MEMORANDUM OF AGREEMENT

BETWEEN

ALASKA DEPARTMENT OF FISH AND GAME

AND

ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

FOR THE

DESIGN, PERMITTING, AND CONSTRUCTION OF CULVERTS FOR FISH PASSAGE

This MEMORANDUM OF AGREEMENT (MOA) is made and entered into between the Alaska Department of Fish and Game, P.O. Box 115526, Juneau, AK, 99811-5526, hereafter referred to as the ADF&G, and the Alaska Department of Transportation and Public Facilities, 3132 Channel Drive, Juneau, AK, 99811-2500, hereafter referred to as DOT&PF. ADF&G enters into this agreement under the authority of 16.05.841 – 16.05.861, 16.05.871 – 16.05.901, 16.20.050 – 16.20.060, 16.20.530 and 5 AAC 95. DOT&PF enters into this agreement under the authority of AS 19.05.010 – AS 19.05.125. This MOA supersedes the August 3, 2001, ADF&G & DOT&PF MOA of the same title.

I. BACKGROUND AND PURPOSE

Anadromous and resident fish depend on reliable passage through drainage structures when migrating to spawning, rearing, and over-wintering grounds. Barriers to fish passage can be a substantial factor in fish distribution and use of available habitat.

In fulfillment of its mission, DOT&PF applies for numerous ADF&G Fish Habitat permits for culvert related work in fish bearing waters. In 2001, recognizing the need for an agreement to provide uniform and consistent guidance to project design and permitting, DOT&PF and ADF&G developed an MOA for the design, permitting and construction of culverts to provide for efficient fish passage.

The State of Alaska is committed both to the maintenance and conservation of its fisheries resources and development of its transportation infrastructure in a safe and economic manner. Therefore, ADF&G and DOT&PF agree to use the procedures, design criteria and guidelines identified in this MOA to ensure that, where DOT&PF and ADF&G have determined that culverts are the appropriate stream crossing structure and are utilized by fish, they are designed and installed to provide efficient fish passage. These procedures, design criteria and guidelines clarify and make certain that individual project review and permit requirements under AS 16.05.841(hereafter referred to as 841), AS 16.05.871 (hereafter referred to as 871), and 5 AAC 95.400 – 5 AAC 95.990 with respect to fish passage requirements through culverts are met.

This agreement extends solely to the design, permitting, and installation of culverts in fish-bearing waters. This includes new culvert installation, culvert replacement and modification of culverts. To the maximum extent feasible and practicable, retrofits of existing culverts shall comply with the relevant portions of this agreement. Non-complying culvert installations or retrofits will be authorized by ADF&G on a case-by-case basis. This agreement does not apply to routine culvert maintenance activities. The agreement does not address any other statutory or regulatory responsibilities of ADF&G or DOT&PF. Additional factors unrelated to fish passage (such as unique environmental considerations, locating culverts in anadromous fish spawning or high-value rearing habitat, or other public safety, engineering, or economic issues) will be addressed on a project specific basis.

II. APPLICATION

This agreement applies to each agency as a whole and specifically to all headquarters, regional, and area personnel within ADF&G Habitat Section, and all personnel within the DOT&PF Statewide sections, and regional Design, Construction and Maintenance sections.

III. ADF&G and DOT&PF mutually agree:

A. To apply procedures, design criteria, and guidelines set forth in Exhibit A for the design, permitting, and construction or modification of culverts in fish-bearing waters. ADF&G and DOT&PF recognize that ongoing research is providing new tools and insight into fish passage design. Therefore, both agencies agree to, every five years, review the procedures, design criteria, and guidelines as set forth in Part VI.D and to amend this agreement, if necessary, to accommodate new information.

B. That DOT&PF is responsible for the selection, project engineering and technical design of fish passage structures consistent with the procedures, guidelines and criteria contained in Exhibit A. DOT&PF will request assistance from ADF&G as needed to interpret and apply fish passage criteria.

C. That ADF&G is responsible for identifying fish-bearing waters, including type of stream (841, 871, or non-fish-bearing) and primary species present. Where applicable, ADF&G may also be responsible for identifying fish species and fish length(s) to be used for culvert design, the time of year fish passage may not be impeded, anadromous spawning locations, high-value rearing sites, and, establishing in-water work windows, as necessary.

D. That disagreements involving interpretation of whether the provisions of this MOA have been fully complied with may be elevated first to ADF&G and DOT&PF's regional supervisors, and secondarily to ADF&G's Habitat Section Operations

Manager and DOT&PF's Chief Engineer, for timely and final resolution. Both agencies recognize the value of this process. Staff in both agencies are encouraged to make use of this process rather than allowing a disagreement to remain unresolved. Nothing in this MOA prevents either agency from resolving permit disagreements in accordance with the provisions of AS 16.05.841—16.05.891, AS 44.62.330—44.62.630, 5 AAC 95.710(c), and 5 AAC 95.920.

IV. DOT&PF agrees:

A. To coordinate with ADF&G during the earliest possible project phase on all projects potentially affecting fish-bearing waters.

B. To timely notify ADF&G of proposed changes to permitted fish passage culverts.

C. To have all proposed fish passage culvert structures reviewed by the Regional Hydraulic Engineer or other qualified technical experts for compliance with the procedures, guidelines and design criteria contained in Exhibit A.

D. To provide ADF&G reasonable opportunity to inspect culverts (site visit or remotely using photos or other methods of site documentation) to ensure that all culverts are installed in accordance with Fish Habitat Permit terms and conditions.

V. ADF&G agrees:

A. To timely identify all fish-bearing waters that require fish passage and to provide a list of species and life stages present.

B. To timely provide DOT&PF with all available and applicable information listed in III.C of this MOA early in the design process.

C. To request additional information, if needed, in a timely manner and in a consolidated form.

D. To provide timely approval of Fish Habitat Permits for culvert installations that comply with this MOA.

E. To timely notify DOT&PF whether proposed changes to permitted fish passage culverts require amendments to the Fish Habitat Permit, and what additional information/analysis is needed if a permit amendment is required (see Sec. IV.B).

