Fishery Data Series No. 14-45

Fish Passage Assessment of Culverted Road Crossings in King Salmon, Naknek, and Dillingham: 2012-2013

by

Gillian M. O'Doherty

December 2014

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 14-45

FISH PASSAGE ASSESSMENT OF CULVERTED ROAD CROSSINGS IN KING SALMON, NAKNEK, AND DILLINGHAM: 2012-2013

by

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ABSTRACT

Culverts in Dillingham, King Salmon, and Naknek, Alaska and on the surrounding road systems were assessed in 2012 and 2013 for fish passage using the Alaska Department of Fish and Game Level 1 assessment methodology. Twenty five culverts were located and assessed during the project, with 7 sites rated as believed to impact fish passage ("Red"), and an additional 11 rated as sites that may impact fish passage ("Gray"). The majority of culverts on fish bearing streams in this study area were found on the Dillingham road system. Recommendations for restoration are made primarily on the Dillingham road system, focusing on larger systems that are known to sustain spawning populations of fish.

Key words: fish passage, fish passage assessments, Dillingham, King Salmon, Naknek, culverts.

INTRODUCTION

GOAL

This project assessed culverted road-stream crossings in King Salmon, Naknek and Dillingham. All of the data collected—including physical measurements of the stream and crossing structure, photographs, and site maps are available online on the Alaska Department of Fish and Game (ADF&G) *Lands and Waters, Fish Resource Monitor, Interactive Fish Passage Maps*, located at: http://extra.sf.adfg.state.ak.us/FishResourceMonitor/?mode=culv (accessed 04/14). The Fish Resource Monitor incorporates the culvert data set, the Anadromous Waters Catalog, the Alaska Freshwater Fish Inventory, as well as USGS base maps, aerial photos, roads, communities, and streams. The results of this project will be used to identify and carry out fish passage improvement projects.

BACKGROUND

The State of Alaska, Department of Fish and Game, Division of Sport Fish, Office of Research and Technical Services, Fish Passage Improvement Program was created and charged with assessing 100% of the state-owned roads in 2000. Since that time ADF&G has also assessed crossings on borough, municipality, private, and federal roads, and on Alaska Railroad properties (O'Doherty 2010). Accurately assessing and cataloging stream crossings is essential to good fisheries management. Salmon and other fish use different habitat throughout the year, and allowing fish unobstructed access to that habitat is critical to helping maintain a healthy fish population. Properly designed bridges and culverts can have little or no adverse effect on fish, aquatic organisms, and other riverine animals, but when a culvert is too small, too steep, or set too high above the stream grade, it obstructs fish movement and access to habitat above the crossing.

In this project we assessed culverted crossings. Culverts are used more frequently than bridges to cross small to mid-sized streams and are more likely to create a barrier to fish passage. Some culverts create a barrier immediately upon installation due to steep gradients or a perched outlet that fish cannot navigate. Others initially pass fish, but are improperly sized or are not maintained frequently, and become barriers over time.

Anadromous fish such as Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and sockeye salmon (*O. nerka*) spend up to 2 years in fresh water as juveniles and commonly migrate within drainages to exploit riverine and wetland habitats for rearing and over-wintering (Bramblett et al. 2002; Healy 1980; Peterson 1982; Sommer et al. 2001). Resident species spend their entire lifecycle in freshwater and must also migrate between habitats to spawn, feed, and overwinter. Culverts are more likely to have a negative effect on the movements of fish with limited swimming and leaping abilities (such as juvenile salmonids or sticklebaclk) and on species such as coho salmon that rely on small tributary streams for spawning and rearing habitat (Beechie et al. 1994; Mueller et al. 2008).

The rivers and lakes of Southwest Alaska support some of North America's most viable and productive salmon fisheries. Salmon migration, spawning, rearing, and ultimately production in these water bodies is dependent on sufficient connectivity within watersheds. The results of this project will be used to identify and carry out fish passage improvement projects and to restore connectivity.

The maintenance of fish resources and habitats in Alaska is a shared responsibility of state and federal resource agencies. These agencies must ensure, among other things, that existing stream crossing structures along Alaska's road system are compatible with the needs of our valuable aquatic resources. Improperly designed, installed, or maintained stream crossings can exclude fish from freshwater habitat, the loss of which is often considered a central factor in the decline of wild fish stocks throughout the range of Pacific salmon (Beechie et al. 1994; Nehlsen 1997).

STUDY OBJECTIVES

There were 3 objectives of this:

1. inventory and assess all stream crossings on the road networks from Dillingham to Wood-Tikchik and King Salmon to Naknek for culverted fish passage,
2. publish data on the ADF&G Fish Passage Interactive Mapper at http://gis.sf.adfg.state.ak.us/FlexMaps/fishresourcemonitor.html,
3. produce an ADF&G Technical Report that contains assessment data and identifies a subset of high priority projects.

METHODS

STUDY AREA

King Salmon, Naknek, and Dillingham are remote communities that together contain the majority of roads within the Bristol Bay Borough in Southwestern Alaska. Approximately 374 people live in King Salmon and 2,329 in Dillingham (U.S. Census Bureau 2010). King Salmon and Naknek are connected by road and are located approximately 25 km apart on the north bank of the Naknek River (Figure 1). Dillingham is isolated and is located on Nushagak Bay at the outlet of the Nushagak River (Figure 1). The area surrounding both communities is largely undeveloped.

