PROTOCOL
FOR
MONITORING EFFECTIVENESS
OF
FISH PASSAGE PROJECTS
(Culverts, Bridges, Fishways, Logjams, Dam Removal, Debris Removal)

MC-1

Washington Salmon Recovery Funding Board

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Lewis County Public Works; Lambert Creek Barrier Removal Project (#01-1219)
Worksite: #1, Lambert Creek Barrier Removal
06/05/2002, Image #2, Culvert outfall

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ACKNOWLEDGMENTS

ORGANIZATION

Fish passage improvements are the most popular kind of habitat restoration project. They have accounted for 35% of all SRFB projects and 36% of the funding. They have the greatest potential to create dramatic improvements in fish production in a very short time (1-5 years). This document details the monitoring procedures and protocols necessary to document and report the reach scale effectiveness of these projects. Projects designed to restore instream passage treated in this protocol include:

- **Bridge projects**
- **Culvert improvements**
- **Dam removals**
- **Debris removals**
- **Diversion dam passage**
- **Fishway construction**
- **Weirs**
- **Water management projects**

This document is in compliance with the Washington Comprehensive Monitoring Strategy (Crawford et al. 2002)

The objective for fish passage projects is to increase access to areas blocked by human-caused impediments.

MONITORING GOAL

Determine whether fish passage projects are effective in restoring upstream passage to targeted species of salmon and trout.

QUESTIONS TO BE ANSWERED

Have the engineered fish passage projects continued to meet fish passage and design criteria post-project for at least five years?

Have fish passage projects as an aggregate demonstrated increased abundance of target species of salmonids post-project within five years?

NULL HYPOTHESIS

Removal or modification of the upstream fish passage barrier has had no effect upon:

- Increasing the linear distance available for salmon production (spawning areas and juvenile rearing areas) as measured by the passage design criteria.
- Increasing the overall abundance of juvenile salmon/steelhead per square meter.
- Increasing the overall abundance of adults per kilometer and/or the number of redds per kilometer will increase relative to the control sites downstream.

OBJECTIVES

BEFORE PROJECT OBJECTIVES (YEAR 0)

Project managers determine the proper design criteria for meeting the fish passage objectives for the project.

Determine salmon abundance both in the downstream control reach and impact reach upstream of the fish blockage for the sampled projects.

AFTER PROJECT OBJECTIVES (YEARS 1, 2, AND 5)

Determine whether fish passage design criteria are being met at each project monitored.

Determine salmon abundance both in the downstream control reach and impact reach upstream of the fish blockage for each project.

RESPONSE INDICATORS

Level 1-- Project design specifications are taken from construction blueprints or pre-project plan.
The SRFB requires that all passage projects consult with the Department of Fish and Wildlife and meet required design criteria. Project design criteria are submitted to the SRFB staff at the time project construction is proposed. The response indicator in this case will be the design criteria built into each sampled project. These criteria will normally follow "*Fish Passage Design at Road Culverts*" (Bates et al. 2003) or "*Draft Fishway Guidelines for Washington State*" (Bates and Wiley, 2000). Methods for monitoring the design criteria are found on page 11.

 Passage design criteria response variable

Indicator Abbreviation	Description
PASSDESIGN	Measure of whether passage design criteria are met - Yes/No

Level 3-- Numbers of adult and juvenile salmon in the reach.
Abundance of salmon can be determined using both adult spawner/redd counts and juvenile counts. Both adults and juveniles will be monitored using methods developed by Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife. Adult estimating procedures are found on page 22. Juvenile estimating procedures for electrofishing and snorkeling are described on pages 18 and 20. The least intrusive monitoring method should be used whenever possible. The impact reach will be

compared to the control reach and to controls and impacts on other streams as well. The metrics used will be numbers per square meter for juveniles and number per kilometer, or redds per kilometer, for adults depending upon the target species.

Fish abundance response variables (only one adult targeted species per project will be monitored; however, any species present will be included in the counts)

Indicator Abbreviation	Description
STRMLGTH	Affected stream length includes meander length affected by the project
CREACHLGTH	The length of the stream control reach actually sampled
CREACHWIDTH	The average stream width of the control reach actually sampled
IREACHLGTH	The length of the stream Impact reach actually sampled
IREACHWIDTH	The average stream width of the Impact reach actually sampled
CHINJV	Measure of juvenile chinook 0 and yearling abundance within the study reach
COHOJV	Measure of coho yearling abundance within the study reach
SHPARR	Measure of steelhead yearling abundance within the study reach
BULLADULT	Measure of bulltrout spawner abundance within the study reach
BULLREDD	Measure of bulltrout redd counts within the study reach
CHINADULT	Measure of chinook spawner abundance within the study reach
CHINREDD	Measure of chinook redd counts within the study reach
CHUMADULT	Measure of chum spawner abundance within the study reach
CHUMREDD	Measure of chum redd counts within the study reach
COHOADULT	Measure of coho spawner counts within the study reach
COHOREDD	Measure of coho redd counts within the study reach
PINKADULT	Measure of pink spawner counts within the study reach
PINKREDD	Measure of pinks redds within the study reach
SHADULT	Measure of steelhead spawner abundance with the study reach
SHREDD	Measure of steelhead redds within the study reach
SOCKADULT	Measure of sockeye spawner abundance within the study reach
SOCKREDD	Measure of sockeye redds within the study reach

MONITORING DESIGN

For all fish passage projects, the design outcome is to meet the approved project design criteria for fish passage. An appropriate sample taken from all fish passage projects should be tested for effectiveness in meeting design criteria.

It is desirable to also evaluate the effectiveness of projects in terms of improved fish presence or production upstream of the barrier. For any of the fish passage projects where restoring or improving upstream passage is the desire, one of two conditions exists.

Either:
- There are currently no salmon of the targeted species utilizing the area upstream of the barrier;
Or;
- The targeted species is present, but considered to be in reduced numbers due to the partial barrier.

The Board will employ a Before and After Control Impact (BACI) experimental design to test for changes associated with barrier removal (Stewart-Oaten et al. 1986). A BACI design samples the control and impact at both locations at designated times before and after the impact has occurred. For this type of restoration, barrier removal would be the impact, a location below the barrier would represent the control, and a location upstream of the barrier would represent the impact, that is, the location impacted by the project.

Each of the projects will utilize one impact reach (generally located immediately upstream of the proposed project) and a paired downstream control reach (generally located immediately downstream of the proposed project). In Year 0 (one year prior to barrier removal), "before" sampling of the project control and impact reaches must be completed. After the restoration project has been completed, the control and impact areas for each of the projects will be sampled for three years (Years 1, 2, and 5) for changes in the fish abundance indicators.

For fish abundance, the BACI design tests for changes upstream of the barrier removal *relative to* the abundance observed at the control reach downstream. This type of design is required when external factors (e.g., ocean conditions and harvesting) affect the population abundances at the control reach. The object is to determine whether the difference between upstream and downstream abundances have changed as a result of the removal project. The presence of multiple projects with control and impact locations will address the concerns detailed by Underwood (1994) regarding pseudoreplications. It is also not considered cost effective to employ multiple control locations for each passage project as recommended by Underwood. Although the ideal BACI would have multiple years of before data as well as after data, this was not possible with locally sponsored projects where there is a need and desire to complete their project as soon as possible.

