

Maine Department of Transportation

FISH PASSAGE POLICY & DESIGN GUIDE



Prepared by
Maine Department of Transportation

In Cooperation With:
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Maine Department of Inland Fisheries and Wildlife
Maine Department of Marine Resources
Maine Land Use Regulation Commission
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Natural Resources Conservation Service
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PART 1: POLICY

SUMMARY

The purpose of this document is to establish a policy, process, and design guide with best management practices for fish passage. The document was specifically developed for Maine Department of Transportation (Maine DOT) projects with water-crossing structures. These structures can include pipes or boxes of any type or size, commonly referred to as bridges, struts, culverts, pipes or pipe arches (with or without footings), and could be part of any Maine DOT program. These structures will be referred to as "culverts" or "pipes" in this report. In the past, case-by-case processing of crossings for fish passage (evaluating site through obtaining regulatory approval) could add unexpected time and expense to projects because there were no consistent, established procedures. This document provides a framework, guidance and tools to process crossing projects by balancing a variety of needs at a site.

The primary goal regarding fish passage is to meet regulatory requirements and resource needs, while delivering safe, cost effective, and timely projects. To reach agreement on how best to achieve this goal, representatives from a variety of agencies have met over several months to discuss the issue. The end result is a protocol that encourages balanced decisions on whether fish passage is necessary and, if it is, whether feasible and possible given site conditions and other, potentially limiting factors. Essentially, the document should allow Maine DOT to do the right thing with agency buy in, after weighing all aspects of a proposed project.

INTRODUCTION

Maine's transportation corridors and fisheries resources cross common areas throughout the State, and the Maine DOT is seeking to develop effective ways to build and repair the travel infrastructure while protecting important fisheries resources. Improperly designing, installing or repairing culverts can block spawning runs of migrating fish, as well as the seasonal movement of resident fish species. New structures should be designed and installed so they don't interfere with passage. In addition, any selected method of replacement or repair should allow proper fish passage where appropriate and reasonably possible. Currently, Maine DOT uses the following practices to address a deficient culvert: rehabilitating the existing culvert by inserting a smaller diameter pipe inside, placing a concrete lining at the inverts or throughout the entire length; or replacing the culvert. Rehabilitation allows a culvert to be repaired in place, usually with less streambed disturbance than replacement. Project costs are lower for rehabilitation than for replacement; however, rehabilitated culverts may have more potential to impede fish passage, especially if they did so when they were initially installed.

When examining whether fish passage and associated habitat issues are compatible with new stream crossing structures or improvements to existing structures, Maine DOT must balance the interrelated needs of the site, including regulatory, biologic, hydrologic, structural, and economic. That is, goals for crossings should:

- Maintain or replicate natural stream channel or flow conditions, as appropriate;
- Pass peak flows in accordance with Maine DOT drainage policy;
- Comply with existing regulations on passing fish;
- Consider potential impacts to rights of way, utilities and traffic;
- Meet appropriate standards and safety requirements;

- Provide reasonable life cycle costs; and,
- Consider the least environmentally damaging solutions.

A multiagency Fish Passage Work Group (the Group) was formed, recognizing that how Maine DOT currently addresses fish passage could be improved to produce better, accelerated and cost effective projects. To identify ways to reach these goals, the Group decided to examine current regulations and policies, current practices in agency coordination, existing standards for fish passage, fish species present and their passage needs, and engineering and other design and construction considerations. After examining these items, representatives of the Group developed recommendations for installing and repairing culverts in a way that:

- Complies to the extent practicable with current state and federal regulations on fish passage [State Natural Resources Protection Act (NRPA) and Land Use Regulation Commission (LURC) guidelines, Federal Endangered Species Act, Magnuson-Stevens Fishery Management Act, and Clean Water Act (CWA)];
- Includes clear protocol for nature and timing of agency coordination;
- Enables the Department to make use of new and developing technologies such as slip lining, plastic pipes, concrete invert lining; and,
- Considers cost and other impacts.

EXISTING REGULATIONS AND RECOMMENDED PRACTICES

Current Regulatory Requirements

Current requirements associated with fish passage and culverts are as follows:

- CWA. Army Corps of Engineers General Permit-39 State of Maine, Item #19(a). "All temporary and permanent crossings of waterbodies shall be suitably culverted, bridged or otherwise designed to withstand and to prevent the restriction of high flows, and to maintain existing low flows, and to not obstruct the movement of aquatic life indigenous to the waterbody beyond the actual duration of construction."
- 38 M.R.S.A. Sections 480 Q. 2.A. and 9. Require fish passage be maintained when existing private or publicly owned culverts are repaired or maintained.
- 12 M.R.S.A., Sections 6121-6123 and 7701-A. May require passage to be constructed at an obstruction (e.g. highway culvert).
- NRPA. Chapter 305. Permit By Rule Standards. Section 11.B.8. Reconstruction or Replacement Projects: "The project will not permanently block any fish passage in any watercourse containing fish. The applicant must improve passage beyond what restriction may exist unless the Department of Inland Fisheries and Wildlife, the Atlantic Salmon Commission, and the Department of Environmental Protection's Division of Environmental Assessment concur that the improvement is not necessary."¹

¹ Work needed on site as part of a fish passage system (e.g. a weir near a pipe outlet) is not considered a project impact and doesn't require a separate permit.