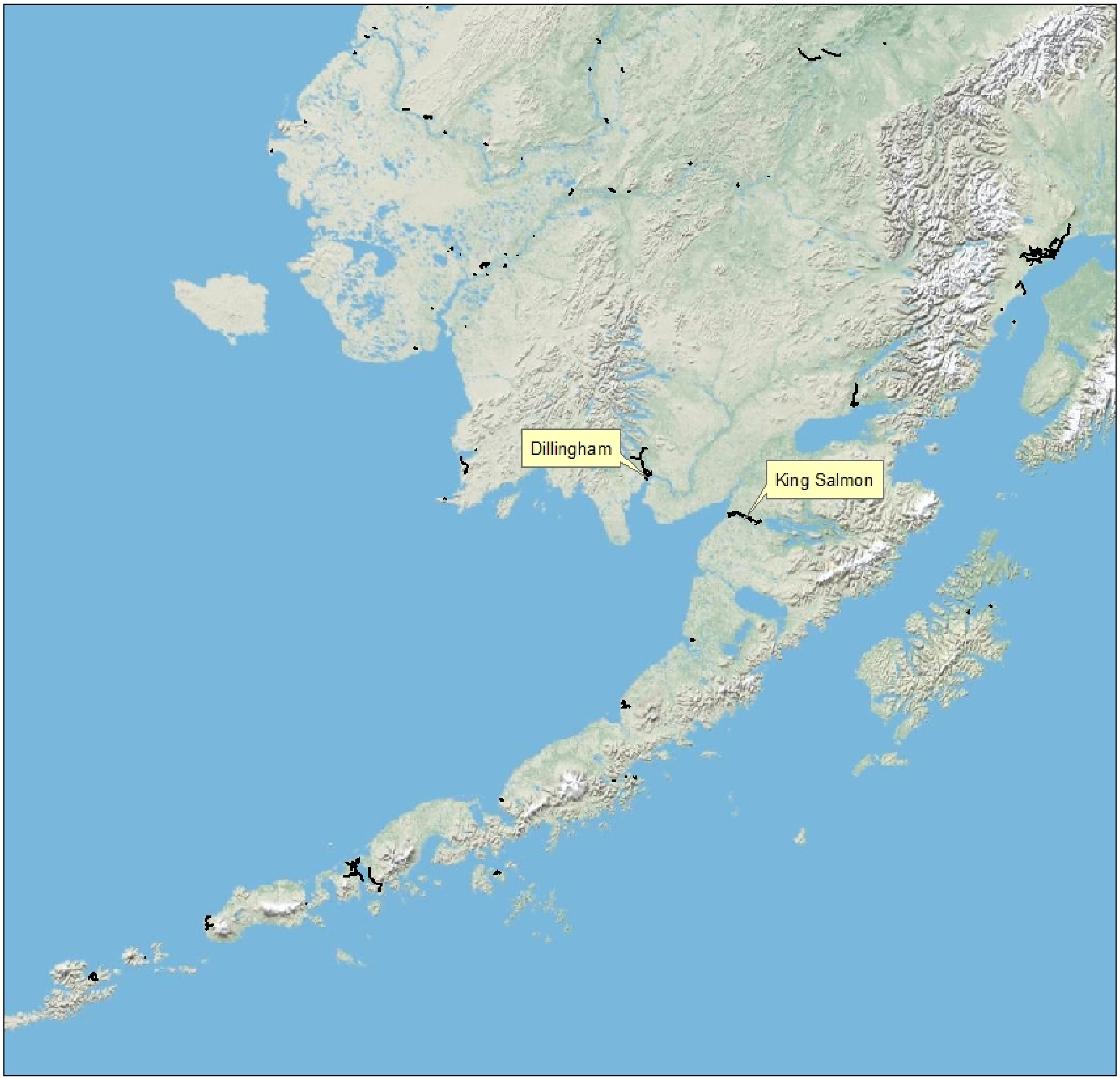

Figure 1.–Map of southwestern Alaska showing the location and extent of road systems originating in Dillingham and King Salmon.

Before the field season began, culvert locations were predicted using GIS analysis of the area. A state roads layer was overlaid on the National Hydrography Dataset (NHD) layer, and where the two intersected possible locations were expected. There are many errors in the NHD in the study area, and during the study, all roads in the study area were driven for their entire length, and some additional culverts were located visually. In the King Salmon-Naknek study area, the NHD was found to significantly overestimate the number of perennial streams present. In addition to predicting the total number of road crossings, the number occurring on known anadromous water bodies was predicted using the Anadromous Waters Catalog (AWC).

ADF&G performed a desktop evaluation of potential road crossings to prioritize remote communities for assessment. After considering total road miles, number of stream, and AWC stream crossings, the different villages of Southwest Alaska were compared to existing assessments from other areas of the state (Table 1). Dillingham and King Salmon were selected for initial assessment, as they contain as many road miles and more potential stream crossings than all other considered villages combined.

Table 1.–Estimated road miles and stream crossings by road network for communities in western and southwestern Alaska.

Area	Road Length (miles)	AWC Catalog Crossings	Stream Crossings (NHD dataset)
Dillingham	75	7	35
King Salmon	78	4	22
Newhalen	31	3	13
Port Heiden	25	0	3
McGrath	24	0	4
Bethel	40	2	11
Kotzebue	22	0	9
Kwethluk	6	0	1

FISH PASSAGE RATING OVERVIEW

To rate sites for fish passage, ADF&G follows a standardized method that was developed through coordination with other state and federal agencies specifically for use in Alaska called the Level 1 Fish Passage Matrix. This is designed to rapidly rate sites over a large geographic area. Culverts are categorized by type and size and rated for fish passage using the gradient, outfall height, and constriction ratio compared to a decision matrix (Table 2; O'Doherty 2010). The following ratings are used:

- Green: no effects on fish passage;
- Red: crossing assumed to be inadequate for fish passage;
- Gray: crossing may be inadequate for fish passage;
- Black: could not be rated.

The decision matrix uses the best available information to predict the ability of a young-of-the-year juvenile coho salmon (55 mm) to pass through a variety of culvert types. A 55 cm coho salmon was chosen as the model fish as they are believed to be the weakest swimming juvenile salmonid, and, therefore, culverts that are passable by 55 cm coho salmon should be passable by other juvenile salmonids.

Where structures were damaged, or there were other factors affecting fish passage, those factors are also taken into account when assigning ratings. For example, if a culvert is damaged to the point that fish cannot swim through, it will be rated Red.

Table 2.–ADF&G Level 1 Fish Passage Matrix.

	Structure Type	Green	Gray	Red
1	Bottomless pipe arch, embedded pipe arch, CMP, box culvert, or other embedded structure that functions in a similar fashion	Installed at channel **gradient** (+/- 1% slope), AND **constriction ratio** greater than or equal to 0.75, OR fully backwatered	Structure not installed at channel gradient (+/- 1%), OR **constriction ratio** of 0.5 to 0.75	**Constriction ratio** less than 0.5
2	Culverts (all span widths) with 2 x 6 inch corrugations or greater, not embedded	Culvert **gradient** less than 1.0%, AND outfall height = 0, AND **constriction ratio** greater than 0.75, OR fully backwatered	Culvert **gradient** 1.0 to 2.0%, OR less than or equal to 4-inch **outfall hgt**., OR **constriction ratio** of 0.5 to 0.75	Culvert **gradient** greater than 2.0%, OR **outfall height** greater than 4 inches, OR **constriction ratio** less than 0.5
3	Pipe arch or circular CMP (span width greater than 4 feet), less than 2 x 6 inch corrugations, not embedded	Culvert **gradient** less than 0.5%, AND outfall height = 0, AND **constriction ratio** greater than 0.75, OR fully backwatered	Culvert **gradient** 0.5 to 2.0%, OR less than or equal to 4-inch **outfall hgt**., OR **constriction ratio** of 0.5 to 0.75	Culvert **gradient** greater than 2.0%, OR **outfall height** greater than 4 inches, OR **constriction ratio** less than 0.5
4	Pipe arch or circular CMP (span width less than or equal to 4 feet), less than 2 x 6 inch corrugations, not embedded	Culvert **gradient** less than 0.5%, AND **outfall height** = 0, AND **constriction ratio** greater than 0.75 OR fully backwatered	Culvert **gradient** 0.5 to 1.0%, OR less than or equal to 4-inch **outfall hgt**., OR **constriction ratio** of 0.5 to 0.75	Culvert **gradient** greater than 1.0%, OR **outfall height** greater than 4 inches, OR **constriction ratio** less than 0.5.
5	Non-embedded box culverts, culverts with non-standard configurations or materials, culverts with baffles or downstream weirs, or step pools, fish ladders, bridges with aprons	Fully backwatered as described below	All others	**Outfall height** at downstream end of structure greater than 4 inches
6	Multiple structure installations	Individual culverts all classified as Green as above	Individual culverts all classified as Gray or as some mix of Green, Gray, or Red as above	Individual culverts all classified as Red as above