VI. MUTUAL AGREEMENT AND UNDERSTANDINGS.

It is mutually agreed that:

A. Nothing in this agreement obligates any party in the expenditure of funds, or for future payments of money, in excess of appropriations authorized by law and administratively allocated for these purposes.

B. Nothing in this agreement is intended to conflict with federal, state, or local laws or regulations.

C. External policy and position announcements relating specifically to this agreement may be made only by mutual consent of the agencies.

D. Both agencies shall meet jointly on at least a five-year basis to discuss matters relating to this agreement. Many of the criteria, guidelines and assumptions contained in this agreement are based on the current best available information.

E. For minor updates to this agreement the approval is required by the ADF&G Habitat Operations Manager and the DOT&PF Chief Engineer. Minor updates will be appended to this agreement.

F. It is recognized that changes may arise over the service life of a culvert that could impact its functionality (e.g., flooding above the design discharge and other natural events).

G. The effective date of this agreement shall be from the date of the final signature.

H. Either party may terminate its participation in this agreement by providing the other party written notice 30 days in advance of the date on which its termination becomes effective.

SIGNATURES

DocuSigned by:
4/14/2025
0B7718E00CC647E...
Lauren Little, P.E., Chief Engineer
Alaska Department of Transportation
and Public Facilities

DocuSigned by:
Ben Mulligan
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939B66571A4D4AB...
Ben Mulligan, Deputy Commissioner
Habitat Section
Alaska Department of Fish and Game

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Ryan Anderson, Commissioner
Alaska Department of Transportation
and Public Facilities

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Douglas Vincent-Lang, Commissioner
Alaska Department of Fish and Game

EXHIBITS

EXHIBIT A
Design, Construction and ADF&G Permitting of Culverts in Fish-Bearing Waters

Contents:

Section 1. Background and Purpose

Many water bodies in Alaska contain one or more species of resident or anadromous fish. Fish migrations in these water bodies involve completing one or more cycles of upstream and downstream movements. Fish migrations may occur during all or part of the year depending on the fish species and life stage. Fish migrate to spawn, feed, seek refuge, and overwinter.

To maintain viable and healthy fish populations, all life stages of fish must be able to freely migrate within these water bodies. Mature adult fish must be able to reach spawning grounds. Since anadromous fish species typically cease feeding when they enter freshwaters to spawn, migration delays can deplete stored energy reserves and impact reproductive success. For juvenile fish, delays in reaching feeding areas, over-wintering habitat, or predator relief areas may affect survival. Some of the most productive rearing habitats are in tributaries of major rivers.

Exhibit A describes the procedures, criteria and guidelines that will be used for culvert related work in fish-bearing waters. The procedures, criteria and guidelines are adopted under this MOA. Users of these procedures, criteria and guidelines should read the entire MOA and enabling statutes and regulations.

The procedures, criteria and guidelines contained in this agreement are minimum standards to ensure fish passage at a wide variety of locations. The guidelines should be applied considering site specific factors and design objectives for each culvert crossing site. There may be cases in which culvert designs exceeding these minimums are selected. Similarly, there may be cases where minimum recommended guidelines are appropriate to meet design objectives. Open communication between the ADF&G and DOT&PF is encouraged throughout the design and permitting process to ensure that design objectives are clearly communicated and understood.

Definitions of terms used in the agreement are contained in Exhibit B. References are cited in the agreement to provide additional context for users in Exhibit C.

Section 2. General Planning

Cross drainage structures, including fish passage culverts, are a substantial part of typical highway project costs. Fish passage can be provided at road crossings through consideration of hydrologic, hydraulic and environmental factors. Guidelines and criteria for siting culverts are discussed in the *Alaska Highway Drainage Manual* and *Alaska Highway Preconstruction Manual*. In addition to engineering considerations, siting considerations can include the location of spawning habitat, location of drainage divides or proximity to natural slope breaks, stream widths versus floodplain widths, icing problems, future access needs, vehicle design speed and vehicle sight distance.

As discussed in Section 5 – Fish Habitat Permit Application Procedures – where practicable, joint site visits to potential culvert sites by DOT&PF and ADF&G personnel are recommended to encourage open communication and collaboration.

Section 3. Culvert Guidelines

Culverts in fish-bearing streams will be designed and permitted using one of the following design approaches. The design approaches are presented in a tiered manner, which encourages use of the stream simulation approach by (1) decreasing the level of detailed engineering required for fish passage consideration and (2) increasing assurances that the structure will receive ADF&G authorization. It is the engineer's responsibility to determine which design method best fulfills all objectives of design, including site conditions, alignment, and project schedule. Tier 1 design most closely replicates natural stream conditions. Each succeeding tier further deviates from natural stream conditions and consequently will require progressively more detailed engineering and analysis to ensure that fish passage is provided.

Tier 1. Stream Simulation Design. (*Applicable to "standard" installations: full invert* culvert*, embedded and backfilled with substrate. Tier 1 culverts are recommended for new or replacement installations. The stream simulation method is applicable in culvert gradients up to six percent. Culvert gradients greater than six percent may be applicable when supported by hydraulic analysis of substrate stability. "Non-standard" installations, including open bottom culverts, require Tier 3 analysis.)*

Culverts designed using the stream simulation method are sized larger than culverts sized hydraulically for floodwater conveyance alone. The recommended minimum culvert width for Tier 1 culverts is 1.2 times the Ordinary High Water (OHW) or 1.2 times the bankfull width of the natural channel. The 1.2*OHW or 1.2*bankfull culvert width allows space for constructed streambanks within the culvert barrel and assumes that the constructed channel width within the culvert barrel is approximately equal to the natural channel OHW or bankfull width.