- L.U.R.C. Chapter 10. Rules and Regulations. Calls for conditions for fish passage to be maintained.¹

Repair and maintenance of highway culverts must also follow floodplain and flood insurance regulations. The Federal Emergency Management Agency (FEMA) has oversight of all activities that may cause an increase in flooding within a 100-year floodplain. For each crossing project, all appropriate permits shall be obtained and Maine DOT's Best Management Practices for Erosion and Sediment Control (1) shall be used.

Agency Contacts

The Group contacted departments of transportation in Maryland, Minnesota, Michigan, New York, North Carolina, Pennsylvania, Virginia, Washington, British Columbia, Oregon, Alaska, Vermont and Wisconsin, to get ideas from how other states address fish passage. Most of the states contacted assess fish passage project-by-project, coordinating with natural resource agencies (2,3). Some have memoranda of understanding (MOU) with fisheries agencies, as with Washington's MOU among the Fisheries, Wildlife, and Transportation departments, addressing compliance with their Hydraulic Code. Other states have developed guidelines and recommendations, as in North Carolina's "Stream Crossing Guidelines for Anadromous Fish Passage" and New York DOT's recommendations for fish passage that were recently incorporated into their draft highway design manual. None of the transportation departments contacted has a written policy on fish passage.

For environmental coordination of fish passage to be successful, all review parties need sufficient information about whether a resource exists on site and the potential impact of the scope of work on the resource (i.e., whether passage could be blocked by the proposed project). Even small crossings may have locally important fisheries that need to be protected. To assure these concerns are addressed, the Group recommends that Maine DOT continue the current practice of coordinating on fisheries issues with Maine Department of Inland Fisheries and Wildlife (MDI F&W)(4,5), Maine Department of Marine Resources (MDMR)(6), Atlantic Salmon Commission (ASC), U. S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), as appropriate. To increase project efficiency, the timing and nature of coordination should be better defined.

Existing Standards

In addition to regulatory requirements, the Group recommends that Maine DOT follow the Natural Resources Conservation Service's (NRCS) recently updated National Practice Standard 396 on Fish Passage (7). Following are excerpts from the standard, including general guidance that directly applies to Maine DOT work. In practice, the following should be considered during design of fish passage:

- Actions taken to provide fish passage shall seek to avoid adverse effects to endangered, threatened, and candidate species and their habitats, as well as state species of concern, whenever possible.
- Fish passage measures shall be designed so fish will not suffer excessive energy deficits or undue physical stress when swimming past a fish passage structure or site.

- Fish passage shall be designed so that fish shall not be excessively delayed during passage at the structure or site unless modification or removal of a barrier, such as a tidegate, could result in undesirable effects to other resources.
- Minimum and maximum flows through fish passage structures or sites must be adequate to attract target fish to the structure or site.
- Location and overall design of fish passage structures, or fish passage features, shall accommodate watershed conditions such as variations in stream flow and bedload movement.
- Location and overall design of fish passage structures or features shall accommodate different aquatic species and age classes to the extent possible.
- Location and overall design of fish passage structures or features shall be compatible with local conditions and stream geomorphology.
- Materials selected for constructing fish passage structures will be non-toxic to fish and other aquatic life.
- At stream crossings, flow velocity through culverts should not exceed the abilities of those target species expected to move upstream and downstream of the site.

NRCS also recommends the following considerations:

- Native game and non-game fish species and amphibians as well as endangered, threatened, and candidate, rare and other sensitive species shall be carefully considered when designing and implementing fish passage features.
- If replacement of an in-channel structure will cause degradation or aggradation of the channel upstream, installation of bed controls appropriate for the geomorphic conditions of the site and fish passage needs should be considered (see Stream Channel Stabilization -Code 584 and Grade Stabilization Structure - Code 410).
- Consider potential negative effects of providing passage for invasive or non-native species that may hybridize with, compete with, or spread disease to native fish or other aquatic species above a barrier.
- Consider other aquatic and terrestrial species, including endangered and threatened species that have established habitat in areas where barriers currently exist or in upstream and downstream areas that would be directly affected by the action.
- Consider seasonal variations in headwater and tailwater levels and how these may impact passage hydraulics for the life history stages of the fish for which the structure is being designed.
- Consider the need to design for strategic resting places for target species facing long passages.

- Consider historical structures when planning, prior to installation and during maintenance of fish passage structure. This practice may affect cultural resources.
- Consider the need to balance fish passage with other water management objectives.
- To the extent possible, fish passage structures should be designed to minimize excessive predation on fish entering or exiting the structure.
- Removal of a fish passage barrier should take into consideration effects on wetlands, flooding potential, existing infrastructure and social impacts.

Fish Species Present

The fishery resources of the State of Maine sustain our coastal and inland ecosystems, and provide economic benefits from commercial and sport fishing. Species such as alewife, blueback herring, and American shad provide forage for numerous fish and wildlife species in both inland and coastal habitats (8), and they support commercial fisheries. Other species, such as trout, are sought by anglers and bring revenue into many areas of Maine. All add in some way to the benefits provided by our public fisheries resources and protecting these valuable resources must be one of Maine DOT priorities. Table 1 includes fish species that have been confirmed by the resource agencies participating in the Group as being particularly vulnerable to mortality during their foraging and spawning migrations, and should be considered when designing fish passage.

