel and the formation of an outlet drop that can block fish passage.

2. *At a minimum, require the use of a hand level (or similar instrument that can be re-calibrated before each use) and stadia rod (or similar instrument that will allow for an accurate height measurement), for stream and culvert slope measures.* Also, the use of even more precise instruments (such as a level and tripod) should be recommended. Further emphasis needs to be placed on ensuring consistency and accuracy of the measurements necessary for the engineering and installation of these crossings. Given that choosing between design alternatives relies on measuring slopes down to a half a percent or less, slope measurement techniques that are plus or minus a percent or more are inadequate. Using measurement techniques with high levels of precision will help ensure that the fish passage alternatives are

effectively implemented. Maintaining a dialogue with forest practices foresters, landowners, and land managers will help to ensure consistency in how stream-crossing parameters are measured.

3. *Further review for installations using weirs for backwatering and for installations using baffled/weir culverts*. Given the poor performance of the weirs monitored in this study that were designed for backwatering, the guidance should require that the construction of weirs always be subject to further review. Similarly, given the poor performance of the baffled culverts monitored in this study, the guidance should continue to require further review of this design and recommend it only as a last alternative.

4. *Increase the consistency and quality of information that is exchanged between the department and the landowner in written plans for stream crossings*. The 12 installations that did not provide enough information in the written plan to determine the intended alternative only had 33% success rate for likely to provide fish passage. This compares to 77% for those installations that did provide enough information. Written plans need to provide greater detail on what is trying to be achieved by referencing a specific guideline alternative (e.g. alternative 7: open-bottom arch) and listing the recommended elements (e.g. resulting culvert grade, stream gradient, valley fill) for that alternative. It should also be specified when the planner is intentionally choosing a design or design characteristics that are outside of channel criteria outlined in the guidelines. An example of an excellent written plan is shown in Appendix D.

5. *Update the Forest Practices Rule and Statute Guidance Manual to include a Synopsis of the Fish Passage Guidance.* The ODF Guidance Manual is a document used by department personnel and available to the public. It provides greater detail on how rules should be implemented. As a means of addressing the written plan content concerns described above, Table 2 was developed to summarize the applicable criteria that should be included in written plans and which criteria apply to each alternative. This level of detail would increase the ability of the forest practices forester, the ODF hydrologist, and landowners to judge if the strategy is appropriate for the particular stream, and to more accurately determine consistency with the guidelines.

   Furthermore, under the current fish passage guidelines (OWEB 1999), the six alternatives described are summarized in Table 3. Tables 2 and 3, or something similar to them, should be embedded in the official ODF guidance manual. This will provide more consistent access to the most recent information about necessary written plan data and juvenile fish passage strategies for department personnel.

6. *The ODF, OSU Extension Service, and Oregon Forest Resources Institute should continue to provide education and training opportunities for landowners, operators and department personnel.* ODF provided three training sessions in northwest, southwest, and eastern Oregon in the spring of 1999 for landowners and forest practices foresters. The training covered the goals and methods for passing juvenile fish through culverts. These training sessions were well attended and a valuable exchange of information took place between the department, landowners and other experts in the field of juvenile fish passage. The department also co-sponsored a forest road stewardship workshop with Oregon State University in March of 2000.

Part of the agenda addressed juvenile fish passage. A series of workshops sponsored by Oregon Forest Resources Institute and For the Sake of Salmon was offered in June 2000. These workshops provided training on juvenile fish passage issues. The ODF will be conducting comprehensive training on the roads and landslide-related rules in fall of 2002-winter 2003, which also could include fish passage training.

7. *Future fish passage compliance monitoring should include a greater sample size on non-industrial forestlands.* There are some important differences between industrial and non-industrial forestland owners in terms of available resources and expertise relative to installing fish passage structures. These differences could result in differences in findings related to compliance and effectiveness between the two types of ownership, but this study could not evaluate that due to a small sample on non-industrial land.

Table 2: Criteria that should be included in written plans for various 1999 guideline alternatives (combining alternatives 4 and 5 (now 4) and renumbering alternative 6 (now 5)).

Required Criteria to Include in the Written Plans	Alternative
List the alternative that is being attempted OR clearly describe strategy for a unique design.	All alternatives
Legal location (Township, range, section)	All
Channel gradient	All
Resulting culvert gradient	3, 4, and 5
Active channel width	All
50-year flow calculation • Acreage or square miles, cubic feet per square mile (CMS) as chosen from ODF Peak Flow Map, and design flow (CFS); OR • Complete calculation if using method other than ODF Peak Flow Map • Account for culvert capacity losses at the inlet due to burying, embedding, or weirs/baffles. • Calculation and diagram for bridge capacity • Adjustment for wide floodplains/overflow dips (Include where applicable)	All All 3, 4, and 5 1
Difference between the channel and culvert gradient	3, 4, and 5
Length of crossing	
Elevation change over length of crossing	
Depth of inlet sinking	
Depth of outlet sinking	
Channel bed material	
Valley fill depth (i.e. depth to bedrock)	2, 3, 4, and 5
Downstream weirs • Outlet weir spacing (relative to outlet and channel width) • Outlet weir heights (relative to inlet elevation and weir drop heights) • Type and size of material used to construct weirs	Where outlet weirs are used
Baffle/weir designs • Baffle/weir configuration • Depth of flow calculations for low and high design flows • Energy dissipation calculations (velocity conditions) at design flows • Backwater length and depth at the outlet • Other calculations/diagrams pertinent to design	6

Table 3: Summary of stream-crossing installation criteria for each alternative in the 1999 ODF Fish Passage Guidelines, combining alternative 4 and 5 (now 4) and renumbering alternative 6 (now 5).

Alternative[1]	Channel Gradient (%)	Culvert Gradient (%)	Outlet Drop (ft)	Effective Culvert Width (Span) = Active Channel Width	Outlet Depth (ft)	Inlet Depth	Channel Bed Material	Valley Fill Depth
1. Bridge	No limit	--	--	Yes	--	--	--	--
2. Open arch culvert	No limit	No limit	--	Yes	--	--	--	Shallow (near bedrock)
3a. Streambed Simulation: Sunken evenly	≤4%	≤4% (Same as channel)	0 ft.	Yes	Round Culvert: Greater of 40% of diameter, or 24 inches Pipe Arch: Greater of 20% of rise or 18 inches	Round Culvert: Greater of 40% of diameter, or 24 inches Pipe Arch: Greater of 20% of rise or 18 inches	≤Cobble (few boulders)	Deep (no bedrock)
3b. Streambed Simulation: Inlet sunken more than outlet	>4%, up to 8%	1.5% to 3% less than channel	0 ft.	Yes	Round Culvert: Greater of 40% of diameter, or 24 inches Pipe Arch: Greater of 20% of rise or 18 inches	Outlet depth **PLUS** 1.5% to 3% of the length of the culvert, (e.g. 50-ft pipe installed at 1.5% less than channel % = (1.5% x 50), or an extra 9" in embedded depth)	≤Cobble (few boulders)	Deep (no bedrock)
4. Culvert at Zero Grade (combined and revised what was Alt 4 and 5)	≤2.5%	≤0.5% (Plan for 0%)	0 ft.	Yes	At least 6 inches	At least 6 inches, greater if stream slope is >0.5%. (e.g. Channel = 2%. For 50 ft pipe, depth = (2% x 50') + 6**"**. Total inlet depth = **18"**)	≤Cobble (few boulders)	Moderately deep, to deep (no bedrock)
5. Weir/baffle culverts[2] (was Alt 6)	≤12%	≤12%	0 ft.	Yes	Sunken adequately to maintain backwatering up to the first weir/baffle	--	--	--

[1]All alternatives must show complete calculations for the 50-year design flood flow. This includes the watershed area, cubic feet per square mile (CMS), and final flood flow calculation in cubic feet per second (CFS) if using the ODF method; OR a complete calculation for an approved alternate peak flow estimation technique. If a bridge is being installed, a diagram and calculation of the capacity is required. All designs except for bridges must account for capacity losses at the inlet due to burying, sediment retention, or weir/baffle designs in the 50-year flow calculation.