Constructed streambanks within the culvert barrel are not required to meet Tier 1 guidelines. In some cases (e.g., permafrost, aufeis/icing risk, wetland complex channels, intertidal settings, etc.) it may be appropriate to design culverts without constructed streambanks within the culvert barrel. For culverts without constructed streambanks within the culvert, the minimum width for a Tier 1 culvert is 1.0*OHW or 1.0*bankfull.

The culvert gradient should approximate the channel gradient, but in no instance should it deviate more than +/-1% from the natural channel grade (e.g. a 3% channel gradient with an installed 4% culvert gradient). In stream channels with gradients less than 1% (e.g. palustrine, estuarine, wetland complex and flood plain channels), culverts should be installed at slopes within 0.5% of the natural channel gradient.

Channel gradient and OHW or bankfull width should be determined using a reference reach on the water body being crossed, where practicable. In cases without a suitable reference reach, other mutually accepted methods to estimate channel gradient and OHW or bankfull width may be utilized.

The Vertical Adjustment Potential (VAP) of the stream in the vicinity of the culvert should be considered in selecting the shape, vertical alignment, and embedment depth of the culvert. For additional guidance on VAP considerations refer to Chapter 5 of USFS (2008).

Invert embedment depths for Tier 1 circular culverts should be approximately 40% of the culvert diameter. For non-round culvert shapes where the span is greater than the rise the embedment depth should be approximately 20% of the culvert rise. The selected invert embedment depth should place the widest portion of the culvert cross section at the approximate OHW/bankfull elevation or floodplain elevation, where applicable.

Within the culvert barrel, substrate material should remain dynamically stable at all flood discharges up to and including a 2% Annual Exceedance Probability (AEP) discharge (Q_{50}). Where practicable, the substrate should approximate the gradation of the naturally occurring streambed material. For crossings without an adequate upstream sediment supply, the substrate material within the culvert should be designed to resist predicted critical shear forces up to the 1% AEP discharge (Q_{100}).

For culverts with a steep gradient (typically greater than 6%), substrate retention sills that allow bed load to continuously recruit within the culvert barrel may be necessary. If substrate retention sills are used, they should have a weir height of 0.5 times the culvert invert embedment depth. Consideration of substrate retention sill shape should be given to ensure that they would not create a fish passage barrier if exposed to flow at installations where there is a risk of substrate loss.

Low flow channels constructed within the culvert substrate and associated channel erosion protection countermeasures will typically be necessary to mimic stream conditions during low flow. Where low flow channels are proposed, material defining the low flow channel should be designed to resist predicted critical shear forces up to the 1% AEP discharge (Q_{100}).

An assessment should be prepared evaluating the low flow characteristics of the proposed culvert design. In some cases, it may be agreed that substrate and/or low flow channels are not necessary (e.g. locations with backwater conditions - tidal and/or low gradient, wetland systems, etc.).

If the above criteria are followed, it is assumed that fish passage is met and no further hydraulic analysis to support fish passage is required. The initial cost for installing oversized culverts under the stream simulation approach is greater than the cost of culverts sized strictly for hydraulic capacity. However, higher initial costs may be offset by lower life cycle costs, improved resilience, and a simpler, more streamlined permitting process.

Tier 2. Design Utilizing Fish Passage Analysis Software. *(For retrofit of existing installations or new installations where Tier 1 is not practicable or preferred).*

Tier 2 uses the swimming capability of the design fish species and length to create favorable hydraulic conditions throughout the culvert crossing. Culverts are designed using a combination of traditional hydraulic engineering analysis methods (e.g., HDS 5/HY-8) and U.S. Forest Service's FishXing software program. Other fish passage analysis software may be utilized, on a case-by-case basis, upon mutual agreement for the specific project.

Adoption of any other alternative fish passage analysis software for use statewide requires joint approval from DOT&PF Chief Engineer and ADF&G Habitat Operations Manager, per VI.E.

Tier 2 designed culverts must meet the site specific fish passage conditions up to the fish passage design discharge - Q_{fish} (Section 4), and adequately pass the DOT&PF design discharge with acceptable effects on the upstream and downstream channel. Appropriate treatments will be investigated if needed to address outlet perching or upstream effects (e.g. head-cutting if the natural stream slope is not matched).

Tier 3. Hydraulic Engineering Design. (*For use where site-specific conditions preclude use of Tier 1 or Tier 2. Or for non-standard culvert installations: smooth walled culvert materials, fish passage baffles at gradients greater than 10%, open-bottom arch culverts on footings, etc.)*

Professionally recognized hydraulic engineering methods will be used to ensure site specific fish passage conditions are met in the culvert at discharges up to Q_{fish} (Section 4). The proposed culvert shall adequately pass the DOT&PF design discharge with acceptable effects on the upstream and downstream channel. Appropriate treatments will be investigated if needed to address outlet perching or upstream effects (e.g. head-cutting if the natural stream slope is not matched).

Tier 3 design requires more detailed evaluation of hydrologic, hydraulic, and biological parameters. ADF&G's permit review is proportionately more complex.

Table A-1. Summary of Fish Passage Culvert Design Options

DESIGN OPTION	BENEFITS / LIMITATIONS
Stream Simulation (Tier 1)	• Minimal design requirements, simplified permitting. • New and replacement culverts. • Assumed passage is provided for all fish species and life stages. • Culvert slope generally equals slope of natural channel. • Culvert gradients are less than 6%; or if >6%, they are supported by hydraulic analysis of the stability of substrate material within the culvert. • Stream widths are relatively narrow and incised (less than 20 feet at OHW or bankfull).
Fish Passage Analysis Software Design (Tier 2)	• Moderate design and permit review process. • Use for culverts narrower than those required for Tier 1. • Use for new, replacement and retrofit culverts when gradient and virtual mass forces are significant and must be considered at culvert inlet and outlet. • Low to moderate gradient slopes. • Baffled culverts up to 10% slope. • Target fish species and life stage identified for passage model. • Suitable for any size watershed or length of pipe.
Hydraulic Engineering Methods Design (Tier 3)	• Detailed design and review process. • Must be used for all baffled culverts when installation slope is greater than 10%. • Appropriate for use when installation includes downstream weirs or other tail water control structures.
Applied Research	• Experimental structures. Joint DOT&PF/ADF&G decision and agreement. • Detailed engineering and permitting requirements. • Must include post-construction monitoring and remediation guarantees.