Table 1. Vulnerable Species

<u>Catadromous Species:</u>	<u>Anadromous Species:</u>	<u>Freshwater Species:</u>
American eel	Rainbow smelt	Rainbow smelt
	Blueback herring	Brook trout
	Alewife	Brown trout
	Atlantic salmon	Rainbow trout
	American shad	Landlocked salmon
	Sea run brook trout	Forage (resident) fish
	Sea run brown trout	White sucker

Site Considerations

First, a resource inventory is conducted at the site and Maine DOT solicits comments from fisheries agencies. Species present, size of fish and seasonal passage needs are determined, using Appendix 1B as a guide. Even after a resource inventory may indicate that fish passage is warranted, additional features of a site need to be considered. All site factors should be balanced to determine the best course of action.

For example, at a particular site, a hanging pipe may not be realistic to replace. Before a decision is reached, additional questions need to be answered such as: What alternative action is least environmentally damaging? Is cost of any alternative prohibitive, considering short-term costs and life cycle costs? What is the most reasonable alternative considering property ownership? Utility location? Safety? What is best for future streamflow conditions regarding the resources present

(fisheries and others) and flood protection? Is there suitable fish habitat upstream of the culvert? In some cases, after it is concluded that fish passage is warranted and appears physically possible, the answers to these questions may alter the final decision on whether passage is practicable and should be provided. Ultimately, a decision to provide fish passage may not be the best decision.

Design Criteria

Introduction

When conditions at a site indicate that fish passage can and should be provided, the appropriate criteria must be used to design effective passage and assure long term stability at the site. According to Maine DOT drainage policy, culverts must protect roads against extreme high flow events to avoid blocking traffic and to minimize wash outs and other damage. In addition, at sites with fish habitat, the culverts should not block fish passage. A culvert can block passage in several ways. The most obvious is to create a physical barrier by its configuration or construction (e.g., a hanging culvert). This condition is addressed in the subsequent Design Criteria section on "Gradient." A more subtle form of barrier can be created hydraulically. Although the culvert may appear to form a clear and continuous passage for fish, in fact, the culvert hydraulics (resulting velocity and depth of flow) may prevent passage.

Ideally, culverts should reproduce, as nearly as possible, the hydraulic conditions of the stream. At high flows, this is not an issue, as fish tend not to move upstream during higher flows and depth is more than adequate for fish to wait out the limited duration of higher flows. Low flows are more critical for fish movement. Natural velocities at lower flows ordinarily permit upstream movement. Undersized culverts can constrict flow and increase velocity above the fish swimming capacity. Oversized culverts can reduce flow depths so they are too shallow for fish to navigate. In either case, the culvert may function as a hydraulic barrier to fish movement.

Ideally, then, to pass fish effectively, culverts must satisfy these objectives:

- 1) Peak Flow: pass the design flood (typically 50-year) event.
- 2) Maximum Velocity: not exceed a specified flow velocity at a specified flow representative of conditions during periods of upstream movement.
- 3) Minimum Depth: maintain a minimum depth for fish movement at a specified flow representative of low flow conditions when fish may be moving
- 4) Gradient: Maintain channel elevation between stream bed and pipe at inlet and outlet that fish can easily pass through (no excessive drops).

Design for fish passage through new and replacement ("new") pipes can be different than for passage through rehabilitated pipes. With new pipes, design is focused on reproducing in the pipe the basic hydraulic geometry of the stream (with $Q_{1.1}$ flow depth and width as surrogates for critical geometry). There is the implicit assumption that fish passage criteria 2) and 3) are automatically satisfied if $Q_{1.1}$ flow depth and width are preserved. With pipe rehabilitation (slip and invert lining), which reduces the size and roughness of the pipe, it is generally not possible to maintain or restore natural hydraulic geometry in the pipe. In this case, criteria 2) and 3) must be addressed directly. The reduced roughness reduces flow depth and/or increases flow velocity. Often, velocity and depth requirements cannot be achieved without additional structural measures (e.g., weirs).

Design Peak Flow

Criterion 1), design flood, is the familiar standard for providing flood protection. In theory, it represents the optimal design that minimizes the expected cost associated with flooding. Damages associated with a design smaller than optimal could be reduced by using a larger culvert. A culvert larger than optimal will cost more than the marginal savings in flood damage. In practice, though, the 50-year event is simply a compromise between underdesign and overdesign. The relationship between the 50-year event and optimal design is largely unknown. Design for criterion 1) is the traditional method of estimating design flow and analyzing culvert hydraulics, as documented in Maine DOT Highway and Bridge Design Manuals (10, 10a).

Design Fish Passage Flow

Strictly speaking, the design flow for fish passage design should be assigned according to the species of interest and the calendar periods of movement. This information is summarized in Appendix 1B. Then the structure is designed to maintain acceptable water depth and velocity at the design flow(s). As a practical matter, adequate water depth at low flows is expected to be the limiting factor in most situations. Therefore, Maine DOT recommends the following approach to determining a design passage flow. Ideally, the final flow value should be based on at least one estimate derived from field measurements.

- 1) Measure low-flow channel geometry upstream and downstream of the structure. Assign a flow depth that will permit passage in the channel at low flow conditions. Calculate velocity using Manning's equation.
- 2) If possible, make actual velocity measurements during passage period of interest. Combine with channel geometry measurements to calculate flow.
- 3) Use monthly median flow equations (13; see also Appendix 2A of Design Guide) to estimate flow during period of interest.

Generic design can be based on the average of the September and October median flows, as this is representative of low-flow conditions during cooler weather when fish will be moving. If the resulting flow presents design problems then a species-specific time period should be used.