[2] All weir/baffle designs require further review by the ODF staff hydrologist. Expertise and/or experience in hydraulic engineering is required for this design. Written plan should include diagram and description of baffle/weir configurations, depth of flow calculations, energy dissipation (velocity conditions) calculations at design flows, and other necessary information.

REFERENCES

Bates, K. M. 1995. Fishway design guidelines for Pacific Salmon. Excerpts for Bureau of Land Management Culvert Design Workshop. January 11-12. 13 Chapters.

Behlke, C. E, D. L. Kane, R. F. McLean and M. D. Travis. 1989. Field observations of Arctic Grayling passage through highway culverts. Trans. Res. Record 1224. pp.63-66.

Bell, M. C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fish passage development and evaluation program, Corps of Engineers, North Pacific Division, Portland, Oregon. 290 p.

Bustard, D. R. and D. W. Narver. 1975. Aspects of the winter ecology of juvenile coho Salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish Res. Board Can. 32:667-680.

Cederholm, C. J. and W. J. Scarlett. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981. IN: Brannon, E. L. and E. O. Salo, editors. 1981. Salmon and Trout Migratory Behavior Symposium. Washington Department of Natural Resources, Forks, Washington. p. 98-110.

Dent, L. 1998a. Forest Practices Monitoring Program Strategic Plan. Oregon Department of Forestry Forest Practices Program. 2600 State Street, Salem Oregon, 97310. 22 pp.

Dent, L. 1998b. Oregon Department of Forestry's Best Management Practices Compliance Audit Project, Version 3.0. Oregon Department of Forestry, 2600 State Street, Salem, Oregon, 97310. 69 pp.

Dent, L. and M. Allen. 2000. Oregon Department of Forestry: Compliance with fish passage and peak flow requirements at stream crossings pilot study results. Technical Report 6. Oregon Department of Forestry Forest Practices Monitoring Program. 2600 State Street, Salem, Oregon. March 2000.

Dent, L and J. Robben. 1999. Forest Practices Compliance Monitoring Project: 1998 Pilot Study Results. Technical Report 5. November 1999. Oregon Department of Forestry, 2600 State Street, Salem, Oregon, 97310. 66 pp

Everest, F. H. 1973. Ecology and management of summer steelhead in the Rogue River. Fishery Res. Rep. No. 7, Oregon State Game Commission. 48p.

Fausch, K. D. and M. K. Young. 1995. Evolutionarily Significant Units and Movement of Resident Stream Fishes: A Cautionary Tale. American Fisheries Society Symposium. 17:360-370.

Gowan, C., M. K. Young, K. D. Fausch and S. C. Riley. 1994. Restricted movement in resident stream salmonids: a paradigm lost? Can. J. Fish. Aquat. Sci. 51: 2626-2637.

Hartman, G. F. and T. G. Brown. 1987. Use of small, temporary, floodplain tributaries by juvenile salmonids in a west coast rain-forest drainage basin, Carnation Creek, British Columbia. Can. J. Fish Aquat. Sci. 44:262-270.

Idaho Department of State Lands. 1998. Fish Passage Guidelines When Installing Stream Crossings. Forest Practices No. 12. July 1998. 8pp.

Maleki, S.M., B.L.K. Riggers. 1999. Watershed Restoration Inventory. Monitoring Program Report No. 1999-2 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, Oregon.

Mills, K. and C. Stone. 1995. Culvert Reconstruction on Type F Streams. January 25, 1995. Memorandum, Oregon Department of Forestry, 2600 State Street, Salem, Oregon, 97310. 1 p.

Oregon Department of Forestry. 26 March 1996. Peak Flows for Forest Streams Page. <http://www.odf.state.or.us/gis/gisatlas.html>

Oregon Department of Transportation. 1997. Memorandum of Understanding 15.142. January 27, 1997. 3 pp.

Oregon Watershed Enhancement Board. 1997. *Interim Fish Passage and Culvert/Bridge Sizing for Road Crossings: June 27, 1997*. Oregon Plan for Salmon and Watersheds - Governor's Watershed Enhancement Board. 255 Capital St. N.E., Salem, OR, 97310-0203. 28 pp.

Oregon Watershed Enhancement Board. 1999. *Oregon Road/Stream Crossing Restoration Guide: June 8, 1999*. Oregon Plan for Salmon and Watersheds - Governor's Watershed Enhancement Board. 255 Capital St. N.E., Salem, OR, 97310-0203. 75 pp.

Reiser, D. W. and T. C. Bjornn. 1979. Habitat requirements of anadromous salmonids. USDA Forest Service General Technical Report PNW-96. 54 p.

Robison, E. G. 1995. Interim fish passage guidance at road crossings. June 16, 1995. Oregon Department of Forestry, 2600 State Street, Salem, Oregon, 97310. 14 pp.

Shirvell, C. S. 1994. Effect of changes in streamflow on the microhabitat use and movements of sympatric juvenile coho (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha) in a natural stream. Can. J. Fish. Aquat. Sci. 51:1644-1652.

Skeesick, D. G. 1970. The fall immigration of juvenile coho salmon into a small tributary. Res. Rep. Fish Comm. Oreg. 2: 90-95.

Washington Department of Fish and Wildlife. 1999. Fish Passage Design at Road Culverts: A Design Manual for Fish Passage at Road Crossings. March 3, 1999. 49pp + Appendices.

APPENDIX A: DETAILED FIELD METHODS

Note: The complete protocol is available upon request. The methods described here represent what is currently being used by the ODF to monitor stream crossings.

SITE SELECTION

One hundred fish-bearing stream sites will be randomly selected from a population of 1580 notifications in 1998. The selection will be stratified by ODF districts and by landowner class. Each district sample will be stratified by the total number of notifications for each landowner type (industrial, non-industrial, or other) with road construction activities occurring within 100 feet of waters of the state. To ensure adequate representation across the state, we will randomly select 5% from each ODF district or a minimum of five sites per district. Some of the sites in this population will not meet the needs of the study for one of the following reasons: the stream is not a Type F stream, the operation did not take place, and/or there is not a stream crossing. In these instances, a new site will be selected.

FIELD METHODS

The following methods were drawn from three documents:

- *Oregon Department of Forestry's Best Management Compliance Audit Project, Version 3.0* (Dent, 1998),
- ODF memorandum titled *Interim fish passage guidance at road crossings* (Robison, June 16, 1995), and
- *Oregon Road/Stream Crossing Restoration Guide: summer 1998 draft* (Oregon Plan for Salmon and Watersheds, 1998).