Culvert Guidelines - Technical Notes

A. A crossing that maintains ecological connectivity over the long term has a cross-section area, slope, and streambed similar to that of the upstream channel and does not disrupt the natural channel pattern.

B. A minimum diameter (or equivalent for non-round shapes) of 6 feet is recommended for culverts designed for fish passage. This recommendation is based on constructability concerns for culverts smaller than the recommended minimum size. Where site conditions preclude installation of culverts less than the recommended minimum, smaller culverts may be utilized upon mutual agreement.

C. For Tier 2 and Tier 3 culverts at least one-fifth of the diameter or 18 inches, whichever is less, of each circular culvert or at least 12 inches of the height of each elliptical or arch type culvert should be embedded and backfilled with substrate, at both the inlet and outlet of the culvert, below the natural channel thalweg.

(*NOTE: This embedment guideline may not be met in all cases. Routinely depressing the culvert invert generally increases barrel roughness tail water depth, and provides greater likelihood that, over time, downstream channel degradation will not result in a perched culvert.)*

D. Generally, culvert boundary roughness is a necessity for successful fish passage. For typical Tier 1 culverts with constructed streambanks within the culvert barrel boundary roughness is provided from the constructed streambed and banks up to the fish passage design discharge. For culvert installations without constructed streambanks, corrugated steel structural plate pipes with 6-inch by 2-inch corrugations or corrugated structural aluminum plate pipes with 9-inch by 2.5-inch corrugations are recommended. Spiral (helical) and smooth-wall culverts are discouraged for installations without constructed streambanks, except at low gradient sites (<0.5%) due to their low Manning's n values. Turbulence in the fish-swimming zone near culvert walls with shallow depth corrugations has been observed to negatively impact passage of juvenile salmonids. Larger depth corrugations also create turbulence; however, field observations suggest the width of the low velocity zone immediately adjacent to the culvert wall with larger depth corrugations is adequate to provide a free passage zone outside the negative influence of turbulence.

E. The erosion potential of streambed material at culvert outlets should be evaluated. Appropriate treatments such as rip-rap aprons, energy dissipation pools, grade control structures or other suitable countermeasures may be necessary to avoid outlet perching. Impact-type energy dissipation structures generally are not conducive to fish passage and should not be used unless they can be designed to provide fish passage.

F. Low flow channels or forcing features constructed within the substrate (within the culvert and associated inlet/outlet treatments) will typically be necessary. Forcing features (rock bands/clusters, habitat rocks, barbs/spurs, etc.) have been observed to enhance hydraulic conditions for fish passage, maintain low flow channel durability and bedform diversity within culvert barrels.

The design of the low flow channel should approximate the depth and velocity of the natural stream. A "V" shaped thalweg section is particularly suitable for streams with very low flow periods. If the dimensions can't be directly observed from a reference reach, the low flow channel's cross-sectional area should be 15-30% of the bankfull cross-sectional area. A typical minimum low flow channel section depth of four inches (measured below the horizontal bottom chord of an approximate trapezoidal channel section) is recommended. (See Figure 1).

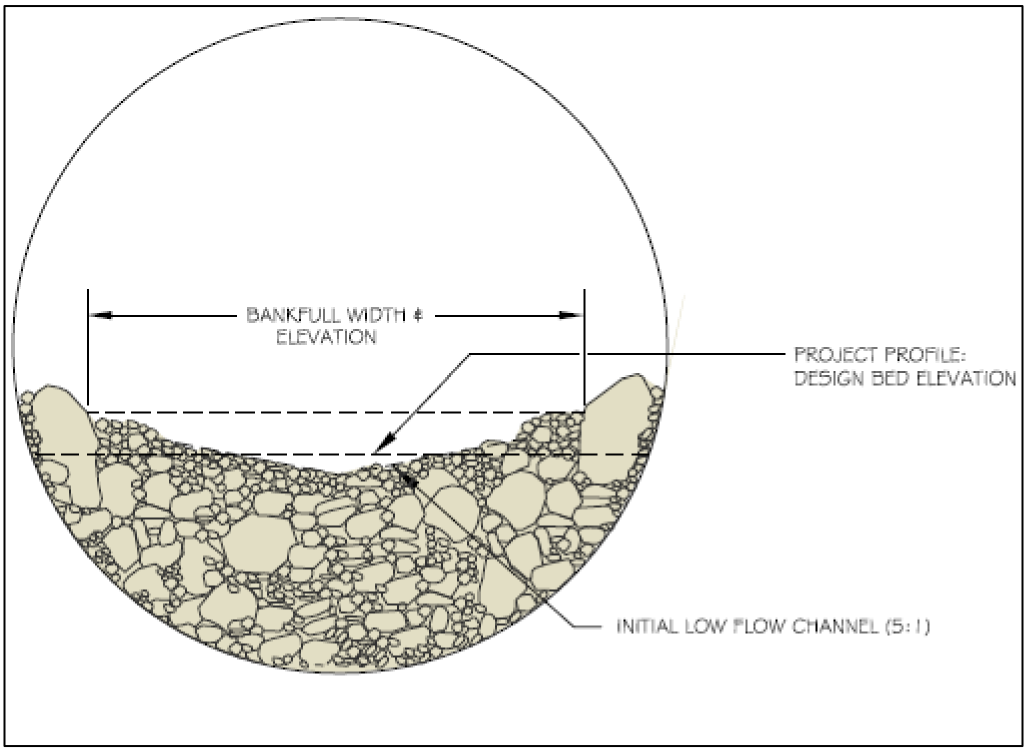

Figure 1. Low Flow Channel [USFS Stream Simulation Guide, 2008]

G. The gradation of the substrate material within a fish passage culvert shall be designed to be a dense, well-graded mixture with adequate fines to ensure that the majority of the stream flows on the surface and the minimum water depth is maintained during ordinary flow conditions.