A paired *t*-test will be used to test for differences between control (downstream) and impact (upstream) sites during the most recent impact year and Year 0. In other words, we first compute the difference between the control and impact and use those values in a paired *t*-test. This test assumes that differences between the control and impact reaches are only affected by barrier removal and that external influences affect population abundance in the same way at both the control and impact reaches. The paired sample *t*-test does not have the same assumptions for normality and equality of variances of the two-sample *t*-test but only requires that the differences are approximately normally distributed. In fact, the paired-sample test is really equivalent to a one-sample *t*-test for a difference from a specified mean value.

To implement the design, we will monitor 10 fish passage projects. The number of projects proposed for monitoring in each category is based upon the calculated sample size needed to obtain statistically significant trend information in the shortest amount of time. If there are insufficient projects funded in Rounds 4 and 5 to obtain a proper sample size, then replicates of the design will be used in multiple years until the critical sample size is reached.

The true variance associated with impact and control areas will not be known until sampling has occurred in Year 0 of both the impact and control reaches. After Year 0, a better estimate of the sample size needed to detect change will be available. Cost estimates and the number of sampling replicates may need to be adjusted at that time.

At the end of the effectiveness monitoring testing, there will be one year of "Before" information for all projects for both the control and impact reaches, and multiple years of "After" information for the same control and impact reaches for each of the projects.

Depending upon circumstances, the results may also be tested for significance, using a linear regression model of the data points for each of the years sampled and for each of the indicators tested.

Testing for significant trends can begin as early as Year 1. Final sampling may be completed as early as 2009 but other projects will take longer to complete.

DECISION CRITERIA

- Engineered design effective if fish passage and design criteria are met for 80% of the structures on Year 5 (i.e., no statistical test). Effective means that the project must have a percent passability greater than 80% to be rated as "Yes.",

- Fish passage effective if a statistically significant change is detected for salmon abundance of either adults, redds, or juveniles between the calculated difference (Impact minus Control (current) as compared to Impact minus Control (baseline)) by Year 5 at the Alpha = 0.10 level for those targeted salmon and trout species present. Additionally, the actual amount of change is compared to the baseline value in the impact reach to determine if the change is biologically significant. Twenty-percent change from the baseline was selected as a benchmark for biological significance.

Table 1. Decision criteria and statistical test type

Monitoring Level	Indicators	Metric	Test Type	Decision Criteria
Passage Structure	Passage design criteria met (PASSDESIGN)	Yes/No	Count of intact structures	≥ 80% of projects are Yes by Year 5 ≥ 80% of criteria measured are met for each project design
Juvenile Fish Abundance	Chinook juvenile abundance (CHINJUV)	#/m2	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Coho juvenile abundance (COHOJUV)	#/m2	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Steelhead juvenile abundance (SHJUV)	#/m2	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
Adult Fish Abundance (Note only one target species will be monitored for adults for each project)	Chinook redds (CHINREDD) or Chinook Spawner abundance (CHINADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Coho redds (COHOREDD) or coho spawner abundance (COHOADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Steelhead redds (SHREDD) or coho spawner abundance (SHADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Bulltrout redds (BULLREDD) or bulltrout spawner abundance (BULLADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Pink salmon redds (PINKREDD) or pink salmon spawner abundance (PINKADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Chum redds (CHUMREDD) or chum spawner abundance (CHUMADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5
	Sockeye redds (SOCKREDD) or sockeye spawner abundance (SOCKADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between impact and control by Year 5

POST-PROJECT DELIVERABLES

The monitoring entity will deliver to the SRFB on Years 1, 2, and 5:

- A completed copy of all monitoring data in the required format.
- A completed metadata form in the required format.
- Kilometers of stream available for salmon post project.
- Relative abundance of salmon per km.
- A statement as to whether Decision Criteria were met as an effective project.

SAMPLING

SELECTING SAMPLING REACHES

IMPACT REACH

Fish passage projects are often larger than other types of restoration projects and may not be measured in its entirety. One stream reach immediately upstream of the project in suitable spawning and rearing habitat will be identified and sampled according to identified methods for each of the projects. The assumption is that fish colonizing new habitat will colonize the area nearest the barrier first.

CONTROL REACH

A paired control reach immediately downstream of each project site should be selected in the same manner as the impact reach for each of the projects.

BEFORE PROJECT SAMPLING

All fish passage projects identified for long-term monitoring by the SRFB must have completed pre-project Year 0 monitoring prior to beginning the project.

Year 0 monitoring will consist of:

- Determining the linear distance in kilometers to the nearest tenth distance to be opened by the passage project.
- Determining the design criteria for the fish passage structure.
- Determining the abundance of adult and juvenile salmon in the impact and control areas.

AFTER PROJECT SAMPLING

Upon completion of the fish passage project, Years 1, 2, and 5 monitoring will:

- Determine whether the fish passage and design criteria are met for the fish passage structure.
- Determine the abundance of adult target species numbers or redds and juvenile salmon in the impact and control areas.

METHOD FOR DETERMINING EFFECTIVENESS OF PASSAGE PROJECT STRUCTURES

PURPOSE

This protocol should be used to determine whether the designed fish passage criteria are met post construction such that fish passage remains possible. The purpose is to determine whether an engineered solution to a fish passage problem remains viable for at least five years.

ENGINEERING CRITERIA

Effectiveness of passage under roadways and other projects associated with culvert improvements, bridge projects, debris removals, and dam removal projects should comply with engineering specifications detailed *in "Fish Passage Design At Road Culverts: A design manual for fish passage at road crossings"* (Bates et al. 1999).

Table 2. Road Crossing BMP Effectiveness Criteria for Culvert Installations

	Adult Trout >6 in. (150 mm)	Adult Pink, Chum Salmon	Adult Chinook, Coho, Sockeye, Steelhead
Culvert Length	Maximum velocity (fps)	Maximum velocity (fps)	Maximum velocity (fps)
10 - 60 feet	4.0	5.0	6.0
60 - 100 feet	4.0	4.0	5.0
100 - 200 feet	3.0	3.0	4.0
Greater than 200 feet	2.0	2.0	3.0
Minimum water depth (ft)	0.8	0.8	1.0
Maximum hydraulic drop in fishway (ft)	0.8	0.8	1.0
Culvert bottom buried	20% of culvert diameter	20% of culvert diameter	20% of culvert diameter

Natural stream channels provide the benchmark for the passage of all fish for the various life stages at which they migrate. The further a crossing structure (e.g., dam, culvert) departs from the prevailing natural condition, the more impaired fish passage typically becomes. The degree to which the completed passage structure complies with design criteria could measure effectiveness.

New stream crossing structures and restoration of fish passage at identified fish passage barriers should utilize design criteria provided through WDFW in the Aquatic Habitat Guidelines guidance documents. These guidance documents are based on best available science related to fish passage. Bridges are most likely to achieve natural stream processes, when correctly designed. Rudimentary bridge design criteria appear in "*Fish Passage Design at Road Culverts"* (Bates et al. 2003). Bates et al. (2003) also identifies criteria for culvert size, slope, extent of placement below grade level, and channel bed characteristics within the culvert (no-slope and stream simulation methods) that promote natural channel processes inside crossing structures. Retrofit of existing culverts, where the culvert can't be replaced using more preferred methods, may be designed and evaluated using the hydraulic method. Fishways, which depart the furthest from natural conditions, should be designed and evaluated using "*Draft Fishway Guidelines for Washington State"* (Bates and Wiley 2000).

In addition to the above recommendations, gradient of the fish passage structure will also be measured and compared to the original design criteria. Deviations of greater than 20% shall be considered out of compliance.

Projects designed and constructed to criteria in the above-referenced guidance documents are presumed to provide fish passage. Therefore, monitoring of project design upon completion of construction and over time constitutes the most appropriate and measurable effectiveness monitoring. While detection of fish presence upstream of a project is an indicator that the project is not a barrier to all fish, design criteria provide a more stringent requirement for fish passage.