Water Velocity

Criterion 2), maximum velocity, is intended to enable the target fish population to swim upstream against the current at critical periods. New and replacement pipes will be sized for consistency with the natural channel bankfull width (bankfull discharge = $Q_{1.1}$), with the implicit assumption that such sizing will automatically produce the desired flow velocities and depths; the adequacy of this assumption should be checked in individual design. When velocity must be designed for explicitly, Maine DOT recommends a generic maximum design of 2.0 ft/s during low flow conditions. This may be refined on a species-specific basis.

It is expected that velocity may be a limiting factor when water is running higher than typical early fall low flow conditions, e.g., late spring. Various fish species use culverts at different times of the year, and have different velocity and depth requirements for passage. Smelt, white sucker, and rainbow trout are the main species moving upstream to spawn during spring higher flows. Smelt, a weak swimming fish, may be present in the late winter and spring, and require slower velocities than other fish that are present at the same or at different times of year. The same structure may need to

sustain a suitable velocity for adult salmonid use in the fall, and to allow low flow passage for juvenile salmon to forage for food during their rearing stage.

Even within species, swimming speeds of fish vary with maturity and size of fish, characteristics of individual fish, and water temperature. There are three categories of swimming speed: cruising, sustained, and burst speed. Cruising speed is the speed a fish can maintain for an extended period of time, sustained speed can be maintained for several minutes and burst speed only for a few seconds. A design to pass fish effectively should be based on sustained speed because it can be used over the relatively short time and distance it takes fish to pass through a pipe. Adults of the weakest swimming fish species found in Maine fisheries, such as smelts, may have maximum sustained speeds around 2.0 feet per second (fps) (8, 9). Therefore, generic design should be for an average flow velocity of 2.0 ft/s at design passage flows. If this is unobtainable or unfeasible from an engineering perspective, the design should be made specific to particular target species during periods of upstream movement; this may allow for design to a higher flow velocity. It is not necessary to consider maximum flow velocity for downstream movement because fish are moving with the current. Appendix 1B provides criteria for passage, by species. The compilation includes sustained swim speed, periods of passage, direction of movement, and size of fish (to determine water depth needed).

Flow velocities vary with depth within the barrel of a pipe, as a function of pipe cross sectional area and surface roughness. A boundary layer of slower moving water develops near the inner pipe surface. Water adjacent to the inner pipe surface (corrugated or smooth) is slower than the flows near the free water surface (or pipe center in case of full pipe flow) and fish will normally seek the lowest water velocity when traversing a culvert (11, 12). Culvert rehabilitation may greatly reduce roughness, thus reducing the boundary layer (slow water) thickness to where it may not provide an adequate passage zone. In this case, velocity is nearly uniform across the pipe section and approximately equal to the average velocity as determined by hydraulic equations. When a pipe is sufficiently rough (e.g., deeply corrugated), hydraulic analysis for a specified flow and size may indicate an acceptably thick lower velocity zone adjacent to the pipe surface. If the natural velocity profile in a pipe does not provide an adequate low velocity zone, then alternative designs or actions should be considered (i.e., linings may need to include additional structural measures on site to meet design criteria or it may not be possible to line the pipe).

Designing for a velocity limit requires that target fish species and an appropriate design flow be specified. Appendix 1B will be used to establish maximum allowable velocity, corresponding velocity zone depth requirements, and periods of upstream movement by species. Ideally, the design should be based on a statistical flow criterion. For example, sea-run brook trout move upstream to spawn from September through November. This policy establishes that the median flow for an appropriate period of interest is an acceptable standard. Statistical measures should be checked against channel geometry measurements and hydraulic calculations, and if possible, actual field velocity measurements.

The Group also examined the use of hydrologic software models, such as FishXing from USFS San Dimas Research Center (www.stream.fs.fed.us/fishxing) as design guidance. Although the model is available, some data needed to run the model are not available for eastern fish species. Therefore, the most feasible approach for Maine DOT is to design passage using the hydrologic: 1) data available; 2) site-specific design criteria; and 3) in-house expertise.

Water Depth

Criterion 3), minimum depth, is intended to assure adequate water depth during periods of simultaneous low flow and fish movement. As already noted for water velocity considerations, new and replacement pipes will be sized for consistency with the natural channel bankfull width and depth, with the implicit assumption that such sizing will automatically produce the desired flow velocities and depths. This assumption should be checked before a design is finalized.

Maine DOT recommends a generic minimum depth requirement of 8 inches. Design may be refined on a species-specific basis if the 8 inch minimum creates engineering difficulties. When recourse is made to species-specific depth, the design depth should be based on the target species present and either the corresponding critical depth (1.5 x the body thickness) (14) for that species during the period of significant movement or the documented prevailing depths during periods of known movement.

Information we received from other regions confirms that sizing and orientation of culverts are regionally specific because of different geographic and hydrologic conditions at water crossings. For example, Washington State requires that a culvert be 1.2 times the bankfull (roughly $Q_{1.1}$) width plus 2 feet at the flow line. This design is inappropriate for Maine because it would create inadequate depths for resident fish passage in many instances. We endorse USFWS (15) recommendations to design for varying suitable flow conditions to match existing stream depth at the pipe location during key periods of use. We also recommend that any replacement pipe should approximately match the width of the existing bankfull stream channel at $Q_{1.1}$, to maintain adequate water depth.