The following measurements and information will be taken at all fish-bearing stream crossings for each site. Refer to Figure 3 for a schematic of features.

GENERAL INFORMATION

Notification number: From notification

Road number: If there isn't one, use NA

Road name: If the road does not have a name, then assign a name (perhaps after a nearby stream, or harvest unit)

Georegion: Coast, South Coast, Interior, Blue Mountains, East Cascades, West Cascades, or Siskiyou

Legal: Township, range, and section

Landowner: Industrial, Non-industrial, or Other (State, county, non-profit, etc.)

Operation: Construction or Reconstruction

Year (4 digits): Completion date of roadwork

Reason for reconstruction: Flood Repair, Reopen, Oregon Plan, Maintenance, Other

Photo documentation: #1 looking upstream with jump in photo, #2 inside the barrel looking upstream, and #3 looking downstream at inlet

Crossing identification: Notification number

Structure location: GPS reading or latitude and longitude from a map if a reading is not possible

Stream classification: Taken from notification or written plan when available, checked with ODF fish presence maps.

S = Small
M = Medium
L = Large

STRUCTURE INFORMATION

Crossing shape (code):

RC = Round Culvert
PA = Pipe Arch
OA = Open Arch
BR = Bridge
FD = Ford
OT = Other

Structure size: Diameter (in) and length (ft) for round culvert, length, rise and span (ft) for arches, span (ft) for bridge or ford.

Resulting culvert gradient (%): Measured with a transit level. Crew will record the elevation at each end of the culvert and divide by culvert length. Where the culvert inlet is beveled, care must be taken to ensure that the culvert length measured corresponds to the length over which the transit level measurements were observed.

Culvert condition: Described as Good, Mechanical Damage, Rusted, Bottom Out, Collapsed, or Other (specify).

Footing condition: Description for bridges and open-bottom arches.

ST = Stable
ER = Eroding
FL = Failing

OVERFLOW DIP MEASURES

Overflow dip: Used on roads built on wide flood plains (use NA if not present). Using a transit level, the crew will measure the elevation of the structure, the lowest elevation of the dip, and the elevation of the lowest point controlling the capacity of the overflow dip. The width of the overflow dip is measured from the height of the lowest point controlling the overflow dip capacity to the opposite side of the dip.

Overflow dip road surface armor (code): Using the codes in Table 1, classify the size of material used to armor the road surface of the dip (may be more than one, but no more than three).

Overflow dip road fill armor size: Using the codes in Table 1, classify the size of material used to armor the road fill associated with the dip (may be more than one, but no more than three codes). This is recorded separately for the downstream and upstream sides of the crossing.

Table 1. Codes used for size classification of material used in road fill armor, road surface armor, stream-crossing structures, and channel substrate.

Code	Material	Size description
BD	Bedrock	Bigger than a car/continuous layer
BL	Boulders	Basketball to car-sized
CB	Cobble	Tennis ball to basketball
GR	Gravel	Ladybug to tennis ball
FN	Fines	Silt/clay muck to visible particle; gritty
NO	---	None
NA	---	Not applicable

Overflow dip road surface condition:

- ST Stable
- ER Eroding
- FL Failing

Overflow dip road fill condition:

- ST Stable
- ER Eroding
- FL Failing

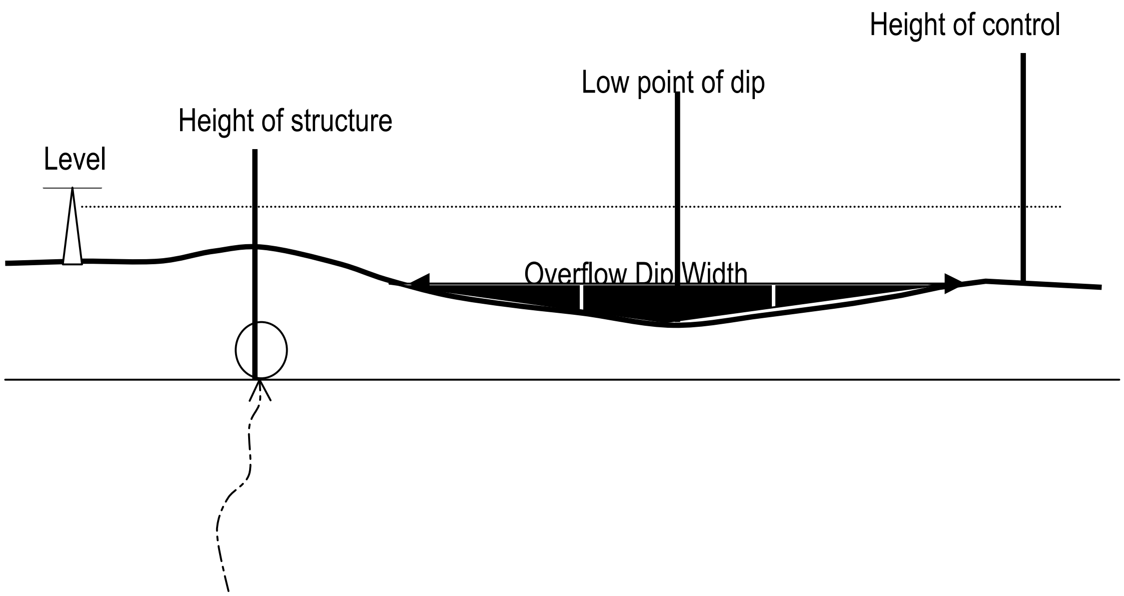
Dip width: The width of the overflow dip is measured from the height of the lowest point controlling the overflow dip capacity to the opposite side of the dip.

Distance from dip to structure: Measured from the center of the crossing structure to the lowest point in the dip.

Dip low point: Lowest point in the overflow dip relative to the crossing structure as measured with the level.

Dip control point: Lowest point of the two upper boundaries of the overflow dip controlling the capacity of the overflow dip.

Overflow elevation (ft): The difference between the height of the culvert bottom and the height of the bottom of the overflow dip.



OUTLET MEASURES

Outlet drop (ft): The difference between the heights of the downstream control point (controlling the residual[2] water surface) and the culvert outlet as measured with a level. If residual water surface is above the bottom of the culvert, these measurements will have a negative value.

Residual pool depth (ft): Max depth of residual pool below the outlet drop.

Outlet mitigation structure type[3]

GW	Gabion weirs
RW	Rock weirs
WD	Woody debris
WR	Wood and rock
NO	None
OT	Other, explain

[2] Residual pool is defined as the remaining pool that exists when riffles are de-watered

[3] Mitigation structures are installed downstream of culverts to back water into the culverts or to retain sediment.

Intent: According to the landowner/crossing designer, was the intent of the outlet structure to mitigate an outlet drop (OD), to backwater the culvert (BA), to retain sediment within the culvert (SR), or other (OT, explain).

Backwatering (ft): Length of backwatering within the pipe due to outlet mitigation.

Outlet mitigation drop (ft): Measured from the residual water surface of the structure to the residual water surface below the structure. If more than one structure (multiple weirs), there will be a measure between each structure.

Distance between outlet mitigation and crossing (ft): Measured from the outlet to the mitigation structure, if there are multiple structures, crew will document distance between them.