Notes:

1. These criteria are not design standards but rather indicate whether the structure is likely to provide fish passage for juvenile salmonids based on a one-time evaluation.
2. Ordinary high water (OHW) is the mean stream width measured either upstream or downstream of the culvert beyond the hydraulic influence of the culvert.
3. An embedded culvert must have 100% bedload coverage. Circular and box culverts must be embedded at least 20% of their height. A pipe-arch must be embedded so that the mean bedload depth is greater than or equal to the vertical distance from the bottom of the pipe to the point of maximum horizontal dimension of the culvert (haunch height) or is 1 foot deep, whichever is greater.
4. A culvert is considered backwatered if one of the following conditions is met: 1) elevation of the tailwater control exceeds the elevation of the invert at both the outlet and inlet of the culvert and the invert of any aprons or other inlet or outlet structures; 2) the culvert is located in a pond, slough, or other area with slow moving or still water, the tallwater and headwaters surface are equivalent, and water surface is continuous throughout the entire structure and at least 0.1 feet in depth at the shallowest point. Culvert gradient, span to OHW ratio, and outfall height criteria are not considered in the assessment of fish passage in backwatered culverts. A culvert is not backwatered if a hydraulic jump occurs within the barrel.
5. Outfall height is the difference between the water surface elevation at the outlet and in the outlet pool (or the equivalent tailwater surface).

Site Selection and Naming

Prior to beginning fieldwork all known and potential road-stream crossing locations were identified and mapped using ArcGIS®. The National Hydrography Dataset (NHD) was overlaid on the most up to date road layer available, and all places where the two intersected were marked as potential crossing locations. These locations were downloaded to a hand-held Garmin® GPS unit used to locate sites in the field. The survey crew also visually located and recorded additional stream crossings on public roads.

Once in the field only sites known or reasonably expected to be fish-bearing were included in the assessment project. Sites that were typically assumed to be non-fish bearing include ephemeral drainages that did not contain a defined channel, disconnected ponds, extremely steep channels, drainage swales, drainage ditches, cross drainage culverts, and other artificial water features. Crossings that are located above man-made barriers were treated as if the man-made barriers did not exist.

All surveys received a Survey ID, which identifies the project, the year, and the survey location and followed the previously used alphanumeric conventions for project name and location (e.g., MSB10PRK01, where MSB10 refers to the project and year, Mat-Su Borough 2010, and PRK01 refers to the road the survey was conducted on and survey number on that road, Parks Highway) (O'Doherty 2010). After fieldwork was completed each new survey was added to an existing Site ID, or, in the case of a previously unidentified culvert, a new Site ID was created in the Fish Passage Database for that survey (Figure 2).

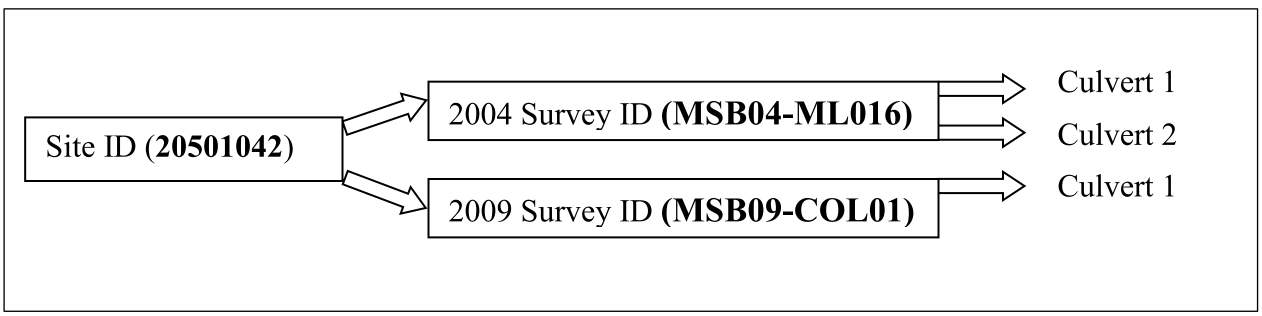

Figure 2.–Example of Site/Survey nomenclature for a Site with more than one survey.

Survey Protocol

A standard survey protocol was used to collect data on crossings throughout the project. A summary of the survey protocol is presented here; a detailed description can be found in *Culvert Inventory and Assessment Manual for Fish Passage in the State of Alaska: A Guide to the Procedures and Techniques used to Inventory and Assess Stream Crossings 2009-2014* (Eisenman and O'Doherty 2014).

Crossing and Survey Information

Information was collected on the location of each crossing (coordinates) as well as the date and time of the survey and the identities of the crew.

Description of the Crossing Structure

Information was collected on culvert length, dimensions, and shape, as well as the type of material used for construction. The type of inlet and outlet (projecting, mitered, or flared) was noted as was the presence of a headwall, wingwalls, or an apron. Where a crossing structure consisted of multiple culverts, each individual culvert was numbered according to its position sequentially from left to right as the observer faces downstream.

Each culvert outfall was categorized as either set at stream grade (AG), a free-fall into the outlet pool (F), a free-fall onto riprap (FR), a cascade over rip-rap (C), a fish passage structure (PS), smooth flow over an apron (SF), an overflow pipe (OP), or a hydraulic jump (HJ) at the time of survey. If an inlet or outlet apron existed, the construction material was noted and the length measured.

Where substrate inside the culvert is greater than approximately 0.5 feet deep, substrate depth was estimated by driving a steel rod of known length into the material and subtracting the height of the rod projecting above the substrate from the total length.

The condition of each culvert was ranked 1 through 5 according to the following definitions:

1. Defective, culvert is in dire need of prompt repair or replacement, flaws threaten to disrupt or are hindering traffic;
2. Poor, culvert is in need of repair and shows potential for further deterioration;
3. Fair, culvert is operational but may need maintenance to restore function to full potential, distinct rust line and/or abraded bottom present, adverse conditions could lead to major problems;
4. Good, culvert shows minor deficiencies, beginning of rust line formation may be visible; with continued maintenance should be trouble free;
5. Excellent, culvert shows no signs of problems or rust, could allow flow at full capacity without disrupting fish passage.

Embeddedness

Culverts that contained substrate were inspected to determine whether they were considered embedded by measuring the depth of the substrate at the inlet and outlet to the nearest 0.10 foot. For a culvert to be considered embedded the following conditions must be met:

- both inverts must be lower than the streambed elevation;
- the barrel must contain streambed material throughout its length;
- circular culverts must be buried at least 20 percent of their diameter or 1 foot, whichever is greater;
- pipe-arch culverts must be embedded so that the mean depth of the substrate within the pipe is equal to or greater than the vertical distance from the bottom of the culvert to the point of maximum horizontal dimension or 20 percent of the height, whichever is greater.