BARRIER EVALUATION

Upon completion of the fish passage project, Years 1, 2, and 5, the engineered solution to the fish passage problem is evaluated using the "*Family Forest Fish Passage Program: Barrier Evaluation Forms*" (DNR 2005). The forms consist of measuring specific parameters based on engineering criteria which assists in determining if the engineered solution is effective at providing fish passage.

EQUIPMENT

Project engineering specifications, engineer's level, tripod, stadia rod, tape measure, field forms, and surveying vest, velocity meter.

PROCEDURE

Step 1:   Evaluate the design blueprints and description of the project for criteria.

Step 2:   Visit the site during summer low flow conditions and measure the parameters such as maximum velocity, minimum depth, percent of culvert buried, gradient of structure, and maximum hydraulic drop. Give each project a percent score based upon one point for every design feature in compliance out of the total design features measured. Also measured are the parameters included in the applicable Barrier Evaluation Form – Single Culvert at crossing, Dams, or Multiple Culverts at crossing. The forms can be obtained at the following web address: http://www1.dnr.wa.gov/sflo/fffpp/. The instructions for completing each form are available at the web address. Based on the measurements taken, the proportion of the measures that are in the passable range as determined by the program standards will be determined. The average value of the proportion of measures in the passable range will be used to evaluate if the project is effective.

Step 3:   Project is effective if the percent passability is 80% or greater; however, if hydraulic drop exceeds criteria in Table 2, or there is no water present, then fish passage structure shall be deemed impassible.

METHOD FOR LAYING OUT CONTROL AND IMPACT STREAM REACHES FOR WADEABLE STREAMS (FOR FISH PASSAGE PROJECTS)

Protocol taken from: *Peck et al. (2003), pp. 63-65, Table 4-4; Mebane et al. (2003)*

EQUIPMENT

Metric tape measure, surveyor stadia rod, handheld GPS device, 3 - 2 ft. pieces of rebar, orange and blue spray paint or plastic rebar caps, engineer flagging tape, waterproof markers

SAMPLING CONCEPT

The concept of EMAP sampling is that randomly selected reaches located on a stream can be used to measure changes in the status and trends of habitat, water quality, and biota over time if taken in a scientifically rigorous manner per specific protocols. We have applied the EMAP field sampling protocols for measuring effectiveness of restoration and acquisition projects. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These "impact" reaches have been matched with "control" reaches of the same length and size on the same stream whenever possible.

Within each sampled project reach a series of Transects A-K are taken across the stream and riparian zone as points of reference for measuring characteristics of the stream and riparian areas (see Figures 1 and 2). The Transects are then averaged to obtain an average representation of the stream reach.
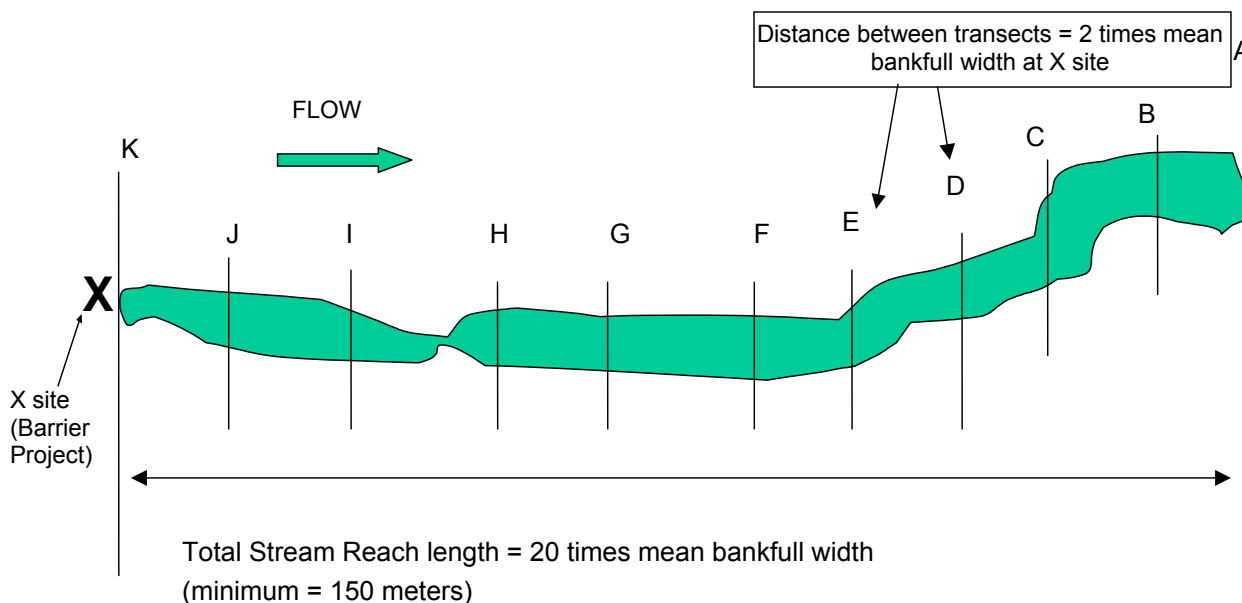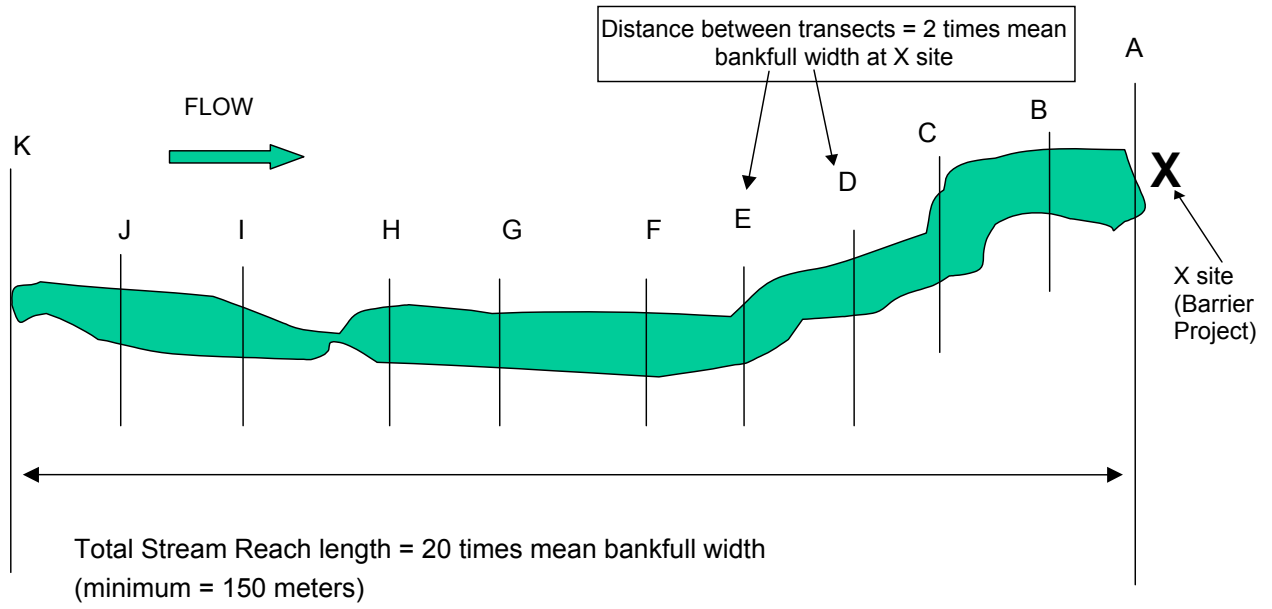