Gradient

In addition to a suitable combination of water velocity and depth, fish need criterion 4), a suitable gradient to enter and exit a crossing structure (3,8,11,12). A drop at a culvert outlet is one of the most critical conditions that can block passage. Culverts should be installed at the proper elevation to avoid perched outlets that fish cannot access. This agrees with current Maine DOT practices that pipes should be embedded and allowed to fill in to maintain a continuous, natural gradient. In some instances, weirs or a check dam can be placed downstream from an existing culvert to raise the tailwater elevation enough to reduce or eliminate a drop and allow passage, as long as passage at the check dam is maintained.

Summary of Maine Criteria

Design for fish passage through new and rehabilitated culverts is fundamentally different. Each site where passage is desired will need biologic and hydraulic analyses, so case by case project review is the best way to address passage issues and design. Pipes will be designed for appropriate flow depth and velocity, either implicitly (new or replacement) or explicitly (rehabilitation). The Design Guide for Fish Passage Through Culverts (Part 2 of this document) will be used as design guidance. If a particular site cannot physically meet these criteria or if cost is prohibitive, design criteria for passage may be revised or suspended.

Considering all the data available and sound current practices, the following conditions should be our goals when fish passage is needed. These goals are in addition to the requirement that culverts pass the design peak flows.

Goals for New or Replacement Culvert

- Establish and verify instream work window.

- Eliminate hanging outlets where practicable.
- Embed culverts according to design guide
- Structures should allow existing stream bed characteristics to be naturally maintained, as much as practicable.
- Do not exceed the existing natural gradient; avoid drops inaccessible to fish.
- Size and place structures to simulate natural stream hydraulic geometry (including bankfull width). For single pipes, match flow depth and width to natural stream depth and width at bankfull ($Q_{1.1}$) conditions.
- For multiple pipes at the same location, install as for single pipe to allow fish passage during low flow periods of regular movement; size and place additional pipe to collectively pass the design peak flows (4, 6, 10). Multi-pipe installations are prone to unintended consequences and should only be designed by experienced hydraulic engineers.
- Calculate flow depth during species-specific periods of movement for the pipe design at appropriate period-specific low flows.

Goals for Rehabilitated Culvert

- Establish and verify instream work window.
- Eliminate hanging outlets where practicable.
- Preserve minimum flow depth during critical periods of species-specific movement.
- Do not exceed maximum flow velocity during periods of species-specific upstream movement.

The Design Guide's Best Management Practices for passing fish (Appendix B) will be used where pipes are being replaced (if replacement pipes cannot be lowered to proper grade) or rehabilitated.

Process

Project Coordination

Maine DOT's Bridge Management Section initially field-reviews bridge project sites to establish a six year plan. A biologist participating in the review will document, at that time, what is known about projects and site conditions (including whether there is a defined stream channel, fish and habitat). The preliminary site inventory form and instructions in Appendix A will be used starting at this initial review and data collected will be entered in a data base. Next, the data collected will be sent to the agencies with requests for work windows, passage needs and other habitat issues. Information received following those requests will be permanently put into each project's file to be used during design and construction.

For the Bureaus of Maintenance and Operations and Project Development (teamed) projects, a Maine DOT biologist or other appropriate staff will also do a preliminary site inventory and record information in the data base as early as possible after projects are initiated. The DOT will then forward data and request agency comments, placing responses in each project's files.

Figure 1 outlines processing steps, beginning with project initiation and continuing through project construction. Proposed scope of work is the first data known for each project. After initial site information is collected, either fish passage is requested for the species of concern, or passage is determined not necessary. When determining needs at site, all other site conditions are defined, including potential environmental effects and overall practicability (cost, property ownership, utilities, safety, etc.). If passage appears practicable after all factors have been reviewed, a hydrologic assessment will be done to determine whether passage can be properly designed. The proposed design is submitted to the appropriate regulatory agencies and a response is sent to Maine DOT. Lastly, agencies agree on what should be done and construction can proceed.

During placement of a weir or other passage measure, a Maine DOT or other environmental representative will be present on the project to assist with placement by offering resource considerations and site-specific adjustments when necessary.

Project Monitoring and Evaluation

Projects completed under the terms of this document will be monitored and evaluated. Hydraulic performance, site stability, and implied or actual use by fish will be evaluated using the form in Appendix A. Results of all sites monitored for any given year will be documented in writing and by photographs/videos. These results will be presented to the Interagency (or similar) group and kept on file at Maine DOT so they are available upon request.

A technical working group will be established to evaluate engineering practices associated with fish passage. This group will assure that examples of successful practices are added to the BMP section of this report as appropriate so they can be used to design future similar projects. Measures that are unsuccessful will be examined for the cause of failure and either eliminated as an alternative (with documentation) or modified in a way that makes them effective.

RECOMMENDATIONS

To reach our goal of compliant, constructible, on time projects, we offer the following additional recommendations for follow up actions.

- Policy and Guidelines. This report is a comprehensive, living document on fish passage, and will be kept current to address future needs concerning resources or crossings. Major proposed changes will be sent to appropriate agencies for review before being incorporated into the document.
- Fish Passage Design Guide and BMPs. The Design Guide and Best Management Practices established in this document will also be included in appropriate Department manuals.
- Data Base. A data base is being developed to record information from the Preliminary Site Inventory Form (Appendix A), which will be linked to related, existing Maine DOT data bases. This will help to identify and expedite future repair or replacement of culverts.