Longitudinal Profile

A longitudinal profile is a survey of the stream down the length of the thalweg; in this case the longitudinal profile encompassed the reach of the stream containing the culvert(s). The purpose was to collect relative elevations of the stream, water surface, and culvert structure in order to calculate water depth at outlet, outfall height, and pipe gradient. Occasionally when a longitudinal profile could not be carried out, the water depth at outlet and outfall heights were measured using had-held tape measures, and this was documented in the survey notes.

Stream Measurements

The average width of the stream at Ordinary High Water (OHW) above the culvert was measured along three straight runs or heads of riffles at locations upstream of any obvious influence of the crossing structure.

OHW is defined by the State of Alaska (AS 41.17.950) as:

A. In the non-tidal portion of a river, lake or stream: the portion of the bed(s) and banks up to which the presence and action of the non-tidal water is so common and usual, and so long continued in all ordinary years, as to leave a natural line or "mark" impressed on the bank or shore as indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics;

B. In a braided river, lake, or stream: the area delimited by the natural line or "mark," as defined in Part A above, impressed on the bank or shore of the outside margin of the most distant channels; or

C. In the tidally influenced portion of a river, lake, or stream: the portion of the bed(s) and banks below the

    a. OHW as described in A or B above, or
    b. mean high water elevation; whichever is higher at the project site.

All channel widths were measured perpendicular to stream flow and to the nearest 0.10 foot. If the upstream channel was a lake, wide slough, or braided channel, channel widths of the downstream channel was recorded instead. If both up and downstream water bodies were ponds, lakes or sloughs average width were not recorded.

The alignment of the inlet with the upstream channel was determined to the nearest one degree using a sighting compass. The approach angle was calculated by subtracting the back azimuth of the line looking downstream through the culvert from the azimuth of the channel looking upstream from the culvert inlet.

The dominant and subdominant substrate types, at both the inlet and outlet of the culvert and in the upstream and downstream channels outside of the culvert influence, were determined visually and recorded.

In 2011, it became standard protocol to measure the gradient of the stream. This was measured as the change in elevation of the water surface over a curvilinear distance of at least 10 times the OHW width. The stream gradient was calculated outside the influence of the culvert.

Site Observation Codes

Site Observation codes refer to circumstances that affect fish passage at a site. They indicate why a culvert is rated as Gray or Red and are also used to note problems that are not part of the Level 1 Fish Passage Matrix but potentially affect fish passage. These include poor alignment, significant sedimentation, beaver grates, deliberate blockage by means of a screen or grill, debris blockage, or various types of structural damage. The complete list of codes and definitions are in Appendix B.

Site Sketch

The site sketch includes the culvert and road, direction of flow, location of fish traps, and any significant features observed at the site.

Photographs.

A series of photographs were taken at each site with a digital camera. The order of photographs and a description of each are recorded in the survey notebook. At a minimum, photographs included the following views:

- site marker (the Site ID, road and date are written on a piece of paper and photographed at the site);
- view of the road surface at the crossing site;
- view from the culvert looking downstream at the tailcrest and beyond;
- view from below the tailcrest looking upstream from a distance that shows the culvert outlet, the culvert condition, and the road embankment (this photograph should show channel roughness [substrate, debris, vegetation, etc.] and culvert outlet height above the tailwater);
- view from an upstream location (looking downstream) showing the culvert inlet type, its condition, and the road embankment (this photograph should show channel roughness [substrate, debris, vegetation, etc.] and culvert inlet conditions);
- view from the culvert looking upstream;
- when possible, a photograph of typical stream substrate and other channel roughness elements upstream of the culvert's influence;
- additional photographs of conditions, if any, that may be negatively affecting fish passage (e.g., damage, debris, undesirable bedload deposition).

Calculating the Critical Values

Gradient

Culvert gradient was calculated as the difference in elevations between inlet invert and outlet invert divided by the length of the culvert and multiplied by 100. In the case of an embedded culvert, or a culvert with sediment at inlet and/or outlet, top of culvert elevations were used instead of invert elevations:

$$\frac{(Inlet\ elevation - Outlet\ elevation)}{Culvert\ lenth} * 100 = Pipe\ Gradient$$

During the project many structures were found to contain sections that were considerably steeper than the average. The gradient of these sections was calculated separately and was referred to as "maximum gradients" and used to rate the culvert. Maximum gradients were also calculated for aprons where they were significantly steeper than the culvert itself and may have impeded fish passage. If a maximum gradient was used it would be noted in the comments for that site.

Outfall height

Outfall height was calculated from longitudinal survey elevation data and is the distance from the water surface at outlet (OWS) to the outlet pool surface or tailwater surface (TWS).

$$OH = OWS - TWS$$

The outfall height for a freefall into pool outfall type is the outlet water surface elevation subtracted from the outlet pool surface elevation (Figure 3).

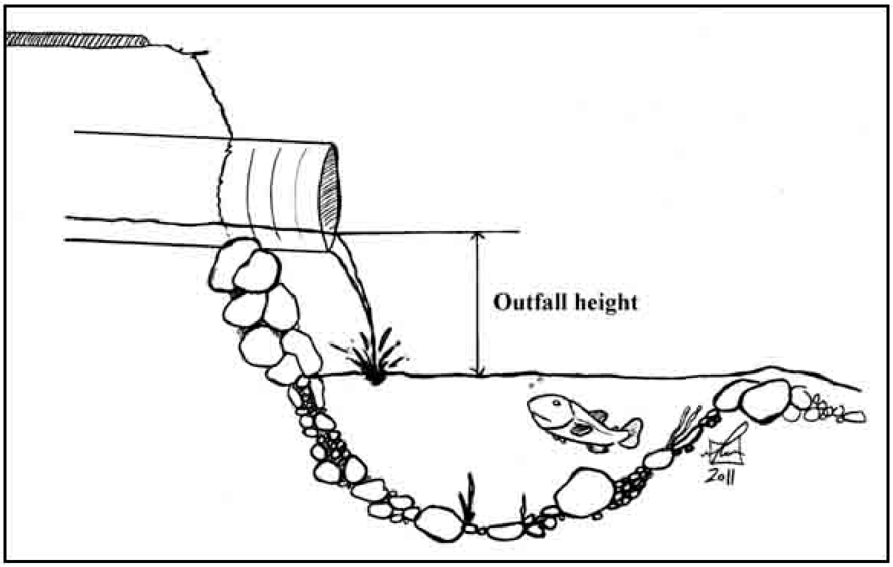

Figure 3.–Illustration showing where outfall height is measured on a freefall into pool outfall type.

Constriction Ratio

The constriction ratio for one culvert was calculated as the culvert width (CW) divided by the average channel width at OHW.

(CW/OHW):1

DATA MANAGEMENT AND QUALITY CONTROL

Data were collected on paper data sheets and entered into the fish passage database throughout the field season. At the end of the field season, all data were printed out and compared to the original field sheets manually by two project staff in order to catch data entry errors. Then a series of automated data checks was used to identify any outlying values or inconsistent entries, such as sites with a high outfall that were not rated as Red. Locations of sites were checked individually using GIS, and photographs and comments were reviewed for accuracy at each site by two project personnel. Where site locations were inconsistent with the mapped locations of creeks and roads, it was found that the mapped locations of creeks and roads were typically in error and therefore sites were not "snapped" to existing GIS features. Instead, locations are accurately represented on the mapper and the coordinates in the database are those collected at the site at the time of survey.