Figure 1. Sampled project control reach

Figure 2. Sampled project impact reach

LAYING OUT THE TREATMENT AND CONTROL STREAM REACHES

Step 1: Using a handheld GPS device, determine the location of the **X site** (barrier project) and record latitude and longitude on waterproof sheets or in a handheld GPS unit with forms. The X site should be considered the barrier project and is in the center of the impact and control study reaches. The control reach is generally located immediately downstream of the X site. The impact reach is generally located immediately upstream of the X site. Use a surveyor's rod or tape measure to determine the bankfull width of the channel at five places considered to be of "typical" width within approximately five channel widths distance upstream and downstream of the X site location. Average those five bankfull widths, then multiply that average bankfull width by 20 to determine the reach length. For streams less than 7.5 m in average bankfull width, the reach length should be at minimum 150 m, and for streams greater than 25 m in width, the maximum reach length shall be 500 m. If the impact reach is less than 150 m, measure and include the entire impact area in the sampling reach. Determine the impact reach length based upon the above, and set the control site reach length equal to the impact reach length.

Step 2: Determine if the reach needs to be adjusted due to confluences with lower order streams, lakes, reservoirs, waterfalls, or ponds. Also adjust the boundaries to end and begin with the beginning of a pool or riffle, but not in the center of the pool or riffle. Hankin and Reeves (1988) have shown that measures of the variance of juvenile fish populations is decreased by using whole pool/riffles in the sample area. To adjust the stream reach, simply add or subtract additional length to Transects A or K, as appropriate (i.e. do not shift the entire reach upstream or downstream to encompass an entire pool). In the case where the impact site is dry in Year 0, reach lengths should still be based upon 20 times the bankfull width.

Step 3: For the impact reach, flag the upstream end of the culvert, or the X site, as Transect "A" (see Figure 2). Using the tape, measure 1/10th (2 average bankfull widths in big streams or 15 m in small streams) of the reach length upstream from the start point (Transect A). Flag this spot as the next cross section or Transect, Transect "B." Proceed upstream with the tape measure and flag the positions of nine additional Transects (labeled "C" through "K" as you move upstream) at intervals equal to 1/10th of the reach length. At the reach end points (Transects A and K) and the middle of the reach (Transect F), install a rebar stake as described in Step 1.

For example, if the reach length is determined to be 200 meters, a Transect will be located every 20 meters, which is equivalent to 1/10th the total reach length.

Step 4: For the control reach, flag the downstream end of the culvert, or the X site, as Transect "K" (see Figure 1). Using the tape, measure 1/10th (2 average bankfull widths in big streams or 15 m in small streams) of the reach length downstream from the start point (Transect K). Flag this spot as the next cross section or Transect, Transect "J." Proceed downstream with the tape measure and flag the positions of nine additional Transects (labeled "I" through "A" as you move downstream) at intervals equal to 1/10th of the reach length. At the reach end points (Transects A and K) and the middle of the reach (Transect F), install a rebar stake as described in Step 1.

METHOD FOR MEASURING WETTED WIDTH (ABRIDGED VERSION FROM CHARACTERIZING STREAM MORPHOLOGY FOR DETERMINING AREA)

Protocol taken from*: Peck et al. (2003), Table 7-3; Kauffman et al. (1999)*

PURPOSE

These modified Thalweg profile methods can be used to determine overall pool-riffle area for calculating salmonid densities.

EQUIPMENT

Surveyor's rod (2-3 m long), 50 m measuring tape, surveyor tape, surveying vest with lots of pockets, chest waders, appropriate waterproof forms

SITE SELECTION

The sample reaches will be used as described on page 13-15.

SAMPLING DURATION

Sampling should occur at the same time that the fish are sampled.

PROCEDURE

The survey of width and length between the two ends of each sampling reach will provide an accurate estimate of wetted area. Wetted width is measured at 21 equally spaced cross-sections (at 11 regular Transects A through K, plus 10 supplemental cross-sections spaced mid-way between each of these).

Step 1: Complete the header information on the waterproof sheets or in a handheld unit with forms. Site ID in the header information is recorded as either the control or impact reach.

Step 2: Begin at the downstream end of the control reach at the first transect (Transect A) and measure the wetted width. Wetted width is measured across and over mid-channel bars and boulders. Record the width on the field data form to the nearest 0.1 m. For dry and intermittent streams, where no water is in the channel, record zero for wetted width.

NOTE: *If a mid-channel bar is present at a cross-section where wetted width is measured, measure the bar width and record it on the field data form. If a side channel is present and contains between 16 and 49% of the total flow, establish secondary cross-section Transects as necessary. Use separate field data forms to record data for the side channel, designating each secondary Transect by checking both "X" and the associated primary Transect letter (e.g., XA, XB, etc.). Collect all wetted width cross-section measurements from the side channel. In the calculation for wetted area, include wetted width measurements for both the main channel and for any surveyed side channels excluding bar width measurements.*

Step 3: Starting at Transect A, determine the distance upstream to the supplemental cross-section mid-way between Transects A and B. Proceed upstream to the supplemental cross-section.

Step 4: Measure the wetted width at the supplemental cross-section mid-way between Transect A and B.

Step 5: Proceed upstream to Transect B and measure the wetted width as previously described.

Step 6: Proceed upstream to the next station and repeat Steps 3 - 5 until you reach the upstream end of the sampling reach (Transect K).

Step 7: Once the control reach information has been completed, repeat the process for the impact reach.

WETTED AREA FORM						
SITE NAME:				**DATE:**	**VISIT: 1**	**2 3**
SITE ID:				**TEAM ID:**		

TRANSECT (X)   A-B   B-C   C-D   D-E   E-F   F-G   G-H   H-I   I-J   J-K

| **Wetted Width** | | | | | **Reach Length (m):** | |

Transect	Wetted Width (XX.X)	Bar Width		Side Channel (X for yes)	Flag	Comments
		Y/N	(XX.X)			
A						
mid A-B						
B						
mid B-C						
C						
mid C-D						
D						
mid D-E						
E						
mid E-F						
F						
mid F-G						
G						
mid G-H						
H						
mid H-I						
I						
mid I-J						
J						
mid J-K						
K						
TOTAL						
MEAN						
VAR						
SE						

Figure 3. Form for recording wetted area (Does not include form for side channels)

METHOD FOR ESTIMATING INSTREAM JUVENILE SALMONID ABUNDANCE USING ELECTROFISHING

Protocol taken from: *Zippin (1956); Hankins (1984); Hankins and Reeves (1988)*

PURPOSE

Estimating the density of juvenile salmonids at the project allows the investigator to obtain a sample over time of the change in abundance of rearing juvenile salmonids produced in the stream reach examined. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These "impact" reaches have been matched with "control" reaches of the same length and size on the same stream whenever possible in order to produce a BACI experimental design.

EQUIPMENT

Use a backpack electrofisher consisting of an anode and cathode pole and capable of producing adjustable pulsed D.C. voltage up to 300 volts and an amp meter allowing adjustable amperage up to 1.5 amps. Determine that all team members are wearing waders and gloves, polarized sunglasses, and capture nets. The electrofisher should have automatic current switches in case the operator falls. The electrofisher should be equipped with an audio indicator when the unit is turned on and warning devices when voltage or current exceeds 300 volts or 1.5 amps. Appropriate capture nets and buckets should be available to capture and hold fish.