H. Culverts with alignments skewed to the direction of flow entering the culvert should be avoided or the skew angle minimized, to the extent practicable. If the culvert is significantly skewed, hydraulic analysis of the inlet hydraulic conditions and barrel boundary layer velocity distributions may be necessary to ensure that fish passage conditions are provided. Alternately, stream realignment into/out of the proposed culvert could be considered or a wider and/or shorter culvert could be proposed to accommodate the skewed channel (see USFS Section 6.1.1.2).

I. To minimize upstream and downstream channel changes (e.g., head cutting), and the need for additional treatments, culverts generally should be horizontally and vertically aligned with the natural stream, to the extent practicable. (*See specific limitations for culverts designed using the Tier 1 – Stream Simulation approach*.) VAP should be considered in vertical alignment.

J. Where feasible, flood relief culverts should be considered to convey the floodplain discharge during greater than bankfull flow conditions. The goal is to minimize floodplain discharge through the fish passage culvert. *(Note: ensure spacing of multiple culverts does not result in the culvert battery meeting the definition of a bridge.)*

K. Culverts should be installed during low flow periods whenever possible. Where significant flow is present, generally acceptable techniques to isolate the construction site from stream flow include, but are not limited to, channel bypasses, temporary flumes, sheet pile or sandbag walls, water filled cofferdams, or pumping the stream flow around the work site. An Aquatic Resources Permit, issued by ADF&G Sport Fish Division may be required to ensure trapped fish are relocated during culvert installation.

L. Installation of trash racks or debris interceptors should be avoided unless they can be designed and maintained to have minimal effect on water and sediment discharge through the culvert, as well as fish passage.

M. Potential changes in watershed land use and/or climate change, that could affect the fish passage design discharge or channel geomorphology during the design life of the structure, should be considered when designing a culvert.

N. Vertical jumping height maxima of 1 foot for adult salmonids and 6 inches for juvenile salmonids are recommended. Jump pool depth must be at least 1.5 times the jump height or at least 2 feet deep to account for resting requirements of salmonid species. Jumping height is applicable to Tier 2 and Tier 3 designs.

O. These fish passage design criteria do not replace or supersede, the *Alaska Highway Drainage Manual*, *Alaska Highway Preconstruction Manual*, or other relevant design criteria. Both hydraulic design requirements and fish passage criteria, where applicable, must be satisfied.

Section 4. Fish Passage Design Discharge

Fish Passage Design Discharge (Q_{fish}) represents the upper bound of discharge at which fish are assumed to be moving within the stream. Q_{fish} is the estimated discharge below which fish passage will be accommodated in the hydraulic structure being designed. Q_{fish} will be lower than the design discharge for the culvert. Q_{fish} is primarily intended for use in Tier 2 and Tier 3 culvert design analyses.

- **DOT&PF's Regional Hydraulic Engineer or qualified hydraulics engineer serving as a project consultant** is responsible for developing the hydrologic estimates for the fish passage design discharge using one of the methods listed below. For ungaged watersheds, ADF&G biologists or others may have local site knowledge that would assist DOT&PF in making this determination.

- **ADF&G Habitat Section** is responsible for identifying fish-bearing waters, including type of stream (841, 871, or non-fish-bearing) and primary species present. Where applicable, ADF&G may also be responsible for identifying fish species and fish length(s) to be used for culvert design, the time of year fish passage may not be impeded, anadromous spawning locations, high-value rearing sites, and, establishing in-water work windows, as necessary.

Current formulas and models for estimating discharges for annual instantaneous peak or daily mean discharge exceedance probabilities (recurrence intervals) are based on statistical analysis of rainfall, runoff records, and/or other drainage basin parameters. These estimates are DOT&PF's best statistical estimate of discharges and have varying degrees of error. The expected magnitude of this variation can be determined, if necessary, for some discharge estimation techniques, as part of the hydrologic design procedure.

A low flow fish passage discharge has not been specified. Many streams used by fish are intermittent or may cease flowing during drought or winter conditions. An assessment should be prepared evaluating the low flow characteristics of the proposed culvert designs.

DOT&PF is encouraged to consult with ADF&G to incorporate site-specific information on design fish species & life stage, timing, and adjacent habitat information when estimating the fish passage design discharge.

Federal, state, and municipal policies directing DOT&PF's hydrologic analysis are outlined in the *Alaska Highway Drainage Manual* and the *Alaska Highway Preconstruction Manual*.

Two techniques are presented for estimating the site-specific fish passage design discharge (Q_{fish}): 1. based on the annual exceedance percentage of daily mean discharges; and 2. based on a ratio of the Q_2 annual instantaneous peak discharge. The culvert designer should select the Q_{fish} with the most supporting hydrologic data for the site.

1. <u>Daily Mean Discharge Exceedance Estimate:</u>

    - For culvert locations with access to spawning habitat Q_{fish} = the estimated daily mean discharge with an annual exceedance probability of 2%.
    - For culvert locations with access to non-spawning habitat Q_{fish} = the estimated daily mean discharge with an annual exceedance probability of 5%.

    Few locations in Alaska have adequate stream gaging records for estimating daily mean discharge annual exceedance probabilities. Regression equations are available for daily mean discharge annual exceedance discharge estimates by region within Alaska (USGS Water Resources Investigation Report 03-4114).

2. <u>Ratio of Q_2 Annual Peak Discharge Estimate:</u>

    - $Q_{fish} = 0.4 \times Q_2$ annual peak discharge

    Q_{fish} is estimated as 0.4 times the instantaneous annual peak Q_2 discharge (50% AEP). The Q_2 discharge may be determined using either a Log Pearson Type III analysis, regression equation or other hydrologic methods in the *Alaska Highway Drainage Manual*.