RESULTS

Twenty-five (25) crossings were located and assessed during this study (Figures 4 and 5). All but 2 crossings were located in the Dillingham area. This is believed to represent all culverted crossings of fish bearing streams on public roads in both communities.

SITE LOCATIONS AND DISTRIBUTION

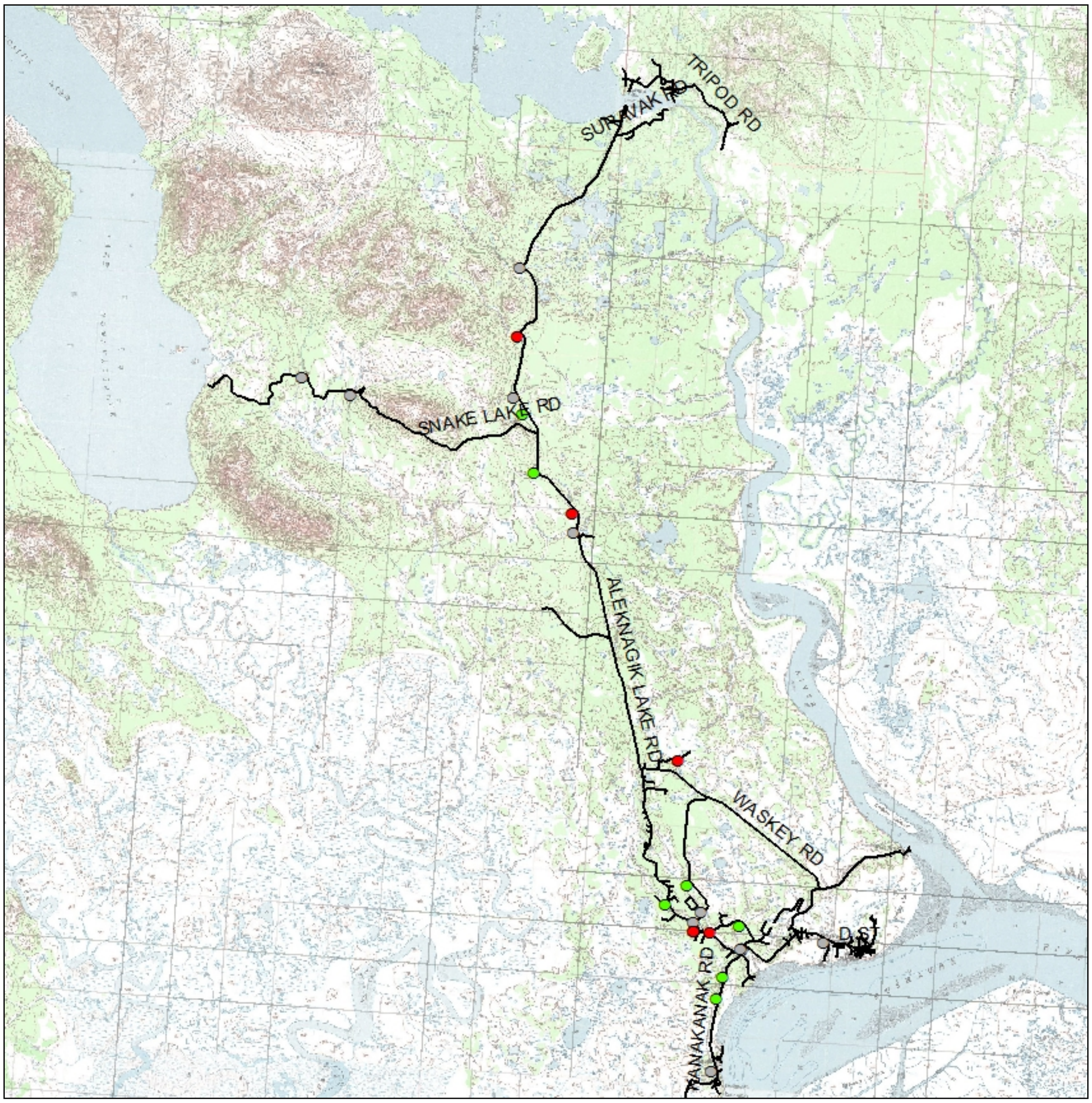

Figure 4.–Location of culverted road crossings assessed in 2012 in the Dillingham area. The color of the sites represents their assessed status.

Figure 5.–Location of sites on the Naknek-King Salmon road system in 2013. The color of the sites represents their assessed status.

Table 3 shows the number of sites by road, and Table 4 shows the sites by stream.

Table 3.–Locations and number of road crossing sites assessed for fish passage in the Dillingham and King Salmon-Naknek areas in 2012 and 2013, organized by road.

Road Name	No. of Sites
Aleknagik Lake Road	9
Kanakanak Road	5
Alaska Peninsula Highway	2
Emperor Way	2
Lupine Drive	1
Nerha Drive	1
New Landfill Road	1
Snake Lake Road	2
Wihdeon Road	1
Y Junction	1

Table 4.–Locations and number of road crossing sites assessed for fish passage in the Dillingham and King Salmon-Naknek areas in 2012 and 2013, organized by stream.

Stream Name	No. of Sites
Squaw Creek	5
Wood River tributary	4
Snake River tributary	2
Nushagak River tributary	2
Belt Creek tributary	2
Unnamed	1
Squaw Creek South Fork	1
Silver Salmon Creek	1
Eskimo Creek	1
Squaw Creek tributary	1
Scandinavian Creek	1
Unnamed Creek	1
Squaw Creek Middle Fork	1
Squaw Creek Middle Fork tributary	1
Belt Creek	1

FISH PASSAGE RATINGS

All sites were rated using the three Critical Values in the ADF&G Level 1 Fish Passage Matrix (Table 2). Outfall heights and gradients were measured at virtually all sites, but the constriction ratio was only measured at sites where it was possible to determine a standard ordinary high water width, meaning that culverts connecting, for example, two sloughs or an artificial channel to a lake are not represented in the data. Of the 25 sites assessed for fish passage, 7 (28%) were rated as Red, 11 (44%) were rated as Gray, and 7 (28%) were rated as Green (Table 5). The distribution of those sites by road and stream is shown in Tables 6 and 7.

Table 5.–All road crossing sites assessed for fish passage in the Dillingham and King Salmon-Naknek areas in 2012 and 2013, organized by assessment rating.

Rating	Sites	%
Red	7	28
Gray	11	44
Green	7	28
Total	25	100

Table 6.–All road crossing sites assessed for fish passage in the Dillingham and King Salmon-Naknek areas in 2012 and 2013, organized by road and assessment rating.