Condition of outlet structures:

ST	Stable
BE	Bank erosion around structure
UC	Actively undercutting structure
SD	Sediment deposition behind structures has filled to elevation of outlet

Stream condition of structure:

Wetted: Water flows over the residual nick point

De-watered: Structure has no water flowing over the residual nick point

BAFFLE MEASURES

Baffle design:

WB	Weir baffles
OF	Offset weir
PW	Porior design notch weir
NW	Notch weir
MW	Multiple weirs
SR	Sediment rack
OW	1 outlet weir only
OT	Other
NO	None

Distance between baffles (ft)*: A*verage for multiple weirs.

Distance between last baffle and outlet (ft): Measured from the base of the last baffle to the outer edge of the culvert.

Height of baffle: Measured at the highest point of the baffle.

Depth of baffle notch (ft): Measured from top of baffle to base of notch.

ROAD FILL MEASURES

Road fill depth (ft): In vertical feet from the outside edge of the road surface to the original channel measured on the downstream side of the crossing with a transit level.

Road fill armor (code): Using the codes in Table 1, classify the size of material used for armoring the road fill on the upstream and downstream side of the crossing.

CHANNEL AND VALLEY MEASURES

Stream channel gradient (%): Measured with a clinometer upstream from the influence of the crossing inlet.

Channel substrate: Upstream of the influence of the culvert inlet, characterize the size of the channel substrate using the codes described in Table 1.

Bankfull flow width (ft): Measured at the average annual high water mark upstream from the influence of the culvert inlet.

Stream/valley fill (code): This refers to the layers of unconsolidated gravel, sand cobble, and other sediment that lie over the top of the bedrock. It is measured from the parent material or bedrock to the top of the deposit.

NF = No fill (mostly bedrock channel, possibly point bar deposits and terrace-like sediment deposits < 5 feet high, may be valley wall constrained)
SF = Shallow fill (limited bedrock plus cobble/gravel/sand channel with narrow floodplain and terraces 5-10 feet high)
DF = Deep fill (no bedrock showing in channel, broad, well-developed floodplain)

Valley type (code):
NV Narrow valley: Less than 3 x channel width or < 100 feet (on a side)
WV Wide valley: Greater than 3 x channel width or >100 feet (on a side)

INLET MEASURES

Inlet opening (%): As compared to design opening area

Inlet design (code):
NM Not mitered
MI Mitered
OT Other

Inlet drop (Yes/No): Note if there is an inlet drop.

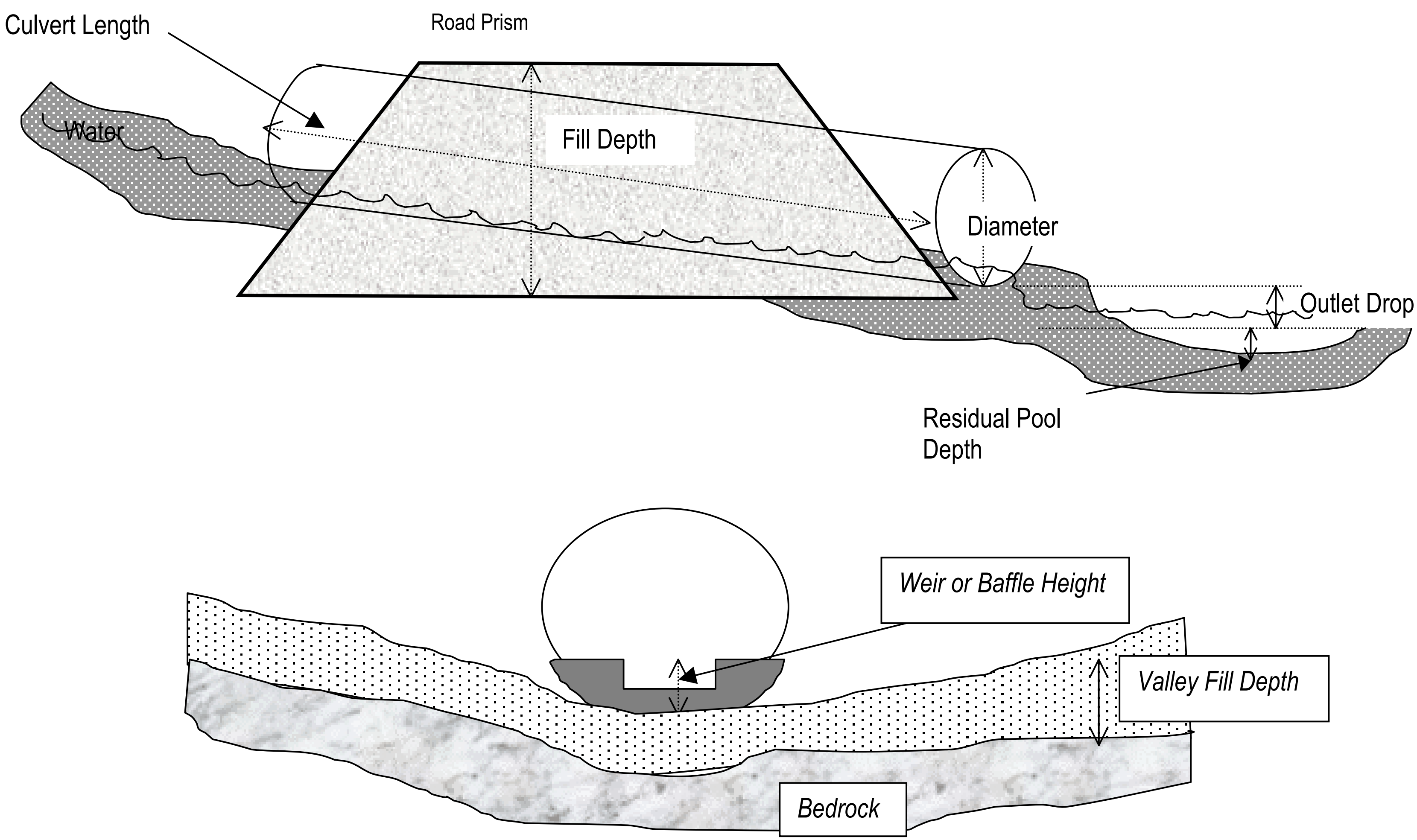


Figure 1. Culvert schematic and measurements for monitoring fish passage and 50-year flow design.

NATURAL-BED OR COUNTERSUNK DESIGNS

Sediment pattern (code): For natural-bed or countersunk structure designs, give a qualitative description of how material is arranged in the structure. Use NA for structures that are not designed to collect sediment (baffled culvert, bridge).

SS	Simulated streambed (channel type forms, such as bars and sinuosity, material contiguous)
CR	Contiguous rock fill (rock contiguous throughout the structure)
SR	Sparse rock fill (rock in culvert, but not contiguous)
NM	No material in culvert
MO	Material in outlet, but barren at inlet
NA	Not applicable

Bed material in structure (code): For natural-bed or countersunk structure designs, document the size of material (listed in Table 1) for the length of the crossing. There may be more than one, but no more than three. Use NA for structures that are not designed to collect sediment (baffled culvert, bridge) and NO if there is no material in the culvert.

Direction of counter-sinking:

IN	Inlet
OT	Outlet
BO	Both
NO	Neither

Depth of countersinking (ft): Quantitative measurement at location of countersinking. This measure is the difference between a level height taken at a point within 5-10 feet of the culvert inlet representing the streambed elevation and a height taken at the bottom of the culvert. Negative values indicate that the culvert is countersunk.