    At locations where adequate channel geometry is available (cross section information or average width/depth, channel slope, and roughness factor), and the channel is in equilibrium, the OHW or bankfull discharge may be estimated using Manning's Equation and substituted for the Q_2 discharge in the equation above.

Section 5. Fish Habitat Permit Application Procedures

Typical DOT&PF fish passage culvert replacement projects will go through at least two pre-application phases of coordination/consultation with ADF&G Habitat: 1.) Agency coordination during the project's Environmental process; and 2.) project design development. During the agency coordination phase DOT&PF will consult with ADF&G to determine fish presence at locations with potential culvert work. During the project design phase DOT&PF will typically consult with ADF&G on proposed fish passage culvert design concepts prior to submittal of Fish Habitat Permit application(s).

Joint site visits are encouraged in all phases of the pre-application coordination. This can be especially beneficial during the agency coordination phase to facilitate discussion. Assessments can be made of the quality and quantity of habitat, site constraints that may affect design and other factors that relate to the project. While site visits are encouraged, they may not be practicable on some projects due to remote locations, funding, schedule or other factors.

Coordination between ADF&G and DOT&PF staff during the design phase, prior to a formal application being submitted, is strongly recommended. When practicable, joint site visits to review draft plans are also encouraged. It is easier and less costly for DOT&PF to revise and modify plans while they are still in preliminary design. Optimally, all permitting details of the proposed design(s) should be resolved before a permit application is submitted to ADF&G.

Application for an ADF&G Fish Habitat Permit for a fish passage culvert structure will describe the proposed culvert installation including estimated construction sequence, timing and duration. For Tier 2 and Tier 3 designs (See Section 3), an application will also include a fish passage analysis for the design fish at the fish passage design discharge (Q_{fish} – See Section 4), and an evaluation of low flow fish passage characteristics.

A standard application form is not required for DOT&PF installations. However, a written description from DOT&PF is required for each individual culvert crossing (overflow and flood relief culverts adjacent to a fish passage culvert do not need a separate application). The application should contain the information identified in Table A-2 below. The amount of information required is directly linked to the specific design tier used. Tier 1 designs require less site-specific information than Tier 2 or 3.

Table A-2. ADF&G Fish Habitat Permit Application Information Requirements For DOT&PF Culvert Installations in Fish Bearing Waters

<u>Tier 1 Culvert Design</u>

1. Name of waterbody	2. Project location (Lat/Long coordinates)
3. Anadromous Waters Catalog and Fish Passage Site Number (if applicable)	4. Culvert material type and dimensions, including corrugation width and depth
5. Channel slope	6. OHW or bankfull channel width
7. Proposed culvert invert slope	8. Assessment of vertical adjustment profile
9. Culvert invert embedment depth	10. Fish passage design discharge (Q_{fish})
11. Description of natural stream substrate and proposed culvert invert substrate	12. Assessment/analysis of culvert substrate stability
13. Low flow evaluation	14. Reference reach location
15. Description of inlet and outlet scour protection (if used)	16. Estimated construction sequence, timing and duration

<u>Tier 2 Culvert Design</u>

1. Name of waterbody	2. Project location (Lat/Long coordinates)
3. Anadromous Waters Catalog and Fish Passage Site Number (if applicable)	4. Culvert material type and dimensions, including corrugation width and depth
5. Channel slope	6. OHW or bankfull channel width
7. Proposed culvert invert slope	8. Assessment of vertical adjustment profile
9. Culvert invert embedment depth	10. Fish passage design discharge (Q_{fish})
11. Description of natural stream substrate and proposed culvert invert substrate	12. Assessment/analysis of culvert substrate stability
13. Low flow evaluation	14. Reference reach location
15. Description of inlet and outlet scour protection (if used)	16. Estimated construction sequence, timing and duration
17. Fish species, size, and time of year (supplied by ADF&G)	18. Baffle details if used (type, spacing, height, top angle, slots, etc.)
19. Jumping height (if any) if tailwater control is required	20. Tailwater water surface elevation at Q_{fish}
21. Summary of fish passage analysis	

<u>Tier 3 Culvert Design</u>

1. Information required for Tier 2 design	2. Summary of hydraulic analyses supporting fish passage

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EXHIBIT B
Definitions

841-Stream requires fish passage in all fish bearing waterbodies, both resident and anadromous. (AS 16.05.841).

871-Stream is a cataloged anadromous fish stream specified under AS 16.05.871(a) and adopted by reference under 5 AAC 95.010(a).

Annual Exceedance Probability (AEP) is the probability that a of an event (flood) occurring in any year. Also see Recurrence Interval.

Annual instantaneous peak discharge is the maximum instantaneous streamflow value recorded or estimated at/for a particular site for the entire water year from October 1 to September 30.

Aufeis is an ice feature formed by water overflowing onto a surface such as river ice or gravel deposits, and freezing, with subsequent layers formed by water overflowing onto the ice surface itself and freezing.

Baffles are panels of concrete, metal or other material mounted in a series on the floor and/or wall of a culvert to increase boundary roughness and thereby reduce the average water velocity in the culvert.

Bankfull discharge is the discharge corresponding to the water surface elevation at which the floodplain of a particular stream reach begins to be flooded. The bankfull discharge is a morphological indicator that is related to the formation, maintenance, and dimensions of a stream channel as it exists under modern climatic conditions. The bankfull discharge, on average, has a flood frequency of approximately 1.5-years on the annual series. However, this frequency can vary widely depending on the particular watershed and stream reach characteristics. Bankfull discharge in one reach of a stream is rarely the same in adjacent reaches.

Bankfull width is the average of at least 3 measurements between bankfull indicator marks across the stream, collected outside of the influence of constructed features, where practicable. Upon agreement, alternate methods may be used for estimating bankfull width at locations where bankfull indicators are not applicable, not available and/or not representative of the current flow regime.