Road	Sites
Aleknagik Lake Road	
Gray	3
Green	3
Red	3
Kanakanak Road	
Gray	3
Green	2
Snake Lake Road	
Gray	2
Emperor Way	
Green	2
Alaska Peninsula Highway	
Red	2
Wihdeon Road	
Gray	1
Y Junction	
Gray	1
Nerha Drive	
Gray	1
New Landfill Road	
Red	1
Lupine Drive	
Red	1
Total	25

Table 7.–All road crossing sites assessed for fish passage in the Dillingham and King Salmon-Naknek areas in 2012 and 2013, organized by stream and assessment rating.

Creek Name	Sites
Belt Creek	
Gray	1
Belt Creek tributary	
Green	1
Red	1
Eskimo Creek	
Red	1
Nushagak River tributary	
Gray	1
Green	1
Scandinavian Creek	
Gray	1
Silver Salmon Creek	
Gray	1
Snake River tributary	
Gray	2
Squaw Creek	
Gray	3
Green	1
Red	1
Squaw Creek Middle Fork	
Gray	1
Squaw Creek Middle Fork tributary	
Green	1
Squaw Creek South Fork	
Red	1
Squaw Creek tributary	
Green	1
Unnamed Creek	
Green	1
Red	1
Wood River tributary	
Gray	1
Green	1
Red	2
Total	25

The most common factors affecting fish passage were poor alignment, damage or structural problems, overly steep gradient, and constriction due to undersized culverts (constriction ratio; Table 8). Perched culverts were rare. Beaver activity itself does not typically affect fish passage but beaver grates frequently do. Culvert condition was mostly average, but 10 culverts were rated as defective or poor (Appendix A).

Table 8.–A summary of the factors affecting fish passage by site in Dillingham and Naknek areas, 2012-2013.

Factors affecting fish passage	Sites	%
Poor alignment	8	32%
Beaver Activity	7	28%
Gradient Gray	6	24%
Constriction ratio Gray	5	20%
Mechanical or structural problem incl. parted joints	5	20%
Gradient Red	4	16%
Compound gradient	4	16%
Inlet Perch	4	16%
Outfall height Red	3	12%
Hydraulic capacity inadequate	3	12%
Culvert is too short	3	12%
Road Eroding	2	8%
Improper Bedding	1	4%
Culvert sagging in middle	1	4%
Ice damage	1	4%

CULVERT TYPES AND DIMENSIONS:

Most culverted stream crossings were located on relatively small streams. The average width of streams surveyed during this project was 7.2 feet, and of the 28 culverts measured at 25 sites, the average width of the inlets was 7.08 feet (Figure 6). As three sites were comprised of multiple culverts, the average constriction ratio was 1.15 meaning that, on average, culverts in the area were as wide or wider than the streams they contained and that constriction of streams was far less of a problem than in other similar studies (O'Doherty and Eisenman *In prep*).

The average length was 74 feet (Figure 7). Most crossings were comprised of a single culvert.

Four sites (16%) were recorded as backwatered at time of survey. None of the sites had fish passage baffles installed or constructed step pools. Four sites were noted as being tidally influenced.

Stream flow was recorded at all 25 sites, and the flows were visually estimated as medium for 14 (56%) of the surveys and high for 11 (44%).

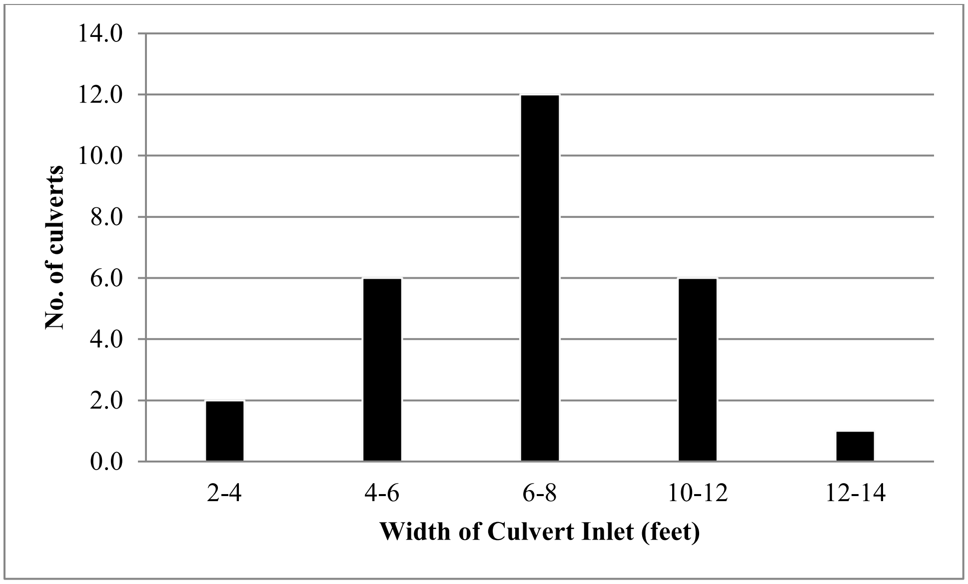

Figure 6.–Distribution of inlet widths of culverts in Dillingham and Naknek areas, 2012-2013.

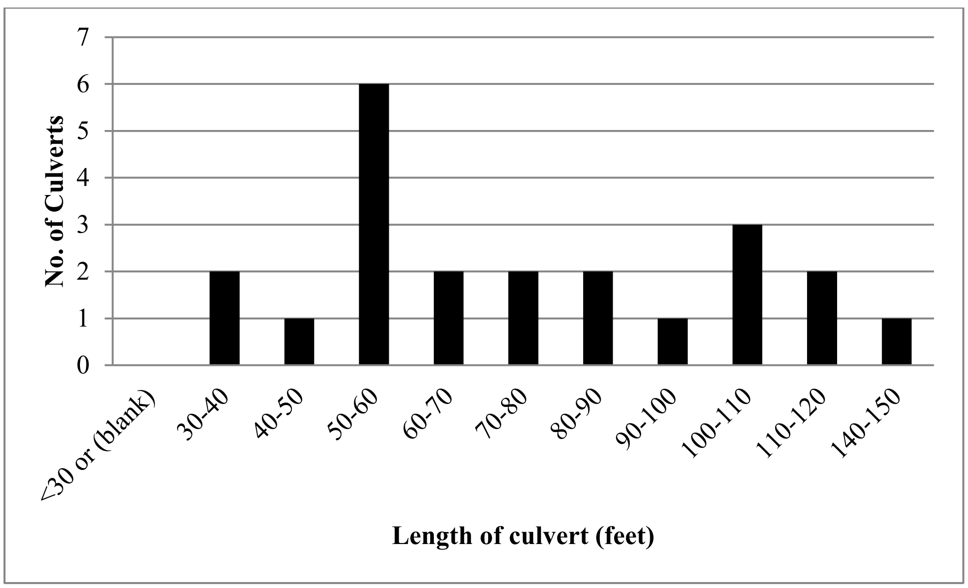

Figure 7.–Distribution of culvert lengths of culverts in Dillingham and Naknek areas, 2012-2013.