Countersunk (yes/no): A qualitative assessment as to whether or not the pipe was countersunk.

FORD MEASURES

Outlet jump (ft): Measured from outlet to residual water surface

Residual flow depth (ft): Measured at the deepest point in the ford to the residual water surface

Residual pool depth (ft): Measured at the deepest part of the pool downstream of the crossing when present to the residual water surface

Material type: Rock, Other (explain)

Material size used for the ford upstream, at the crossing and downstream of the crossing (code): Characterize the size of material in each location, as described in Table 1. There can be more than one, but no more than three.

Minimizing sediment

Filtering: Distance between crossing and last cross drain structure (waterbar, grade shift, pipe) upslope from the crossing.

Armor at road drainage site (code): Using the codes listed in table 1, characterize the size of material used to armor the ditch outlet at the site of the crossing.

Road surface condition: Describe the section of road draining into the stream crossing as:

GD	*Good*
RU	*Rutted*
GU	*Gullied*
FL	*Failing*

FIFTY-YEAR RECURRENCE FLOW

For all crossings:

Area upstream of the crossing (square miles): Will be measured from a 7.5 minute topographic map

Baffled/embedded culverts:

Height of baffle or embedded material (ft): Measured at inlet or where cross-section represents the average constriction

Bridges (Figure 2):

Bridge type:	LS	Log stringer
	RR	Railroad car
	MI	Metal I-beam
	CC	Concrete

Bridge span (ft): Measured from one side of the stream to the other

Bankfull depth – d (ft): Measured from channel bed to the bottom of the bridge (this measure will be used to calculate wetted perimeter and cross-sectional area) every 0.5 feet on streams with a wetted width less than 10 feet and every foot on streams 10 feet and greater. Ability of the bridge to pass 50-year stream flow event will be calculated assuming three feet of freeboard.

Increment: Record the increment used to measure depth

Distance from left bank (ft): Record distance from left bank, taking a measure every 0.5 feet on streams less than 10 feet and every foot on streams 10 feet and greater (this measure will be used to calculate wetted perimeter and cross-sectional area)

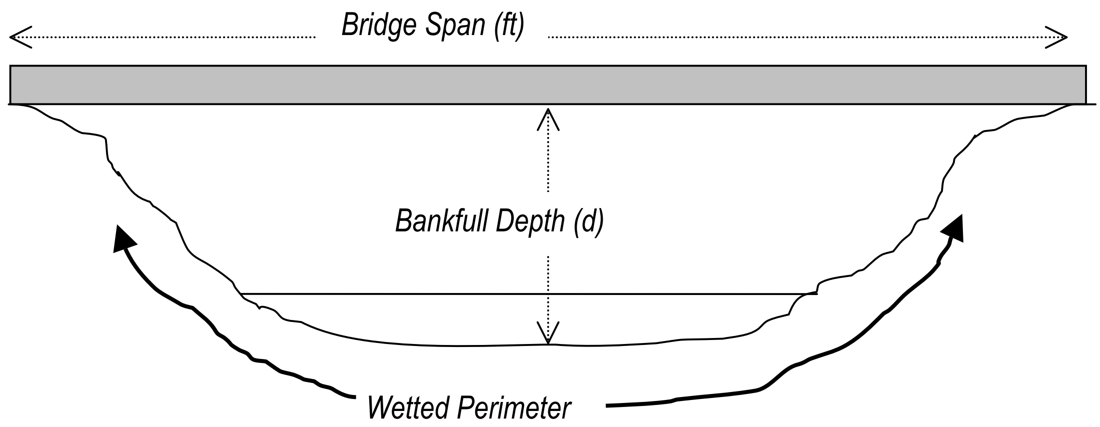


Figure 2. Schematic of measurements needed for calculating flow capacity of bridge design.

WRITTEN PLANS

A copy of the written plan will be made for each site. Two documents have recently described guidelines for what should be included in a written plan. The first was an ODF Memorandum circulated within the department and to landowners and operators. The subject was: *Interim fish passage guidance at road crossings*, (E. George Robison, June 16, 1995). The information in the ODF memorandum was duplicated in a section (pages 12-14) of the document titled: O*regon road/stream-crossing restoration guide: summer 1998 draft* (Oregon Plan for Salmon and Watersheds, 1998). The following checklist was developed for assessing written plans, based on the June 16, 1995, ODF memorandum and the stream-crossing restoration guide.

CROSSINGS

Location: Legal description
Structure: Round culvert, pipe arch, open-bottom, bridge, ford, overflow dip, other
Structure size: Diameter, length, rise, and span
Existing stream gradient
Resulting culvert gradient
Bed material in stream channel
Valley fill information
Outlet mitigation
Inlet condition

PEAK-FLOW RELATED DATA
Cross-sectional data: Detailed stream channel cross-section data (bridges and open-bottom arches): wetted perimeter, cross-sectional area

Watershed size: Size of watershed above stream crossing for 50-year peak flow calculation

Quality Assurance/Quality Control

There is a detailed section on this topic in the *Oregon Department of Forestry's BMP Compliance Audit Project* (Dent 1998). The Oregon Department of Forestry's hydrologist and monitoring coordinator will train the fish-passage crews. On a subset of sites, two crews will measure the same sites to test repeatability of the methods.

Data will be collected on standardized field data sheets. A file containing a copy of the written plan, a map showing the site location, any relevant paperwork, and field data sheets will be kept for each site. Field data will be entered into a computer database on an ongoing basis.

Reports

A preliminary report will be prepared and presented to the Oregon Board of Forestry in 1999 along with the overall BMP Compliance Audit Findings. The project will be continued in 1999 and possibly 2000, with a final report by 2001.

References

Dent, Liz. 1998. *Oregon Department of Forestry's Best Management Practices Compliance Audit Project, version 3.0*. Oregon Department of Forestry, 2600 State Street, Salem, Oregon, 97310. 69 pp.

Oregon Plan for Salmon and Watersheds. *Oregon Road/Stream-Crossing Restoration Guide: Summer 1998 Draft*. 1998. Governor's Watershed Enhancement Board. 255 Capital St. N.E., Salem, OR, 97310-0203. 52 pp.

Robison, E. George. 1995. *Interim fish passage guidance at road crossings.* June 16 1995. Oregon Department of Forestry, 2600 State Street, Salem, Oregon, 97310. 14 pp.

APPENDIX B: STREAM-CROSSING EVALUATION METHODS

Provides the basis for comparisons between the ODF field data, written plan data, and the guidelines. Actual Access database formulas are shown followed by written explanations.

Field vs. Guidelines

Culvert %

GradeDifference(FvsG): [Culvert Grade (%)]-[Guideline Culvert Gradient (%)]

CulvGradeDiffCall(FvsG): IIf([Guideline Culvert Gradient (%)] Is Null,"NA",IIf([GradeDifference(FvsG)]<=[ODFCulvGradeError] Or [GradeDifference(FvsG)]<0 Or [Culvert Grade (%)]<=[Guideline Culvert Gradient (%)],"Accept","Reject"))

Where a guideline culvert gradient exists, accept if the difference between the ODF culvert gradient and the guideline gradient is less than the measurement error, if the difference is negative, or if the culvert gradient is less than the guideline gradient (else reject).