SITE SELECTION

The sample reaches are those laid out according to identified methods on page 13-15.

Be sure that all required collectors' permits and ESA clearances have been obtained before proceeding with electrofishing.

SAMPLING DURATION

Sampling for juvenile abundance should occur during the low flow period in late summer. It should be done in one or two days within the same week to avoid changes in conditions, rainfall events, etc.

SAMPLING PROCEDURE

The removal method is based upon the theory that a segment of stream can be fished two or more times to attempt to remove all of the fish and obtain a total count. Because some fish are successful in avoiding capture, a total count cannot normally be obtained. However, a regression equation can be developed that will estimate, with known accuracy and precision, the total number of fish in the sampled reach.

Step 1:   Place blocking nets at the upstream and downstream end of the sample reach in order to reduce escapement of fish from the sample area.

Step 2:   Using an electrofisher adjusted for maximum efficiency, fish the entire sample reach thoroughly. Capture all fish discovered in capture nets and placed them in buckets with cool water for later enumeration.

Step 3:   At the end of each pass of the reach, enumerate all fish by species and size and record this information on the Juvenile Fish Survey Form (Figure 4).

Step 4:   Repeat steps 2 and 3 two more times, for a total of three passes, to improve accuracy of the sampling. Use the total number of fish collected within the sampled area and follow procedures described in Zippin (1956) to develop an estimate of the total number of fish.

ASSUMPTIONS

The assumptions that underlie the method are:

- The population is essentially stationary;
- The probability of capture during a trapping is the same for each animal exposed to capture;
- The probability of capture remains constant from trapping to trapping.

EFFICIENCY

Although we know that the electrofisher does not catch all of the fish in the sample reach, we assume that the regression reflects the true abundance within the sample reach and that none of the fish were able to escape during sampling.

Turbidity and flow are the dominant factors affecting electrofishing efficiency. Turbid water makes it more difficult to detect and capture fish responding to the electric charge. On the other hand, turbid water is often more conductive and may improve catching efficiency. High flows make it easier for fish to avoid the electric field and to escape downstream.

FISH HANDLING

Sampled fish should be enumerated and identified to the species level, when possible, and measured for fork length. Data should be recorded on Juvenile Fish Survey Form (Figure 13). Fish may be anaesthetized using carbon dioxide.

ESTIMATING TOTAL STREAM REACH POPULATION

Source: Zippin (1956)

Estimating total juvenile population utilizes the following mark recapture formula:

$$T = \text{Total catch} = \Sigma y_i = y_1 + y_2 + y_3$$

where y_i is the number of fish captured on the ith pass.

$$\Sigma(I-1)y_i = (1-1)y_1 + (2-1)y_2 + (3-1)y_3$$

$$= y_2 + 2y_3$$

$$\text{Ratio} = R = y_2 + 2y_3 / T$$

To obtain the estimated probability of capture during a single capture, one can utilize Zippin's first graph in Figure 2 (of Zippin (1956)) for three passes or one can use the formula

$$R = (q/1-q) - kq^3/1 - q^3$$

$$N = \text{total population} = \text{total catch/estimated proportion of population captured} = T/(1 - q^3)$$

The formula for the standard error of the population estimate N is approximately

$$SE(N) = \left[\frac{N(N-T)T}{T^2 - N(N-T)\frac{(kp)^2}{(1-p)}} \right]^{1/2}$$

METHOD FOR ESTIMATING INSTREAM JUVENILE SALMONID ABUNDANCE USING SNORKELING

Protocol taken from: Rodgers (2002) and Thurow (1994)

PURPOSE

Estimating the density of juvenile salmonids at the project allows the investigator to obtain a sample over time of the change in abundance of rearing juvenile salmonids produced in the stream reach examined. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These "impact" reaches have been matched with "control" reaches of the same length and size on the same stream whenever possible in order to produce a BACI experimental design.

EQUIPMENT

Waterproof field forms or electronic forms are necessary for recording fish counts. A thermometer to measure water temperature is necessary. Persons conducting snorkel counts should be equipped with dry suits or wet suits, masks, snorkels, and rubber or felt soled boots. Additional equipment such as hand counters, underwater white boards, and dive lights are helpful for enumerating fish.

SITE SELECTION

The sample reaches are those laid out according to the methods on page 13-15.

Be sure that all necessary collectors' permits and ESA clearances have been obtained before proceeding with snorkeling.

SAMPLING DURATION

Sampling for juvenile abundance should occur during the low flow period in late summer. It should be done in one or two days within the same week to avoid changes in conditions, rainfall events, etc.

SAMPLING PROCEDURE

Step 1: Measure the water temperature and record the temperature in the Juvenile Fish Survey Form (Figure 13). Estimate visibility as low, medium, or high and record it in the field form.

Step 2: Begin at the downstream boundary of the control reach (Transect A) and proceed upstream through each Transect, ending at Transect K. In wadeable stream reaches, one crew member should snorkel each pool-riffle area while the other crew member records the counts as they are given by the snorkeler. In non-wadeable areas, crew members should snorkel side by side and sum their individual counts. Each snorkeler counts the fish to the immediate front and to the sides opposite the other snorkeler or as designated by the team leader to avoid duplication of counts. In all wadeable and most non-wadeable stream reaches, snorkeling should involve only a single pass through each Transect.

Note: In many smaller streams the riffle areas will be too shallow to snorkel and will contain mostly smaller young of the year trout species. A two person snorkeling crew can conduct snorkel surveys in wadeable stream control and impact study reaches. In areas where the stream is not wadeable, up to four snorkelers may be needed.

Step 3: Counts of the number of juvenile salmonids should be recorded from one Transect to the next (juvenile salmonids from Transect A to B, Transect B to C, etc.) in the Juvenile Fish Survey Form (see Figure 4). Continue proceeding upstream counting the number of juvenile salmonids until the survey is completed at Transect K. Salmonid forklengths should be estimated to the nearest 5 mm.

Step 5:   After snorkeling, the underwater visibility of each study reach is ranked on a scale of 0 to 3 (see Table 3) and recorded on the Juvenile Fish Survey Form.

Table 3. Visibility Ratings and Descriptions

Visibility Rating	Description
0	Not snorkelable due to an extremely high amount of hiding cover or zero visibility
1	High amount of hiding cover or poor water clarity
2	Moderate amount of hiding cover or moderate clarity
3	Little hiding cover and good water clarity

Note: Only reaches with a visibility rank of two or three should be used in data analysis. Where possible, the proportion of trout estimated by sample electrofishing that were cutthroat and steelhead should be used to reclassify unknown trout as underwater determination of species is often impossible.

Step 7:   Proceed to the impact reach and repeat steps 1-5.

Step 8:   Determine the area (m^2) for both the control and impact reaches by utilizing the data collected for each reach in Step 4 of the Method for Characterizing Stream Morphology,Thalweg Profile. Reach area is determined by multiplying the averaged wetted width by the reach length.

Step 9:   For each study reach, the number of fish/m^2 can be calculated for each salmonid species by dividing the total number of fish counted for each species (Step 3) which are < 250 mm by the reach area. This would result in fish/m^2 for each species in the control reach and in the impact reach.

Note: Consult Thurow (1994) and Johnson et al. (2007) for additional information.