EMBEDDEDNESS

None of the culverts were recorded as being embedded under the ADF&G definition, although many did contain sediment throughout and were clearly intended to be embedded upon installation. Because of this the ratings may overestimate the severity of barriers, particularly in the Dillingham area.

DISCUSSION

The results indicate that passage of juvenile salmonids and other weak-swimming fish is less impacted on the two studied road systems than in other similar studies (O'Doherty 2010; O'Doherty and Eisenman *In prep*). Total permanent barriers to adult anadromous fish movement were not encountered in either study area, although beaver grates, beaver dams, and other temporary obstructions were encountered on both anadromous and non-anadromous systems.In Dillingham there were several culverts that were rated as Gray or Red, though if they were slightly larger or more fully embedded they would likely have received a Green or Gray rating. This particularly applies to culverts located on Squaw Creek and the Aleknagik Lake Road.

RECOMMENDATIONS

RESTORATION RECOMMENDATIONS

Four high-priority sites were identified in Dillingham based on the severity of the barrier and the amount of potential fish habitat. Other Red and Gray culverts are located on small systems with limited habitat and potential for anadromy. Road ownership is both state and local.

Site #30303067 and Site #30303068 are both located on unnamed creeks on Snake Lake Road. Both of these crossings consist of undersized culverts with high water velocities and associated scour and channel impacts. Site #30303068 is on AWC stream 325-20-10030-2024-3100, and is cataloged for coho salmon rearing. Site #30303067 is on a large unmapped stream that appears to be a tributary to AWC stream 325-20-10030-2024-3100.

Figure 8.–Site #30303067 showing undersized culverts on a tributary to the Snake River, Dillingham.

Figure 9.–Site #30303068, an undersized culvert on an unnamed Snake River tributary, Dillingham.

Site #30303073 is Squaw Creek at Lupine Drive. Squaw Creek is catalogued to support Chinook, coho, pink, chum and Sockeye salmon. This culvert was installed in 1999 as part of a United State Fish and Wildlife Service (USFWS) funded fish passage project but has been damaged by frost heave. It is almost certainly a total barrier to juvenile fish and is a partial barrier to adult fish.

Figure 10.–Site #30303073 Squaw Creek at Lupine Road, Dillingham showing frost heave that has raised the inlet of the culvert several feet causing ponding upstream and a fish passage barrier inside the culvert.

Site #30303078 is the South Fork of Squaw Creek at Aleknagik Lake Road. At the time of survey this culvert was blocked by a chain-link fence, presumably to prevent beavers blocking the culvert.

Figure 11.–Site #30303078 showing a chainlink fence preventing fish passage on the South Fork of Squaw Creek, Dillingham.

A single high-priority project was identified in King Salmon. Site #30203269 is Eskimo Creek at the Alaska Peninsula Highway. This pipe is undersized and perched. This was the sole barrier on a stream of any significant size located in the King Salmon-Nakenk area. There are believed to be culverts on military land, but crews were not able to access them for assessment.

Figure 12.–Site #30203269 Eskimo Creek and the Alaska Peninsula Highway, King Salmon.

In addition to the specific projects discussed in this section, we recommend that fish passage replacement projects be

1. considered as part of all road upgrades and incorporated wherever possible;

2. concentrated within watersheds for maximum benefit; in practice this may mean replacing one or more lower-priority culverts concurrently with a high-priority culvert in order to improve fish passage throughout the watershed.

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REFERENCES CITED

Beechie, T., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration. North American Journal of Fisheries Management. 14(4): 797-811.

Bramblett, R. G., M. D. Bryant, B. E. Wright, and R. G. White. 2002. Seasonal use of small tributary and main-stem habitats by juvenile steelhead, coho salmon, and Dolly Varden, in a southeastern Alaska drainage basin. Transactions of the American Fisheries Society 131(3): 498-506.

Eisenman, M. E., and G. O'Doherty. 2014. Culvert inventory and assessment manual for fish passage in the State of Alaska: A guide to the procedures and techniques used to inventory and assess stream crossings 2009-2014. Alaska Department of Fish and Game, Special Publication 14-08, Anchorage

Healy, M. C. 1980. Utilization of the Nanaimo river estuary by juvenile Chinook salmon (*Oncorhynchus Tshawytscha*). Fishery Bulletin 77(3): 653-658.

Mueller, R. P., S. S. Southard, C. W. May, W. H. Pearson, and V. I. Cullinan. 2008. Juvenile coho salmon leaping ability and behavior in an experimental culvert test bed. Transactions of the North American Fisheries Society 137(4): 941-950.

Nehlsen, W. 1997. Pacific salmon status and trends–a coastwide perspective. Pages 41-50 [*In*] D. J. Stouder, P. A. Bisson, R. J. Naiman, and M. G. Duke, editors. Pacific salmon and their ecosystems: status and future options. Chapman & Hall, New York.

O'Doherty, G. 2010. ADF&G fish passage program: summary of existing inventory and assessment data and gap analysis, September 2009. Alaska Department of Fish and Game, Special Publication No. 10-17, Anchorage.

O'Doherty, G., and M. Eisenman. *In prep*. Fish passage at culverts in the Mat-Su Borough, Alaska. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Peterson, N. P. 1982. Immigration of juvenile coho salmon (*Oncorhynchus kitsutch*) into riverine ponds. Canadian Journal of Fisheries and Aquatic Sciences 39(9): 1308-1310.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58(2): 325-333.

U.S. Census Bureau. 2010. Profile of General Population and Housing Characteristics: 2010. http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml (Accessed April 4, 2014).

APPENDIX A: SUMMARY OF SITE DATA

Appendix A.–Summary of site information. Additional data and site photographs are available online on the Fish Resource Monitor located at: http://extra.sf.adfg.state.ak.us/FishResourceMonitor/?mode=culv

Site ID	Creek Name	Road Name	Rating	Stream Width	Construction Year	Stream Gradient	Condition Rating	Site Observations
30203269	Eskimo Creek	Alaska Peninsula Highway	Red	10.97			3	Outfall height red, Inlet perch, Beaver Activity
30203270	Unnamed Creek	Alaska Peninsula Highway	Red	1.63			2	Culvert gradient red, Mechanical damage or joints parting, Structural Problem, Culvert sagging in middle.
30303063	Silver Salmon Creek	Aleknagik Lake Road	Gray	14.3		0.96	3	Constriction ratio gray, Culvert is too short, Road bank erosion.
30303064	Wood River tributary	Aleknagik Lake Road	Red	15.3			3	Culvert gradient red, Constriction ratio gray, Road bank erosion, Culvert is too short, Culvert is poorly aligned.
30303065	Wood River tributary	Aleknagik Lake Road	Gray	7.26		3.63	3	Culvert gradient gray, Culvert is poorly aligned.
30303066	Wood River tributary	Aleknagik Lake Road	Green	5.93			3	
30303067	Snake River tributary	Snake Lake Road	Gray	12.55			3	Constriction ratio gray.
30303068	Snake River tributary	Snake Lake Road	Gray				2	Culvert gradient gray, Constriction ratio gray, Inlet perch, Beaver Activity.
30303069	Belt Creek tributary	Aleknagik Lake Road	Green	4.6		1.25	3	Culvert is poorly aligned.
30303070	Belt Creek tributary	Aleknagik Lake Road	Red	4.6		0.56	3	Outfall height red, Culvert gradient gray, Beaver Activity.
30303071	Belt Creek	Aleknagik Lake Road	Gray	5.3		0.64	3	Culvert gradient gray, Culvert is poorly aligned.
30303072	Squaw Creek tributary	Emperor Way	Green	6.33	1999	0.08	4	
30303073	Squaw Creek	Lupine Drive	Red	11.1	1999		1	Culvert gradient gray, Inlet perch, Mechanical damage or joints parting, Improper bedding, Damage associated with ice problems.