Channel %

StreamGradeDiff(FvsG): [Channel Gradient (%)]-[GuideStreamGrade]

StreamGradeDiffCall(FvsG): IIf([Alternative]="7" Or [Alternative]="8" Or [Alternative]="9","NA",IIf([Channel Gradient (%)]>[GuideStreamGrade] And [StreamGradeDiff(FvsG)]>[TlbFieldError]![FieldStreamError],"Reject","Accept"))

Where a stream gradient is applicable, reject if the ODF channel gradient is greater than the guidelines and the difference between the ODF channel gradient and the guidelines is greater than the measurement error (else accept).

Culvert Length (ft)

LengthDiffCall(FvsG): IIf([Guideline Culvert Length (ft)] Is Null,"NA",IIf([Length (ft)]<[Guideline Culvert Length (ft)],"Accept","Reject"))

Outlet Drop (ft)

OutDropCall(FvsG): IIf([Alternative]="7" Or [Alternative]="8" Or [Alternative]="9","NA",IIf([Outlet Drop (ft)]-[Guideline Outlet Drop (ft)]<=[T Guidelines]![ODFOutDropError],"Accept","Reject"))

Where applicable, accept if the difference between the ODF measured outlet drop and the guidelines is less than the measurement error (else reject).

Culvert Elevation Drop (ft)

CulvertDropCall(FvsG): IIf([Alternative]<>"3","NA",IIf(([Culvert Grade (%)]*[Length (ft)])/100-([ODFCulvGradeError]*[Length (ft)])/100<=[T Guidelines]![GuideCulvertDrop],"Accept","Reject"))

Where applicable, accept if the culvert elevation drop minus the error term is less than or equal to the guidelines (else reject).

Channel – Culvert %

ChanCulvDiff: [Channel Gradient (%)]-[Culvert Grade (%)]

ChanCulvDiffCall: IIf([Alternative]<>"3" And [Alternative]<>"5","NA",IIf(Abs([ChanCulvDiff])>[T Guidelines]![GuideChanCulvDiff] And Abs([ChanCulvDiff])-[ODFChanCulvDiffError]>[T Guidelines]![GuideChanCulvDiff],"Reject","Accept"))

Where applicable, reject if the absolute difference between the channel and culvert gradient exceeds the guidance and exceeds the guidelines after accounting for measurement error (else accept).

Channel Bed Material

SubTypeCall(FvsG): IIf([Alternative]<>"3" And [Alternative]<>"4" And [Alternative]<>"5","NA",IIf([T Channel/Valley]![Sed Size 1]="BD","Reject","Accept"))

Where applicable, reject if the ODF determined channel bed material is bedrock (else accept).

Valley Fill Depth

SubDepthCall(FvsG): IIf([Alternative]<>"3" And [Alternative]<>"4" And [Alternative]<>"5","NA",IIf([T Channel/Valley]![Stream/Valley Fill]="SF","Reject","Accept"))

Where applicable, reject if the valley fill is shallow.

50-year Flow

CapacityCall(FvsG): IIf([Alternative]="9","NA",IIf([T Guidelines]![Guideline Year]<>"Jan 1995" And [ODFCapYesLoss]*1.07<[ODF CFS]-([ODF CFS]*0.1),"Reject",IIf([T Guidelines]![Guideline Year]="Jan 1995" And [T Structure Information]![ODFCapNoLoss]*1.07<[ODF CFS]-[ODF CFS]*0.1,"Reject","Accept")))

If it applies to the alternative used, and the guidelines used were not January 1995, then a structure is rejected if the structure capacity measured in the field (including losses to sediment/baffles) with a 7% measurement error is less than the ODF determined 50-year flow with a 10% error. If the guidelines used were January 1995, then the same logic applies except structure capacity losses due to sediment retention were not accounted for.

Overall

Overall(FvsG): IIf([CulvGradeDiffCall(FvsG)]="Reject" Or [StreamGradeDiffCall(FvsG)]="Reject" Or [LengthDiffCall(FvsG)]="Reject" Or [OutDropCall(FvsG)]="Reject" Or [CulvertDropCall(FvsG)]="Reject" Or [ChanCulvDiffCall]="Reject" Or [SubTypeCall(FvsG)]="Reject" Or [SubDepthCall(FvsG)]="Reject" Or [CapacityCall(FvsG)]="Reject","Reject","Accept")

If any of the applicable criteria were rejected, site is rejected overall (else accept).

Field vs. Written Plan

Note: Where the alternative is known (and the criteria applies), a site receives a “reject” if it does not meet both the written plan AND the guidelines.

Culvert %

GradeDifference(FvsP): [Culvert Grade (%)]-[Plan Culvert Gradient (%)]

CulvGradeDiffCall(FvsP): IIf([Alternative]="7" Or [Alternative]="8" Or [Alternative]="9","NA",IIf([Plan Culvert Gradient (%)] Is Null,"ND",IIf([GradeDifference(FvsP)]<=[ODFCulvGradeError]+[T Guidelines]![LOwnerCulvGradeError] Or [GradeDifference(FvsP)]<0 Or [Culvert Grade (%)]<=[Plan Culvert Gradient (%)] Or [Culvert Grade (%)]<=[T Guidelines]![Guideline Culvert Gradient (%)],"Accept","Reject")))

Where culvert gradient applies to the alternative used, if the culvert gradient is greater than that in the written plan and exceeds the guidelines (after accounting for ODF and landowner measurement error), reject the design. Note: sites where the alternative used is unknown are compared ONLY against the written plan.

Channel %

StreamGradeDiff(FvsP): [Channel Gradient (%)]-[T Written Plan]![Plan Stream Gradient (%)]

ODF Measured Channel Gradient – Channel Gradient in the Written Plan

StreamGradeDiffCall(FvsP): IIf([Alternative]="7" Or [Alternative]="8" Or [Alternative]="9","NA",IIf([Plan Stream Gradient (%)] Is Null,"ND",IIf([Channel Gradient (%)]>[T Written Plan]![Plan Stream Gradient (%)] And [StreamGradeDiff(FvsP)]>[ODFStreamGradeError]+[T Guidelines]![LOwnerStreamGradeError] And [Channel Gradient (%)]>[T Guidelines]![GuideStreamGrade],"Reject","Accept")))

Where stream gradient applies to the alternative used, if the channel gradient measured by ODF is greater than that in the written plan and exceeds the guidelines (after accounting for ODF and landowner measurement error), reject the design.

Culvert Length (ft)

LengthDiffCall(FvsP): IIf([Guideline Culvert Length (ft)] Is Null,"NA",IIf([Plan Culvert Length (ft)] Is Null And [Guideline Culvert Length (ft)] Is Not Null,"ND",IIf([Length (ft)]>[Guideline Culvert Length (ft)] And [Length (ft)]>[Plan Culvert Length (ft)],"Reject","Accept")))

Where it applies to the alternative used, if the ODF measured culvert length is greater than that in the written plan and exceeds the guidelines, reject the design.

Outlet Drop (ft)

OutDropCall(FvsP): IIf([Guideline Outlet Drop (ft)] Is Null,"NA",IIf([Outlet Drop (ft)]>[Guideline Outlet Drop (ft)]+[T Guidelines]![ODFOutDropError] And [Plan Outlet Drop (ft)] Is Not Null And [Outlet Drop (ft)]>[Plan Outlet Drop (ft)],"Reject",IIf([Outlet Drop (ft)]>[Guideline Outlet Drop (ft)]+[T Guidelines]![ODFOutDropError] And [Plan Outlet Drop (ft)] Is Null,"Reject","Accept")))

Where it applies to the alternative used, if the culvert outlet drop is greater than that in the written plan and exceeds guidelines (after accounting for ODF measurement error), reject the design. Furthermore, if the outlet drop exceeds that in the guidelines and no information is provided in the written plan, reject the design.