Boundary roughness is a measure of the irregularity of channel bed and banks, and/or culvert invert and sides, as they contribute to resistance to flow. For open channel flow this is commonly quantified using Manning's roughness coefficient.

Channel is a natural or artificial waterway of perceptible extent that periodically or continuously contains moving water. It has a definite bank and bed that serves to confine the water.

Daily mean discharge is the average discharge for an entire day, from midnight, local time to midnight local time.

Design discharge is used to size/design hydraulic structures. It is an estimate of a peak discharge with a specific annual exceedance probability (e.g 1% probability of occurrence in any given year).

Dynamic stability means that substrate material mobilized at higher flows will be replaced by bed material from the channel upstream of the crossing. From HEC-26: *dynamic stability means that channel dimensions, slope and planform do not change radically even though they adjust to changing inputs of water, sediment and debris. Dynamically stable channel features will fluctuate around a mean value but will stay within the predicted VAP lines.* (FHWA, 2010).

Embedment depth is the depth the culvert invert is buried into the streambed measured below the stream thalweg. Post construction channel adjustments should be considered in the embedment depth.

Fish passage design discharge (Q_{fish}) is the estimated discharge below which fish passage will be accommodated in the hydraulic structure being designed.

Forcing features are features constructed within the culvert barrel and associated erosion protection countermeasures to enhance hydraulic conditions for fish passage, maintain low flow channel durability and bedform diversity. Forcing features include rock/boulder clusters, rock/boulder bands, habitat rocks and rock barbs/spurs, among other designed features.

Grade control structure is a structure placed in a stream channel (generally with its central axis perpendicular to flow) to control bed elevation. Grade control structures can be used to control tailwater elevation and to prevent head-cutting.

Head-cutting is channel bottom erosion moving upstream through a basin and may indicate that a readjustment of the stream's flow regime (slope, hydraulic control, and/or sediment load characteristics) is taking place.

Invert is the flow line of the culvert (inside bottom).

Jumping height is the maximum vertical height that the design fish is required to jump to pass a barrier (tailwater/grade control structures, step pools, etc.). The jumping height for a design fish is a function of swimming speed and water depth.

Low flow channel is intended to provide fish passage during periods of low flow. Low flow channels are typically constructed in the substrate placed within the culvert barrel and associated erosion protection countermeasures (where installed).

Manning's Equation is an empirical formula devised by Manning for computing flow in open channels and pipes. Also called a "single section analysis".

$$Q = A*(1.486/n)R^{2/3} S^{1/2} \quad \text{[U.S. Units]}$$

Where:

Q = discharge (ft/s);
R = hydraulic radius or A/Wp (ft);
A = cross section area (ft^2);
n = Manning's Roughness Coefficient (see below);
WP = wetted perimeter (ft);
S = Hydraulic Gradient.

Manning's n is a coefficient of channel roughness, used in a Manning's Equation for estimating the capacity of a channel to convey water.

Migration is the deliberate movement of fish from one habitat to another. Includes the downstream movement of young anadromous fish from streams to sea; the upstream movement of adult anadromous fish from sea to freshwater spawning streams; the movement (upstream and downstream) of juvenile anadromous fish to rearing and over-winter habitats; and the movement (upstream and downstream) of resident fish to spawning, rearing and over-wintering habitats.

Modification is a change to the culvert structure that results in significant impact to the cross-sectional shape, conveyance, hydraulic roughness and/or structural stability.

Ordinary High Water (OHW) mark (per AS 41.17.950) means the mark along the bank or shore up to which the presence and action of the tidal or nontidal water are so common and usual, and so long continued in all ordinary years, as to leave a natural line impressed on the bank or shore and indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics.

OHW width is the average of at least 3 measurements between OHW marks across the stream, collected outside of the influence of constructed features, where practicable.

Recurrence interval is the average time between flood events. The return interval is equal to the inverse of the Annual Exceedance Probability (e.g. 1% AEP = 1/0.01 = 100yr recurrence interval).

Reference reach is a portion of a stream that represents a stable channel (dimension, pattern, profile) within the geomorphic context that exists in that segment and can represent a natural or a stable, modified condition (USFS 2008). Where practicable, the reference reach should be outside any anthropogenic influence, including the existing/nearby drainage structure(s). A reference reach should be a minimum 20 times the reference OHW/bankfull width and no less than 200 feet in length for creeks less than 10 feet in OHW/bankfull width. A reference reach should also include a minimum of 4 stable grade control features, where practicable.

Routine culvert maintenance activities are minor repairs to the culvert and/or associated appurtenances and are not covered by this agreement. See the definition of “modification” above to differentiate between typical maintenance activities and modification. Typical maintenance activities include but are not limited to: clearing of debris from in and around the culvert; repair or replacement of marker posts; repair or replacement of thaw pipe/wire; repair or removal of culvert end sections; repair or placement of culvert scour countermeasures. A Fish Habitat permit may be required for typical culvert maintenance activities in fish bearing waters, as determined by ADF&G.

Speed is the time rate of motion divided by the time required to travel that distance. This differs from velocity because the distance is measured along the path taken, not the straight-line distance between the beginning and end point.

Substrate is a mixture of granular material placed within the culvert barrel invert to mimic the natural streambed material.

Substrate Retention Sills are plates of metal, concrete or other material welded or bolted into a culvert with a height of no more than one half of the invert embedment depth. Retention sills are intended to hold substrate in place in culverts. Retention sills should not protrude into the flow (USFS 2008).