- Inspection Protocol. Maine DOT will coordinate culvert inspections to identify specific needs early so culverts can be assessed and replaced or repaired before they fail. This will also allow ample time for agency coordination.
- In-house Training. Potential users of the Fish Passage policy, guidelines, design guide and BMPs will be offered training on how to use the information in this report. These users include Maine DOT staff who coordinate environmental aspects, design and construct crossing projects.
- Effective Date. This document will be officially announced at appropriate state, federal, local or other appropriate forums, beginning in the spring of 2004 and posted on the Maine DOT web site.

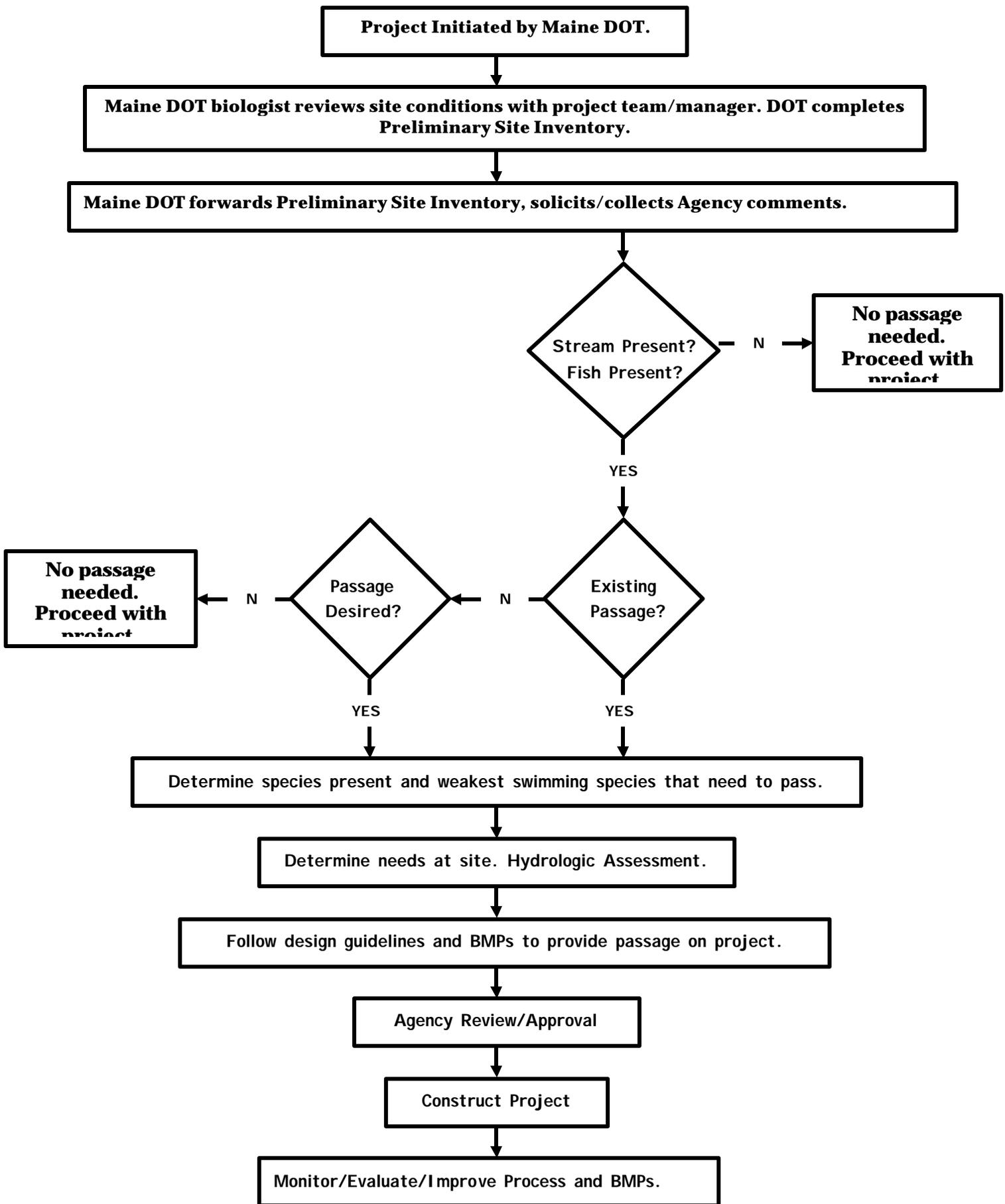


Figure 1. Steps in processing Fish Passage.