Culvert Elevation Drop (ft)

CulvertDropCall(FvsP): IIf([Alternative]<>"3","NA",IIf([Plan Culvert Drop (ft)] Is Null,"ND",IIf([Culvert Drop (ft)]>[Plan Culvert Drop (ft)] And [Culvert Drop (ft)]>[T Guidelines]![GuideCulvertDrop] And [Culvert Drop (ft)]-[Plan Culvert Drop (ft)]>([T Guidelines]![ODFCulvGradeError]*[Length (ft)])/100,"Reject","Accept")))

*(Culvert drop equals the difference between the culvert elevation at the inlet and at the outlet. Culvert drop error was determined as: (ODF Culvert Gradient Error * Culvert Length)/100) Written plan culvert drop was utilized if provided, otherwise it was calculated from the culvert gradient and length in the written plan.)

Where it applies to the alternative used, if the culvert drop is greater than that in the written plan and exceeds the guidelines (after accounting for ODF measurement error), reject the plan.

Channel – Culvert %

ChanCulvDiff: [Channel Gradient (%)]-[Culvert Grade (%)]

ODF Measured Channel Gradient – ODF Measured Culvert Gradient

ChanCulvDiffCall: IIf([T Guidelines]![GuideChanCulvDiff] Is Null,"NA",IIf([Plan Chan-Culv Grade] Is Null And [T Guidelines]![GuideChanCulvDiff] Is Not Null,"ND",IIf([ChanCulvDiff]>[Plan Chan-Culv Grade] And [ChanCulvDiff]>[T Guidelines]![GuideChanCulvDiff]+[ODFChanCulvDiffError]+[LOwnerChanCulvDiffError],"Reject","Accept")))

*(Channel – Culvert Measurement Error = Stream Gradient Measurement Error + Culvert Gradient Measurement Error)

Where it applies to the alternative used, if the Channel Gradient – Culvert Gradient value was greater from field measurements than that in the written plan and exceeds the guidelines (after accounting for ODF and landowner measurement error), reject the design.

Channel Bed Material

SubTypeCall(FvsP): IIf([Alternative]<>"3" And [Alternative]<>"4" And [Alternative]<>"5","NA",IIf([Plan Bed Material] Is Not Null,"Accept","ND"))

Where applicable to the alternative used, if the type of channel substrate was included in the written plan, accept the design.

Valley Fill Depth

SubDepthCall(FvsP): IIf([Alternative]<>"3" And [Alternative]<>"4" And [Alternative]<>"5","NA",IIf([Plan Valley Fill] Is Not Null,"Accept","ND"))

Where applicable to the alternative used, if the depth of valley fill was included in the written plan, accept the design.

50-year Flow

CapacityDiff: [Plan Capacity (Actual) (cfs)]-[ODFCapYesLoss]

*(Losses = depth of sediment retained in structure or baffles, weirs, etc.)

Plan Capacity Including Losses – ODF Measured Capacity Including Losses

CapacityCall(FvsP): IIf([Alternative]="9","NA",IIf([Plan Capacity (Actual) (cfs)] Is Null Or [Plan CFS] Is Null,"ND",IIf([T Guidelines]![Guideline Year]<>"Jan 1995" And [CapacityDiff]>0 And [ODFCapYesLoss]*1.07<[PlanCFSFinal]-[PlanCFSFinal]*0.1,"Reject",IIf([T Guidelines]![Guideline Year]="Jan 1995" And [Plan Capacity (Chart) (cfs)]-[T Structure Information]![ODFCapNoLoss]>0 And [T Structure Information]![ODFCapNoLoss]*1.07<[PlanCFSFinal]-[PlanCFSFinal]*0.1,"Reject","Accept"))))

Reject if the capacity of the installed structure is smaller than planned (either due to a smaller structure or the amount of sediment retained in the structure – capacity allowed a 7% error) AND does not pass the written-plan determined 50-year flow with a 10% error. Because January 1995 guidelines do not describe accounting for capacity losses, the structure is not judged including losses to sediment retention/baffles.

Overall

Overall(FvsP): IIf([Alternative]<>"U" And [CulvGradeDiffCall(FvsP)]="Reject" Or [StreamGradeDiffCall(FvsP)]="Reject" Or [LengthDiffCall(FvsP)]="Reject" Or [OutDropCall(FvsP)]="Reject" Or [CulvertDropCall(FvsP)]="Reject" Or [ChanCulvDiffCall]="Reject" Or [SubTypeCall(FvsP)]="Reject" Or [SubDepthCall(FvsP)]="Reject" Or [CapacityCall(FvsP)]="Reject","Reject",IIf([Alternative]="U" And [OutDropCall(FvsP)]="Reject" Or [CapacityCall(FvsP)]="Reject" Or [CulvGradeDiffCall(FvsP)]="Reject" Or [StreamGradeDiffCall(FvsP)]="Reject","Reject","Accept"))

If any criteria for a site are rejected, then the site receives “Reject” overall. Note: sites with unknown alternatives are judged only against the written plan for culvert and channel gradient and against both the written plan and the guidelines for outlet drop and the 50-year flow.

Written Plan vs. Guidelines

Culvert %

GradeDifference(PvsG): [Plan Culvert Gradient (%)]-[Guideline Culvert Gradient (%)]

CulvGradeDiffCall(PvsG): IIf([Alternative]="9","NA",IIf([Guideline Culvert Gradient (%)] Is Null,"NA",IIf([Plan Culvert Gradient (%)] Is Null,"ND",IIf([GradeDifference(PvsG)]<=[ODFCulvGradeError]+[T Guidelines]![LOwnerCulvGradeError] Or [GradeDifference(PvsG)]<0 Or [Plan Culvert Gradient (%)]<=[Guideline Culvert Gradient (%)],"Accept","Reject"))))

Where applicable and where the data is provided, accept if the difference between the plan culvert gradient and the guidelines is less than the measurement error or if the difference is less than zero or if the plan gradient is less than the guidelines (else reject).

Channel %

StreamGradeDiff(PvsG): [T Written Plan]![Plan Stream Gradient (%)]-[GuideStreamGrade]

StreamGradeDiffCall(PvsG): IIf([Alternative]="7" Or [Alternative]="8" Or [Alternative]="9" Or [GuideStreamGrade] Is Null,"NA",IIf([Plan Stream Gradient (%)] Is Null And [GuideStreamGrade] Is Not Null,"ND",IIf([T Written Plan]![Plan Stream Gradient (%)]>[GuideStreamGrade] And [StreamGradeDiff(PvsG)]>[ODFStreamGradeError]+[T Guidelines]![LOwnerStreamGradeError],"Reject","Accept")))

Where applicable and the data is provided, reject if the plan channel gradient exceeds the guidance and the difference between the plan and guidance gradients is greater than the measurement error (else accept).