Swimming speeds of fish vary from essentially zero to over six meters per second, depending upon species, size, and activity. Three categories of performance are generally recognized:

> **Cruising speed** is the speed a fish can maintain for an extended period of travel without fatigue. Metabolic activity in this mode is aerobic and utilizes only red muscle tissues.
>
> **Sustained (prolonged) speed** is the speed that a fish can maintain for a prolonged period, but which ultimately results in fatigue. Metabolic activity in this mode is mixed anaerobic and aerobic and utilizes some white muscle tissue and possibly red muscle tissues.
>
> **Burst (darting) speed** is the speed a fish can maintain for a very short period, generally 5 to 7 seconds, without gross variation in performance. Burst speed is employed for feeding, escape, and negotiating difficult hydraulic situations, and represents maximum swimming speed. Metabolic activity in this mode is strictly anaerobic and utilizes all of the white muscle tissues.

Thalweg is the line connecting the lowest points where water flows along a channel streambed and is the flow path during very low flows.

Velocity is the time rate of motion between two points. This differs from speed because it is the straight-line distance between two points, not the actual path taken, divided by the time required to travel between the two points.

Mean culvert cross-sectional velocity ($V_{Q/A}$) is the discharge divided by the Cross-sectional area of the flow. Usually termed "average velocity".

Mean column culvert velocity is the average velocity measured on an imaginary vertical line at any point within a culvert. A velocity measurement at 60% of the depth, measured from the surface, closely approximates the average velocity for the water column. In water greater than 76 cm (30 inches) in depth, the average of measurements made at 20% and 80% of the depth approximates the mean column velocity.

Maximum culvert velocity (V_{max}) is the highest velocity encountered in all cross-sectional profiles in a culvert.

V-occupied culvert velocity (V_{occ}) is the water velocity in the locations within a culvert where fish are actually swimming as opposed to a mean cross-sectional velocity or the maximum velocity.

Fish swimming velocity (V_{fw}) is the velocity of a swimming fish with respect to the ground. It is the summation of the V-occupied velocity and the forward rate of movement of the fish through the water.

Vertical Adjustment Potential (VAP) are elevation lines between which the streambed might vary over the service life of the structure. Vertical adjustment profile is typically estimated from the longitudinal profile of thalweg elevations collected upstream and downstream of the proposed structure crossing location. See figure below.

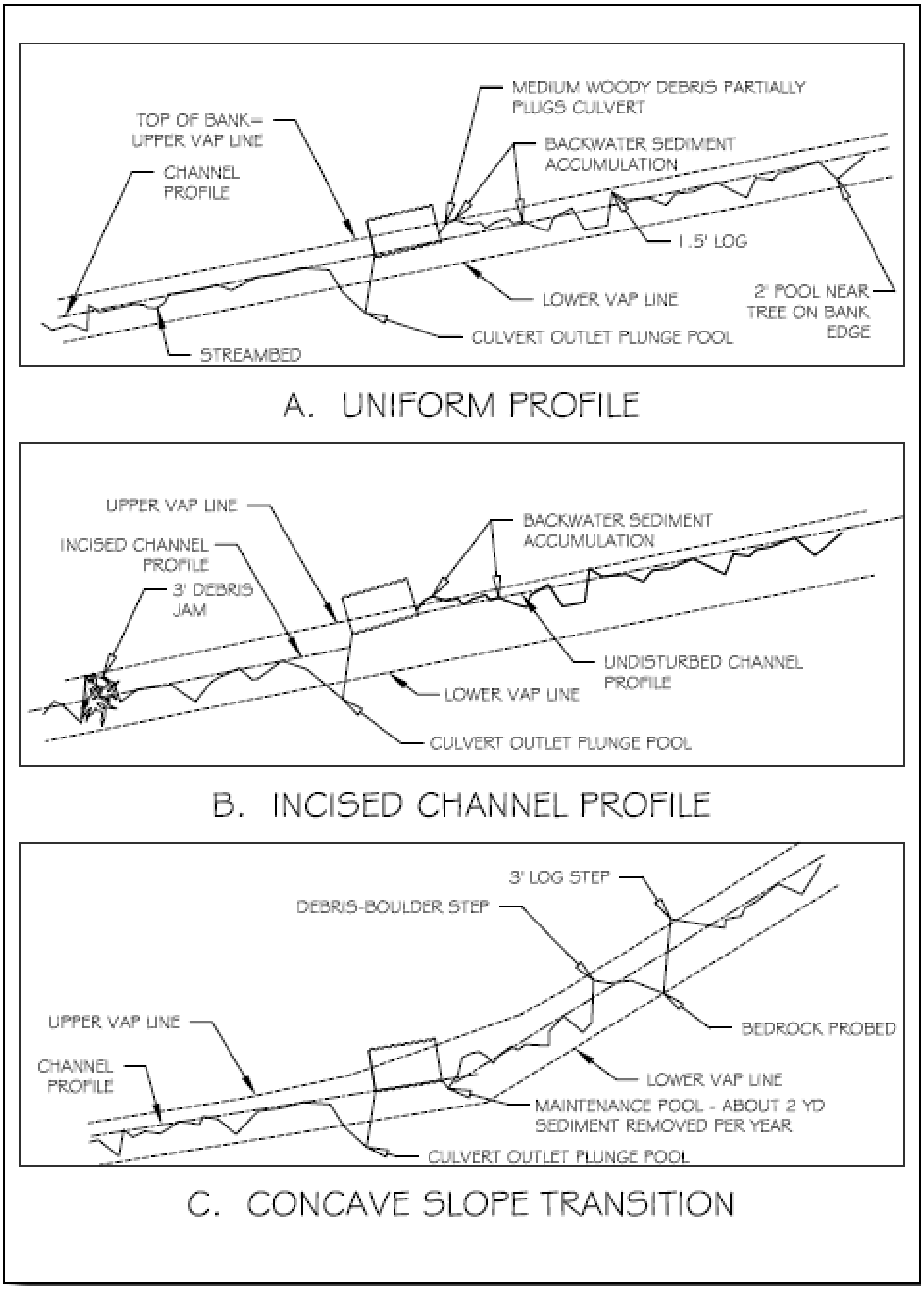

Figure 2. Vertical Adjustment Potential [USFS Stream Simulation Guide, 2008]

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EXHIBIT C
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