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Appendix A.–Page 2 of 2.

Site ID	Creek Name	Road Name	Rating	Stream Width	Construction Year	Stream Gradient	Condition Rating	Site Observations
30303074	Squaw Creek	Nerha Drive	Gray	6.4	1999	1.13	4	Beaver Activity, Hydraulic flows exceeded capacity
30303075	Squaw Creek Middle Fork	Wihdeon Road	Gray	8.78	1999	0	5	Beaver Activity, Culvert is poorly aligned.
30303076	Squaw Creek Middle Fork tributary	Emperor Way	Green	4.07		1.27	3	Culvert gradient gray, Mechanical damage or joints parting.
30303077	Squaw Creek	Aleknagik Lake Road	Green	7.4		0.52	4	
30303078	Squaw Creek South Fork	Aleknagik Lake Road	Red	5.23		1.6	2	Culvert gradient red, Compound gradient in pipe, Inlet perch, Culvert is poorly aligned.
30303079	Wood River tributary	New Landfill Road	Red	1.7			3	Outfall height red, Culvert gradient red, Culvert is poorly aligned.
30303080	Scandinavian Creek	Kanakanak Road	Gray	4.67			1	
30303081	Nushagak River tributary	Kanakanak Road	Gray	7.3			1	Compound gradient in pipe, Constriction ratio gray.
30303082	Nushagak River tributary	Kanakanak Road	Green	6			2	Compound gradient in pipe, Beaver Activity, Hydraulic flows exceeded capacity, Structural Problem, Culvert is too short.
30303083	Unnamed	Kanakanak Road	Green				1	Beaver Activity, Hydraulic flows exceeded capacity.
30303084	Squaw Creek	Kanakanak Road	Gray				1	
30303085	Squaw Creek	Y Junction	Gray					

APPENDIX B: DEFINITIONS OF SITE OBSERVATIONS AND LIST OF CODES

Critical Values

OHG	Outfall Height Gray – Culvert with an outfall greater than zero and less than 4 inches receive this code.
OHR	Outfall Height Red – Culverts with an outfall over 4 inches receive this code.
GRDG	Culvert Gradient Gray – Depending on structure class the culvert slope, determined from the longitudinal profile, will be used to assess if the culvert has a gray gradient (Table 2).
GRDR	Culvert Gradient Red – Depending on structure class the culvert slope, determined from the longitudinal profile, will be used to assess if the culvert has a red gradient (Table 2).
CRG	Constriction Ratio Gray – Sites determined to have a constriction ratio between 0.5 and .75 will be labels CRG.
CRR	Constriction Ratio Red – Any site determined to have a constriction ratio under 0.5 will receive this code.

Other site codes – These codes are visually-observed codes.

AL	Alignment – Culvert is poorly aligned. This code is used for culverts that have an approach angle over 45 degrees or where the alignment is causing erosion, debris clogging or other observed problems.
BV	Beaver Activity – Sites that show signs of being influenced by beaver activity. This can refer to dams upstream and downstream of the culvert(s) or culverts plugged by beavers.
CG	Compound Gradient – Any culvert that has a noticeable change in the gradient (a gradient break) within the crossing structure.
CS	Cut-Slope Sliding into Culvert – This code refers to the cut slope of the road sliding into the stream channel or culvert.
DF	Debris Flow – This code is used when a site shows signs of a large amount of debris and/or sediment movement at the site, typically the culverts will be partially filled with debris.
EC	Hydraulic Flows Exceed Capacity – This code is used when the culvert(s) are visually observed to be undersized for the stream size at the site. Examples include culverts that are more than half full at medium stream flows, culverts that are entirely submerged or any location where it's possible to observe that the stream regularly overtops the culverts.
IAS	Inlet Apron too Steep –an apron, bolted on metal or concrete, has a gradient steeper than the culvert.
IB	Improper Bedding – The substrate underneath the culvert was not installed properly. Examples include the culvert sinking in wetland areas, bowing down in the center or having up or rocks being forced up through the culvert from thaw/freezing actions.

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IC	Damage associated with icing problems. Typical ice damage is inverts being bent upward, pressure damage in the barrel of the culvert, and other invert damage.
IP	Inlet Perch – sediment or debris creates a perch at the inlet so that the stream drops down into the culvert at the inlet. Typically associated with undersized culverts that have upstream ponding at higher flows.
MP	Mechanical Damage or Parting Joints – This code is used if a culvert shows signs of damage or sections coming apart.
MT	Material Inadequate for Designed Use – This is code is used if the culvert at a crossing is obviously not suited for the site. Examples are plastic or smooth concrete culverts on salmon streams and steel culverts used in a tidal zone.-
OAS	Outlet Apron too steep – This code is used like IAS code only at the outlet.
OT	Other – This is a catch all code used to describe some other issue that is not covered in any of the other codes. Examples have included sinkholes in the road, water diversion dams in the outlet pool and culverts that have been deliberately blocked to keep livestock in. If this code is used, it should be explained in the notes section.
RD	Road Bank Erosion – This code is used if the road bank is eroding around the culvert. This can be caused by the stream eroding the road prism or run off from the road.
RF	Road Fill – This code is used if road fill is being pushed off the road prism by grading and substrate is filling the culvert.
SD	Sediment Accumulation – If the culvert or some part of the crossing structure is causing sediment accumulation in the upstream channel, typically observed where an undersized structure causes ponding at high flows.
SF	Shallow Fill Above Culvert – This code is used if there is not enough road fill over the top of the culvert(s). There should be a minimum of twelve to eighteen inches of fill over most culverts. Insufficient fill can result in the culvert collapsing from heavy loads being driven over it.
SG	Culvert Sagging – This code is used if there is a visible sagging of the culvert inside the barrel. These sags are usually caused by insufficient fill or improper bedding and are more common on longer culverts.
SS	Subsidence – This code is used when a culvert has started to sink or the roadbed is sinking at the crossing.
ST	Structural Problem – This code is used when the culvert(s) have some other structural issue or damage such as headwalls failing or scoured footers.
TS	Too Short – This code is used when the culvert is too short for the road prism. Culverts that are too short do not extend past the end of the road bank and can cause road bank erosion.
WD	Woody Debris – This code is used when there are large amounts of wood debris plugging the culvert or causing other problems at the crossing site.
NO	None of this type – If a culvert crossing has no site codes associated with it this code is entered to show that no one of the above conditions exist at the site.