Culvert Length (ft)

LengthDiffCall(PvsG): IIf([Guideline Culvert Length (ft)] Is Null,"NA",IIf([Plan Culvert Length (ft)] Is Null And [Guideline Culvert Length (ft)] Is Not Null,"ND",IIf([Plan Culvert Length (ft)]>[Guideline Culvert Length (ft)],"Reject","Accept")))

Where applicable and the data is provided, reject if the plan culvert length exceeds the guideline culvert length (else accept).

Outlet Drop (ft)

OutDropCall(PvsG): IIf([Alternative]="7" Or [Alternative]="8","NA",IIf([Plan Outlet Drop (ft)]>[Guideline Outlet Drop (ft)],"Reject","Accept"))

OutDropCall(PvsG): IIf([Alternative]="7" Or [Alternative]="8" Or [Alternative]="9","NA",IIf([Plan Outlet Drop (ft)]>[Guideline Outlet Drop (ft)],"Reject","Accept"))

Where applicable and the data is available, reject if the plan outlet drop exceeds the guidelines (else accept).

Channel – Culvert %

ChanCulvDiffCall(PvsG): IIf([Alternative]<>"3" And [Alternative]<>"5","NA",IIf([Alternative]="3" And [Plan Chan-Culv Grade] Is Null Or [Alternative]="5" And [Plan Chan-Culv Grade] Is Null,"ND",IIf(Abs([Plan Chan-Culv Grade])>[T Guidelines]![GuideChanCulvDiff],"Reject","Accept")))

Where applicable and the data is available, reject if the difference between channel and culvert in the plan exceeds the guidelines (else accept).

Channel Bed Material

SubTypeCall(PvsG): IIf([Alternative]<>"3" And [Alternative]<>"4" And [Alternative]<>"5" Or [T Written Plan]![Guideline Year]="Jan 1995","NA",IIf([Plan Bed Material] Is Null And [GuideSubType] Is Not Null,"ND",IIf([Plan Bed Material] Is Not Null And [Plan Bed Material]<>"BD","Accept","Reject")))

Where applicable, accept if the written plan provided a channel bed material and it was not bedrock (else reject).

Valley Fill Depth

SubDepthCall(PvsG): IIf([Alternative]<>"3" And [Alternative]<>"4" And [Alternative]<>"5" Or [T Written Plan]![Guideline Year]="Jan 1995","NA",IIf([Plan Valley Fill] Is Null,"ND","Accept"))

Where applicable, accept if the written plan provided information about the valley fill depth (else no data).

50-year Flow

CapacityCall(PvsG): IIf([Alternative]="9","NA",IIf([Plan Capacity (Actual) (cfs)] Is Null Or [Plan CFS] Is Null,"ND",IIf([T Guidelines]![Guideline Year]<>"Jan 1995" And [Plan Capacity (Actual) (cfs)]<[ODF CFS]-[ODF CFS]*0.1,"Reject",IIf([T Guidelines]![Guideline Year]="Jan 1995" And [T Written Plan]![PlanCapNoLoss]<[ODF CFS]-[ODF CFS]*0.1,"Reject","Accept"))))

If it applies to the alternative, and the data is available in the written plan, then a written plan is rejected if the ODF determined 50-year flow (with a 10% error) exceeds the capacity of the structure in the plan. Capacity losses to sediment/baffles are not accounted for if the January 1995 guidelines were used.

Overall

Overall(PvsG): IIf([CulvGradeDiffCall(PvsG)]="Reject" Or [StreamGradeDiffCall(PvsG)]="Reject" Or [LengthDiffCall(PvsG)]="Reject" Or [OutDropCall(PvsG)]="Reject" Or [CulvertDropCall(PvsG)]="Reject" Or [ChanCulvDiffCall(PvsG)]="Reject" Or [SubTypeCall(PvsG)]="Reject" Or [SubDepthCall(PvsG)]="Reject" Or [CapacityCall(PvsG)]="Reject","Reject","Accept")

Where any of the applicable criteria are rejected, reject overall (else accept).

APPENDIX C: DATA, GUIDELINE CRITERIA, EVALUATION, AND FISH PASSAGE RESULTS

Glossary:

Guideline Year: Date of guideline in use when written plan was submitted.

Alternative: Fish passage strategy used from guidelines

1: Culvert placed with little or no gradient.
2. Culvert placed with little or no gradient with a backwatering structure at the outlet.
3. Culvert placed with little or no gradient by sinking the inlet.
4. Culvert with inlet and outlet sunk equally to retain sediment.
5. Culvert with inlet sunk more than outlet to retain sediment.
6. Culvert with baffles or weirs.
7. Bottomless-arch culvert.
8. Bridge.

Culvert Elevation Drop: The change in elevation from the inlet to culvert outlet in feet.

Channel substrate: FG – fine gravel, FN – fines, SC – small cobble, LC – large cobble, SD – sand, CG – coarse gravel, BL – boulder, BD – bedrock, ND – no data, NA – not applicable.

Valley Fill Depth: Are the sediments in the valley and stream bottom deep (DF) or near bedrock/shallow (SF).

Capacity (with losses): The structure flow capacity reduced by sediment retention or baffle/weir design.

Capacity (no losses): The structure flow capacity without sediment retention or baffles/weirs.

APPENDIX D: EXAMPLE WRITTEN PLAN

Date: July 29, 2002

Revision to July 22, 2002 Plan
Project Name: X Creek (Notification #)
Legal: T xx R xx S xx
Protected Waters: X Creek

Stream Characteristics:

- X Creek is a Large Type 'F' stream with a stream gradient of 3%.
- The stream gradient was measured upstream of the pipe using a clinometer, above the influence of the old culvert.
- The active channel width is 8.5 feet. This was estimated by averaging ten measurements taken above the influence of the old culvert, each about one channel width upstream of the other.
- The bed is comprised mainly of small to large cobbles.
- The bed material appears deep enough to countersink these culverts, since the crossing is in an area with deep valley fill material.

Installation Plan:

- No work will take place during wet conditions.
- The existing wood culvert will be removed and disposed of in an approved disposal site.
- The road width will be reduced to 20 feet to limit fill volume.
- The road grade will increase to limit fill height and fill volume.
- Excess material removed from the fill will be placed in disposal site as shown on the map.
- Backfill material will be replaced in one-foot lifts and machine compacted across the entire width of the fill.
- The lower road and the wood culvert between the two roads will be removed to restore the original streambed.
- All work will be done during the in-water work period between August 1 and September 30.
- A well-rocked equipment access road to the inlet of the culvert will be left for maintenance purposes.
- All exposed soil will be seeded immediately after construction.

Pipe Installation:

- Alternate 3a in the fish passage guidance will be used (Streambed Simulation: Sunken evenly)
- A 60-foot long, 77-inch by 114-inch pipe arch will be placed in the crossing.
- The pipe will be placed on a 3% gradient, same as the channel gradient.
- The culvert will be buried 18 inches below the natural channel elevation at the inlet and the outlet.
- The elevation of the first riffle observed downstream of the old culvert will be used as the reference elevation to determine the natural channel elevation at the outlet.
- The culvert will be manual-filled with material similar in size to what is seen in the stream channel above and below the crossing.
- Watershed area = 1565 acres, or 2.45 square miles.
- 50-year event, using ODF method: 94 cfs/square mile
- Estimated 50-year flow at the crossing: 230 (2.45 x 94)

- Culvert capacity, from ODF guidance: 340cfs
- Percent loss in capacity because of being buried 18 inches: 25%
- Effective capacity: 255 cfs (greater than the 50-year flow)