JUVENILE FISH SURVEY FORM

Fish Survey	**Fish Species**				**Widths** (fish passage projects only):		
Project Type:	Chinook	CH	Rainbow	RB	1:	8:	15:
Site #:	Coho	CO	Bulltrout	BT	2:	9:	16:
Station:	Sockeye	SK	Brooktrout	BK	3:	10:	17:
Date:	Chum	CM	Sculpin	SC	4:	11:	18:
H$_2$O temp:	Steelhead	ST	Lamprey	LP	5:	12:	19:
Team:	Pink	PK	Dace	DC	6:	13:	20:
Visit:	Cutthroat	CT	Stickleback	SB	7:	14:	21:
Visibility:							

Transect (A-B, B-C, etc.)	Bank	Snorkeler	Species	Number	Size (mm)	Comments

Figure 4. Juvenile Fish Survey Form

METHOD FOR ESTIMATING ADULT SPAWNER ABUNDANCE

Protocol adopted from: *Nickelson (1998); Hahn et al. (2001); Jacobs and Nickelson (1999)*

PURPOSE

The estimates of adult spawner abundance and/or redd counts pre- and post-project will allow the investigator to determine whether there has been an increase in the abundance of spawners post treatment and to ascertain whether the project was effective in allowing more adult fish to spawn. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These impact reaches have been matched with control reaches of the same length and size on the same stream whenever possible in order to produce a BACI experimental design.

EQUIPMENT

Waders, engineering flagging tape, Polaroid glasses, knife, appropriate waterproof notebook or forms.

SITE SELECTION

The sample reaches are those laid out according to Identified methods on page 13-15.

Be sure that all collectors' permits and ESA clearances have been obtained before proceeding.

SAMPLING DURATION

Sampling should occur in both the impact and control stream reaches beginning with the earliest anticipated spawning for the target species and should continue until the end of the normal spawning period.

PROCEDURES

FOOT SURVEYS

For most SRFB fish passage restoration projects, foot surveys are the most appropriate method for detecting adult spawning salmon. Foot surveys are conducted on designated stream reaches to obtain counts of all live and/or dead salmon and to record the number of redds observed in control and impact stream reaches.

Step 1:   Walk along the entire reach length on the banks whenever possible, entering the stream only as needed to confirm redds and/or species of fish on the redds. The observer should wear Polaroid sunglasses and carry a "write-in-the-rain" notebook to record data.

Step 2:   Record the number of live and/or dead salmon that are observed, as well as any redds that are observed in both the impact and control reaches. Use surveyor's plastic flagging to mark the location of any redds observed.

Step 3:   Conduct surveys at intervals of less than ten days during the spawning season for the target species. Weather conditions, water clarity and number of redds are also recorded.

CARCASS SURVEYS

Carcass sampling should be conducted as part of any adult spawner survey in order to obtain an accurate estimate of the total abundance of males and females in the treatment and control reaches.

Step 1:   Walk along the entire reach length on the banks whenever possible, entering the stream only as needed to confirm carcasses. The observer should wear Polaroid sunglasses and carry a "write-in-the-rain" notebook to record data.

Step 2:   Count all dead salmon encountered within the reach. Remove the caudal fin, flag the jaw, or use some other method to mark those carcasses that have been counted to avoid double counting.

Step 3:   Conduct carcass counts on a weekly basis throughout the sampling period along with the ground counts of redds. For steelhead, bull trout, and cutthroat, these methods will not be applicable.

MARKED REDD CENSUS METHOD

Counting redds is the preferred method for enumerating chinook and steelhead. This method sums the number of new redds counted during the spawning season. By marking redds, old but still visible redds are not counted twice.

Step 1:   Mark redds by either tying plastic flagging around an oblong rock that is subsequently placed in the redd, or by flagging tied to bushes or trees adjacent to the redd on the stream bank. The color of the flagging should be changed for each survey, or some method should be used to track redd visibility.

Incomplete redds should not be flagged and not counted until the next survey.

On subsequent surveys, the absence of a flagged rock on a redd means that it is a new redd not previously marked, or that another redd has been superimposed on a previous redd.

Step 2:   Some bias of results can occur from removal of flagging by people. Mapping of redds on a weekly basis onto an aerial photograph or sketch of the stream can help reduce bias from this source.

Step 3:   All carcasses of spawned-out target species are examined for fin clips and tags.

Step 4:   All carcasses are marked for future identification during future surveys.

Step 5:   Number of redds, carcasses, and live spawners should be recorded for each Transect (A-B, B-C, etc.).

The investigator should be familiar with the size of the redds produced by the various species of salmonids and the species of fish that may be spawning at the time the surveys are conducted. Surveys will focus on one target species; however, if other species are observed during the surveys, the information should also be recorded.

Estimating Total Redds

Because all redds are marked in the sampled control and impact reaches, they represent a total count and not an estimate.

Redd Visibility

Redd visibility estimates should not normally be needed because foot surveys allow each redd to be identified and marked.

SUMMARY STATISTICS

After field data collection, the data are uploaded into an MS Access® database which then computes summary statistics to reflect habitat conditions at the reach scale. These summary statistics were generally developed as part of the EPA EMAP and were selected for this program based on their high signal to noise ratios as compared to other potential summary variables. The following variables are reported for Fish Passage Projects.

Reach Length
Reach length is measured onsite as the distance between the start and end of a reach, or calculated as forty times the average wetted width of the stream. The reach length is determined for both the impact and control reaches, as described in the Method For Laying Out Control And Impact Stream Reaches For Wadeable Streams. The Reach Length variable is simply reported as this measurement or calculated distance.

Reach Width
Reach width is calculated as the average wetted width of the reach. A measurement of wetted with is taken at each Transect in meters and entered into the Physical Habitat form. Wetted width and bar width are measured at station 5, between each Transect, in meters during the thalweg profile. Each of the 11 wetted width measurements from the physical habitat form and the 10 measurements of wetted width from the thalweg profile (the width used from the thalweg profile is defined as the wetted width minus the bar width) are summed and divided by the number of measurements to come up with the average wetted width, which is Reach Width, in meters.

GPS Coordinates
The GPS coordinates taken at Transect A, Transect F (also known as the X-site), and Transect K in each reach. These response variables are the GPS coordinates in Degrees, Minutes, Seconds, which are entered into the stream verification form onsite.

Sample Date
This is the date that the reach was surveyed, which is entered into the stream verification form onsite.

Juvenile Fish Density
The response variables for juvenile fish are calculated in the same way for Chinook, coho, and steelhead parr. The metric used is number of fish per square meter within each reach (impact and control). The number of fish is found by querying the snorkel survey results for fish of each species that are less than 250 mm in length. Water surface area is calculated as reach length multiplied by the average wetted width of the reach. This is taken directly from the two response variables above, Reach Length and Reach Width. In addition, if there Is a side channel present with more than 16 percent of the flow, and is surveyed (query for Transects XA-XB, XB-XC, etc.), the surface area of each of the spaces between these transects must be added into the total water surface area calculation. Similarly, the fish counts from the side channel for each species would be added into the total fish count. The final calculation performed for each species of juvenile fish is:

$$\frac{\text{Number of fish counted in snorkel survey}}{\text{Reach Length*Reach Width}} = \text{number of fish per m}^2$$

Spawner Density
Spawner density is calculated primarily for the target species identified for each project. However, if additional spawners are observed, the densities for these fish will also be presented. The density is calculated by dividing the cumulative number of spawners (by species) by the linear distance (in meters) of the sample reach. This number is then converted into spawners per km.

Redd Density
Redd density is calculated primarily for the target species identified for each project. However, if additional redds are observed, the densities for these redds will also be presented. The density is calculated by dividing the cumulative number of redds (by species) by the linear distance (in meters) of the sample reach. This number is then converted into redds per km.

Fish Passage Design
Following implementation of the project, the fish passage structure is evaluated against the engineering plans to determine if it was constructed per the design. This variable is reported as a "Yes" or "No" in response to whether or not the project meets the design specifications.