REFERENCES

- (1) Maine Department of Transportation. 2000. Best Management Practices for Erosion and Sediment Control.
- (2) North Carolina Department of Transportation. Stream Crossing Guidelines.
- (3) New York Department of Transportation. 2000. Highway Design Manual - Chapter 8 - Highway Drainage.
- (4) Maine Department of Inland Fisheries and Wildlife. 1986. Administrative policy regarding fish passage requirements.
- (5) Maine Department of Transportation and Maine Department of Inland Fisheries & Wildlife. 1976. Standard Operating Procedures between the Maine Department of Transportation and the Maine Department of Inland Fisheries & Wildlife.
- (6) Flagg, L.N. 1997. Personal communication with Dr. William F. Reid, Jr. Stock Enhancement Division, Maine Department of Marine Resources.
- (7) United States Department of Agriculture. 2001. Natural Resources Conservation Service National Handbook of Conservation Practices. Standard 396 - Fish Passage.
- (8) United States Fish and Wildlife Service. August 2000. Comments from Curt Orvis to Sandra Lary of Maine Department of Marine Fisheries.
- (9) Votapka, F. E. 1991. Considerations for fish passage through culverts. Transportation Research Record. Transportation Research Board. National Research Council. Washington, D.C.
- (10) Maine Department of Transportation. 1996. Bridge Design Manual.
- (10a) Maine Department of Transportation. 2002. Highway Design Manual, Drainage Design.
- (11) Washington Department of Fish and Wildlife. 1999. Fish Passage Design at Road Culverts.
- (12) Behlke, C.E., Kane, D.L., McLean, R.F., and Travis, M.D. 1991. Fundamentals of Culvert Design for Passage of Weak Swimming Fish. Alaska Department of Transportation. FHWA-AK-RD-90-10. 177 pgs.
- (13) Dudley, R.W., 2004, Estimating monthly, annual, and low 7-day, 10-year streamflows for ungaged rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2004-5026, U.S. Geological Survey, Augusta, Maine.
- (14) Orvis, Curt. 2001. Personal Communication. United States Fish and Wildlife Service.
- (15) United States Fish and Wildlife Service. October 2000. Richard Quinn Memo to Curt Orvis.

APPENDIX 1A. Preliminary Site Inventory Form and Instructions

Part I. Preliminary Site Inventory. (Use back of form or additional pages as necessary.)

Purpose: This site inventory should be completed as early as possible for projects with crossing structures, and used to help evaluate alternatives for final scope of work at a site (rehabilitation or replacement). The completed form will provide a portion of the information needed to determine appropriate action and is part of the Maine DOT Fish Passage Policy and Guidelines.

Please complete sections I. through IV. For help, see Selected Instructions by Section below.

I. General		Date:	Reviewer:	
Town/Route/Road Name:			PIN/Div/Br. #:	
Waterbody Name:			Watershed:	
Map Location:			Latitude\Longitude:	
Collector Route Code:	Route Mileage:	Element ID:		
II. Stream\Fisheries Observations				
Cover type: forested shrub grassy Describe:				
% Gradient Upstream: 0-1 1-4 >4			% Shading Upstream:	
% Gradient Downstream: 0-1 1-4 >4			Downstream:	
Existing structures or barriers: Upstream Downstream Describe:			Estimated Stream Velocity:	
Culvert width: Matches stream Narrower than stream Wider than stream				
Fish present: Yes No Unsure			Fish Observed: Upstream Downstream	
Fish species/size/age class:				
Existing structure passable?: Yes No Unsure If no, why? Describe:				
III. Culvert Observations/measurements				
Structure type/shape: Depth of corrugations:			Corrugated: Yes No Spacing of corrugations:	
Structure Height/Diameter: Length:		Width:	Orientation:	
Embedded invert: Yes No Approx. depth below substrate at Inlet: at Outlet:				
Alignment with stream: Horizontal: Good Fair (Upstream or Downstream) Poor Vertical: Flatter Same Steeper				
Water depth in structure: at Inlet:			At Outlet: High water marks:	
Inlet: Describe:			Apron: Yes No Type:	
Outlet: Physical drop Cascade If drop, difference from invert to streambed:			Apron: Yes No Type: Age of structure: years	

Average water depth in stream:		Size of area draining into pipe:	
IV. Other	Photos: Digital (preferred) Other		Sketch: On back On additional page
	Other observations: Back Added page(s)		
Rare, Threatened, Endangered Species present? Yes No Unknown Describe:			
Need further review? Yes No Describe:			

Part II. Instructions for completing Preliminary Site Inventory

Selected Instructions by Section:

I. General

Watershed: Name of watershed basin that contains the waterbody from DeLorme Maine Atlas (DeLorme) or U.S.G.S. Map.

Map Location: 7.5 minute USGS topographic map name or coordinates from DeLorme. For DeLorme, use Map Number and alphanumeric locator (e.g.: Davis Brook, #34, B - 1).

Latitude and longitude: From GPS coordinates or U.S.G.S. map.

Collector Route Code, Route Mileage, Element ID: These are identifiers from the M&O Asset Inventory Data Base that can be used for cross-referencing.

II. Stream and Fisheries observations

Cover type: Circle one or more, as appropriate. Add brief description of cover/habitat in area of structure. Include human development in adjacent area, evident disturbances, special concerns.

Gradient: Circle as appropriate. Look at channel up and downstream of crossing to make determination. As a general rule: **0-1%** slope area characterized by no to slow moving current; **1 to 4%** gradient usually show a riffle\pool overall flow pattern, with moderately fast moving water spaced between pools and no to slight current; **> 4%** characterized by 'pool and drop' overall flow pattern, with steep drops (such as rapids and waterfalls) spaced between pools of significantly slower flow.

Shading: Approximate percent cover in areas near inlet and outlet. Observe canopy over water up- and downstream of crossing. (Vegetation cover is important in moderating stream temperatures and providing basis for food webs within waterbody.)

Estimated Stream Velocity: Use flow meter or estimate travel time over known distance.

Culvert width: Note how width of crossing structure 'fits' stream channel width near inlet and circle appropriate response.

Fish species/size/age class: If possible, note. If not possible, record numbers, body shape or any other apparent characteristics of observed fish.

III. Culvert observations and measurements:

Structure type: Fill in type of structure, including metal, concrete, pipe, box, arch, etc.

Orientation: For example, N/S or E/W

Embedded invert: Is invert of structure below substrate surface? Circle appropriate response. If structure below streambed elevation, estimate depth of invert below substrate at inlet and outlet.