TESTING FOR SIGNIFICANCE

We can create a table resembling the following from the data collected for each of the indicators for fish passage design (Table 4), juvenile abundance (Table 5), and adult abundance (Table 6).

Table 4. Example table for passage design criteria met (Yes/No)

	Year 0 2003	Year 1 2004	Year 2 2005	Year 5 2008
	Impact	**Impact**	**Impact**	**Impact**
Proj. 1	N	Y	Y	N
Proj. 2	N	Y	Y	Y
Proj. 3	N	Y	Y	Y
Proj. 4	N	Y	Y	Y
Proj. 5	N	Y	N	N
Proj. 6	N	Y	Y	Y
Proj. 7	N	Y	Y	N
Proj. 8	N	Y	Y	Y
Proj. 9	N	Y	N	N
Proj.10	N	Y	Y	Y
Percent Effective	**0**	**100**	**80**	**60**

Table 5. Example table of hypothetical juvenile abundance (#/m^2) for steelhead yearlings <250mm for Year 0 (BEFORE) and Year 1 (AFTER)

	BEFORE Year 0 (2003) #/m^2			AFTER Year 1 (2004) #/m^2		
	Control	**Impact**	**Diff. (I-C)**	**Control**	**Impact**	**Diff (I-C)**
Proj. 1	0.0000	0.0123	0.0123	0.0050	0.0177	0.0127
Proj. 2	0.0166	0.0739	0.0573	0.0171	0.0525	0.0354
Proj. 3	0.0000	0.0206	0.0206	0.0121	0.0313	0.0192
Proj. 4	0.0000	0.0402	0.0402	0.0410	0.0411	0.0001
Proj. 5	0.0206	0.0464	0.0258	0.0190	0.0499	0.0309
Proj. 6	0.0008	0.0056	0.0048	0.0228	0.0100	-0.0128
Proj. 7	0.0113	0.0479	0.0366	0.0400	0.0555	0.0155
Proj. 8	0.0014	0.0008	-0.0006	0.0127	0.0076	-0.0051
Proj. 9	0.0000	0.0000	0.0000	0.0511	0.0422	-0.0089
Proj. 10	0.0019	0.0166	0.0147	0.0040	0.0330	0.029
Mean	0.0045	0.0324	0.0279	0.0203	0.0406	0.0203
Var.	0.0001	0.0009	0.0008	0.0003	0.0007	0.0009
SD	0.0068	0.0294	0.0283	0.0166	0.0273	0.0297

STATISTICAL TESTING FOR CHANGES IN JUVENILE ABUNDANCE

The number of juveniles per square meter has been shown to be more descriptive than using either linear measures (#/m) or volume measures (#/m^3).

The data will be tested using a paired *t*-test. The paired *t*-test is a very powerful test for detecting change because it eliminates the variability associated with individual sites by comparing each stream to itself,

that is, at upstream and downstream locations within the same stream. The impact reach and control reach for each stream are affected by the same local environmental factors and local characteristics in the fish population in contrast with other stream systems with their own unique environmental conditions. In other words, the two observations of the pair are related to each other.

Because the paired *t*-test is such a powerful test for detecting differences, very small differences may be statistically significant but not biologically meaningful. For this reason, biological significance will also be indicated by a 20% increase in populations between the mean yearly difference for the 10 sampled fish passage projects.

The statistical test will be one-sided for an Alpha=0.10. We use a one-sided test because a significant decrease in salmon abundance after the impact would not be considered significant, that is, the project would not be considered effective. In other words, we are not interested in testing for that outcome. The test will be conducted in Years 1, 2, and 5. If the results are significant in any of those years, the fish passage projects will be considered effective.

Our conclusions are, therefore, based upon the differences of the paired scores for the 10 sampled fish passage projects. Though somewhat confusing, it may be helpful to think of the statistic as the "difference of the differences". A one-tailed paired-sample *t*-test would test the hypothesis:

H_0 : The mean difference is less than or equal to 0 of the difference observed in Year 0.
H_A : The mean difference is greater than 0 of the difference observed in Year 0.

The test statistic is calculated as:

$$t_{n-1} = \frac{\bar{d}}{S_{\bar{d}}}$$

where
$\bar{d}$ = mean of the differences for Year 0 and a subsequent year

$S_{\bar{d}}$= variance of the differences

$S_{\bar{d}} = S_d / n^{1/2}$ = variance mean

n = number of sites (or site pairs).

STATISTICAL TESTING FOR CHANGES IN ADULT ABUNDANCE

Using hypothetical steelhead redd data from Table 5, the test statistic using the same formula as above would be calculated as:

$$t = \frac{3.3}{3.1 / 10^{1/2}} = \frac{3.3}{0.98} = 3.39 \qquad\qquad t_{0,10\,(1),9} = 1.38$$

For this example, 3.39 was much greater than the *t*-value required for significant change (*t* = 1.38). In other words, the amount of change observed for these data from Year 0 to Year 1 was significantly different from 0. This demonstrates that the group of 10 sampled fish passage projects was effective.

Table 6. Example table of hypothetical data for adult abundance (# redds/km) for steelhead

Project	Year 0 2003	Year 0 2003	Year 0 2003	Year 2 2005	Year 2 2005	Year 2 2005	Test yr 2 minus. yr 0
	Cntrl	Impact	Diff yr 0	Cntrl	Impact	Diff yr 1	Diff yr 0 vs. yr 1
1	9	0	-9	10	7	-3	6
2	20	4	-16	19	8	-11	5
3	15	5	-10	15	5	-10	0
4	12	0	-12	16	10	-6	6
5	16	7	-9	14	8	-6	3
6	7	4	-3	9	5	-4	-1
7	4	2	-2	3	4	1	-3
8	0	0	0	1	1	0	0
9	15	5	-10	17	10	-7	3
10	11	0	-11	14	12	-2	9
Mean			-8.1			-4.8	3.3
Variance							9.72
SD							3.1

DATA MANAGEMENT PROCEDURES

Data will be collected in the field using various hand-held data entry devices. Raw data will be kept on file by the project monitoring entity. A copy of all raw data will be provided to the SRFB at the end of the project. Summarized data from the project will be entered into the PRISM database after each sampling season. The PRISM database contains data fields for the following parameters associated with these objectives.

Table 7. Category 1 Fish Passage Projects - no fish present pre-project

Indicator	Metric	Pre impact Year 0	Post impact Year 1	Post impact Year 2	Post impact Year 5
Stream distance made available	km	√			
Passage structure Level 1 effective	Yes/No		√	√	√
Adult salmon abundance impact	#/km	√	√	√	√
Adult salmon abundance control	#/km	√	√	√	√
Juvenile salmon abundance impact	$\#/m^2$	√	√	√	√
Juvenile salmon abundance control	$\#/m^2$	√	√	√	√

REPORTS

PROGRESS REPORT

A progress report will be presented to the SRFB in writing after the sampling season.

FINAL REPORT

A final report will be presented to the SRFB in writing by the monitoring entity after the sampling season for Year 5. It shall include:
- Raw data in the required data format.
- Estimates of precision and a power analysis of the data.
- Confidence limits for data.
- Summarized data required for PRISM database.
- Determination whether project met decision criteria for effectiveness.
- Analysis of completeness of data, sources of bias.

Results will be reported to the SRFB during a regular meeting after 1, 2, and 5 years post project. Results will be entered in the PRISM database and will be reported and available over the Interagency Committee for Outdoor Recreation web site and the Natural Resources Data Portal.

ESTIMATED COST

It is estimated that approximately 120 hours per project would be required to conduct all field activities under the protocol. This results in a relative 2004 cost of $9,000-$10,000 per project.

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APPENDIX A
Transect Measurement and Densiometer Reading Locations

TRANSECT MEASUREMENTS AND DENSIOMETER READING LOCATIONS

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7
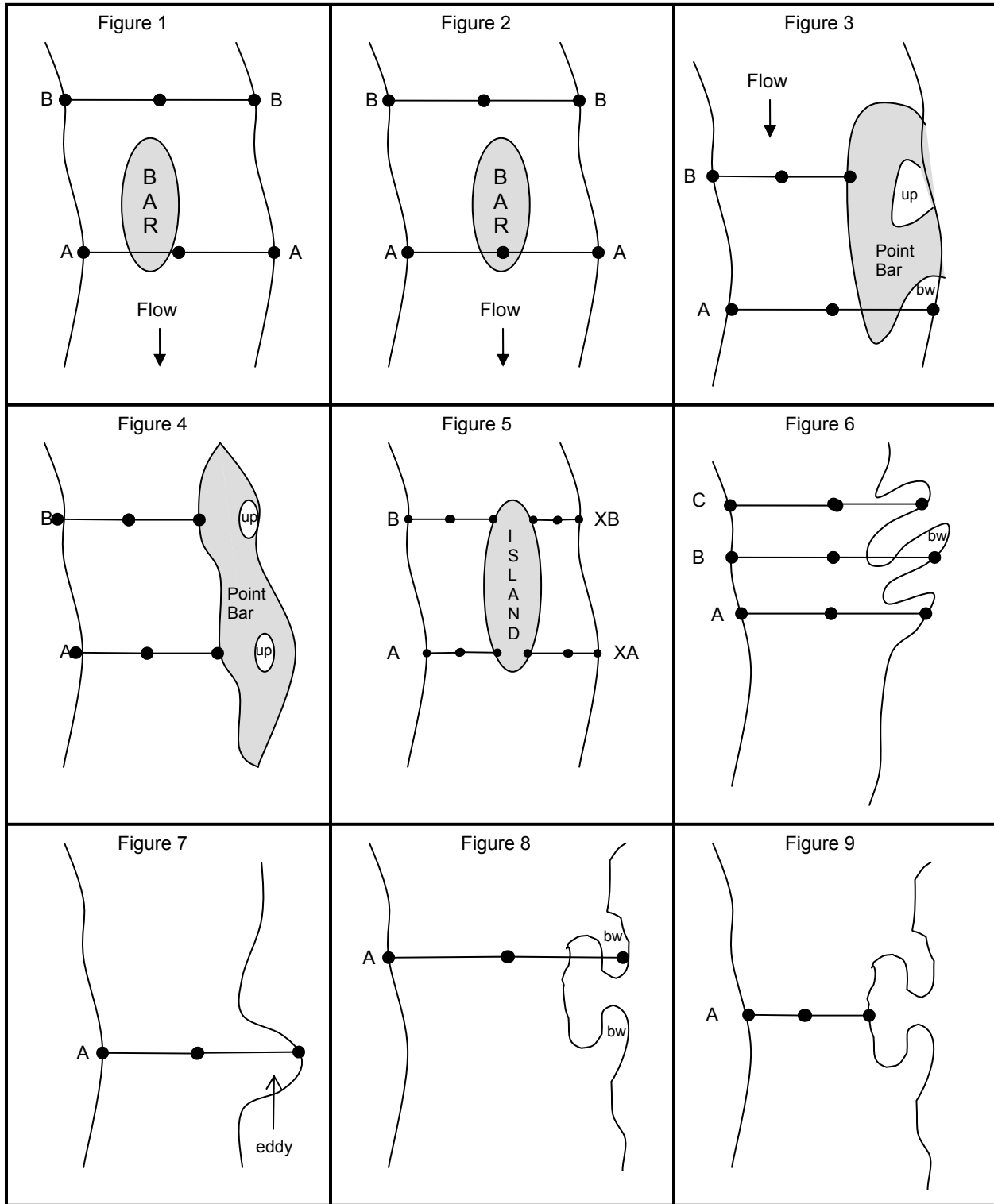
Figure 8

Figure 9

Notes:

- up = unconnected puddle; bw = backwater

- In all figures, flow is from the top of the figure to the bottom of the figure.

- In all figures, each line across the channel represents a Transect and the dots represent the locations of densiometer measurements.

- Measurement locations within the reach are determined based on the conditions present at the time of the survey.

- Substrate measurements (not illustrated in the figures) are made at five equal distance locations across each Transect and each secondary/mid-Transect (e.g., between Transect A and B).

- Right bank is on the right side of the stream when facing downstream; left bank is on the left side of the stream when facing downstream.

- Regardless if a bar is present, densiometer readings occur at the right bank, in the center of the channel, and at the left bank (Figures 1 and 2).

- Wetted width is measured across bars from the right edge of water to the left edge of water (Figures 1 and 2). The bar width is also measured and is independent of the wetted width measurement.

- If a point bar is present (e.g., gray areas in Figures 3 and 4), the edge of water is where the point bar and water meet (i.e., the bank). In Figures 3 and 4, the left bank measurements occur where the point bar and water meet (i.e., the left edge of the water). However, in the case of Transect A, in Figure 3, backwater is present and, therefore, the left edge of water (i.e., the left bank) would be on the left bank of the backwater. Unconnected puddles are never included in any measurements.

- Bars are mid-channel features below the bankfull flow mark that are dry during baseflow conditions. Islands are mid-channel features that are dry even when the stream is experiencing a bankfull flow. Both bars and islands cause the stream to split into side channels. When a mid-channel bar is encountered along the thalweg profile, it is noted on the field form and the active channel is considered to include the bar. Therefore, the wetted width is measured as the distance between the wetted left and right banks. It is measured across and over mid-channel bars and boulders. If mid-channel bars are present, record the bar width in the space provided in the form.

- If a mid-channel feature is as high as the surrounding flood plain, it is considered an island (Figure 5). Treat side channels resulting from islands different from mid-channel bars. Manage the ensuing side channel based on visual estimates of the percent of total flow within the side channel as follows:

  Flow less than 15% - Indicate the presence of a side channel on the thalweg field data form.

  Flow 16 to 49% - Indicate the presence of a side channel on the thalweg field data form.

  Establish a secondary Transect across the side channel (Figure 5) designated as "X" plus the primary Transect letter; (e.g., XA), by creating a new record in the physical habitat form and selecting "X" and the appropriate Transect letter (e.g., A through K) in the new record on the field data form. Complete the physical habitat and riparian cross-section measurements for the side channel on this form. No thalweg measurements are made in the side channel. When doing width measurements within a side channel separated by an island, include only the width measurements of the main channel in main channel form, and then measure the side channel width separately, recording these width measurements in the physical habitat side channel form. Refer to Peck et al. (2003) for detailed instructions on side channel measurements.

- When multiple backwaters and eddies are encountered (Figure 6), measurements are made across the entire channel, over depositional areas (e.g., Figure 6, Transect B) to the edge of water.

- When eddies are encountered (Figure 7), measurements are still made from the right bank to the left bank.

- In instances where a depositional area has become a peninsula and the Transect falls in a location where backwater is present (Figure 8), measure from the right bank across the depositional area to the left bank (e.g., Figure 8, Transect A). When the Transect falls in a location where backwater is not present (e.g., Figure 9, Transect A), only measure to where the water meets the edge of the depositional area/peninsula.