Alignment with stream: Is existing structure aligned with channel? Look at local setting upstream and downstream before completing.

Horizontal:

Good: approximates general course of stream.

Fair: structure not well aligned with either inlet OR outlet of waterway.
Indicate upstream or downstream.

Poor: structure distinctly out of line with channel.

Water depth in pipe: Measure any high water mark above existing water level.

Inlet: One or two words describing inlet. Include whether inlet is projecting, has a headwall, wings, is eroded, has physical drop, etc. Note existence/type of inlet apron or protection.

Outlet: One or two word entry where necessary. Identify whether outlet has physical drop, falls over a barrier, has pool, etc. Note existence/type of any outlet apron or protection.

IV. Other

Photos: Digital photographs or video recommended.

Sketch: Sketch 'plan view' and unusual conditions on back of form or additional sheet.

Other observations: Include other considerations not specifically requested on form. Include anything considered appropriate - wildlife observations, plant community composition, severe erosion, pollution, etc.

Need further review: Is there need to gather additional or more complete information about site? Use your judgment to decide if conditions/resources warrant.

Appendix 1B. Maine Fish Species: Times of Impact and Related Data.(1)

Months

Stage/species	Body Length (inches)	Body Thickness (inches) (% body length)	Direction	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Sustained Swim Speed (feet per second)	Basis of Swim Speed
				1	2	1	2	1	2	1	2	1	2		
adult smelt-landlocked	5.5 - 9.7*	0.9 - 1.5 (16%)#	U	S	S	S	S	S	S					1.8 - 3.2	L
adult smelt-anadromous**	5.5 - 9.7*	0.9 - 1.5 (16%)	U		S	S	S	S						1.8 - 3.2	L
adult smelt-anadromous**	5.5 - 9.7*	0.9 - 1.5 (16%)	D		F	F	F	F						1.8 - 3.2	L
juvenile smelt-	0.74 - 5.5	0.1 - 0.9 (16%)	D		F	F	F	F						0.2 - 0.4	L
juvenile eel (glass & elvers)	2.3 - 5*	1/8 - 1/2	U			S	S	S	S	S				0.8 - 2.6	L
adult eel	7.8 - 26***	1 - 2 #	D								F	F	F	5.2 - 9.1	L
adult alewife	2.6 - 9.4*+	0.8 - 2.8 (30%)	U				S	S	S	S				3 - 5	Pb
adult alewife	2.6 - 9.4*+	0.8 - 2.8 (30%)	D				F	F	F	F				3 - 5	Pb
juvenile alewife	1.7-4.5*	0.5 - 1.4 (30%)	D							F	F	F	F	0.6 - 1.0	L
adult shad	12-17*	2 - 3 (18%) +	U				S	S	S	S				2.3-7.2	Pb
adult shad	12-17*	2 - 3 (18%) +	D				F	F	F	F				2.3-7.2	Pb
juvenile shad	3*	0.6 (18%) +	D							F	F	F	F	1.0 - 1.8	L/Pb
adult blueback herring	9.4 +	2.2 (23%)	U				S	S	S	S				3 - 5	Pb
adult blueback herring	9.4 +	2.2 (23%)	D				F	F	F	F				3 - 5	Pb
juvenile blueback herring	1.4 - 2.8*	0.3 - 0.7 (23%)	D							F	F	F	F	0.4 - 0.8	L
adult salmon (sea-run and	15 - 36*	3 - 7.2 (20%)	U								S	S	S	5.0 - 8.8	L
juvenile salmon	4.5 - 6.8*	1 - 1.4 (20%)	Both			F	F	F	F	F	F	F	F	1.6 - 2.6	L
smolt salmon	7.8 - 15*	1.4 - 5 (20%)	D			F	F	F	F	F				2.5 - 4.4	L
adult white sucker	4 - 14 +#	0.7 - 2.6 (18%)	U			S	S	S	S					1.2 - 2.1	L
brown trout	6-16*+	1.6 - 3 (18%)+	Both			F	F	F	F	F	F	F	S	2.3-7.5	Pb
brook trout	6-16#	1.5 - 4 (25%)	Both			F	F	F	F	F	F	F	S	2.0 - 3.5	L
sea-run brown trout	9-16*+	1.6 - 3 (18%)+	U								S	S	S	2.3-7.1	L
sea-run brook trout	6-12#	1.5 - 4 (25%)	U								S	S	S	2.0 - 3.5	L
rainbow trout	6-18 +*	1 - 3 (17%)	Both		S	S	S	S	S					2.0 - 3.5	L/P+
resident fish movement	3 - 10#	Varies	Both			F	F	F	F	S	S	S	F	1.0 - 1.8	L

Abbreviations/comments

(1) Jan, Dec no feeding or spawning needs noted

Body thickness x 1.5= water depth needed for passage

Months of passage may vary over different regions of Maine

Not intended as denoting construction work windows

Swim speeds - based on smallest size measurement

Sustained speed = 4 to 7 body lengths per second

* USFWS HIS Models

**For culverts just above head-tide; tidal culverts would impact over longer period

*** USFWS HIS New Brunswick

D=downstream migration

U=upstream migration

1= first half of month
2= second half of month

F=Feeding, foraging, refugia (any instream movement)
S=Spawning or spawning migration

P =Published Speeds. b (Bell); + (Fishbase)
L = Body Length Formula

Anecdotal or observed ranges
+ Sizes from: www.fishbase.com

