



Fish Passage Inventory, Assessment, and Prioritization Manual

WASHINGTON DEPARTMENT OF FISH & WILDLIFE



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Updates, Feedback, Questions

The *Fish Passage Inventory, Assessment, and Prioritization Manual* is a work in progress. It has been updated three times since first published in 1998. We welcome feedback that would make the content more useful. Questions or comments regarding the manual can be e-mailed to:

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Table of Contents

CHAPTER 1: WELCOME TO FISH PASSAGE	1-1
1.1 INTRODUCTION, PURPOSE, AND SCOPE	1-1
<i>Evolution of the Manual</i>	<i>1-1</i>
<i>Reasons for Updating the Manual</i>	<i>1-1</i>
<i>Definition of ‘Adult Salmonid’</i>	<i>1-2</i>
<i>‘Fish Use Potential’</i>	<i>1-2</i>
<i>Barrier Criteria.....</i>	<i>1-2</i>
<i>‘Culvert Case’ Injunction Implications</i>	<i>1-2</i>
<i>Design Criteria</i>	<i>1-2</i>
1.2 FISH PASSAGE PROGRAM SERVICES	1-3
<i>Training</i>	<i>1-3</i>
<i>Technical Assistance.....</i>	<i>1-3</i>
<i>Fish Passage Database.....</i>	<i>1-3</i>
1.3 OVERVIEW OF FISH PASSAGE ASSESSMENTS AND PRIORITIZATION	1-3
<i>Fish Passage Features.....</i>	<i>1-3</i>
<i>Fish Use</i>	<i>1-3</i>
<i>Fish Passage Flows and Percent Passability</i>	<i>1-4</i>
<i>Prioritization.....</i>	<i>1-5</i>
1.4 PLANNING FISH PASSAGE AND SURFACE WATER DIVERSION INVENTORIES.....	1-5
<i>Defining the Goals and Scope of the Project.....</i>	<i>1-5</i>
<i>Road-based Inventory.....</i>	<i>1-6</i>
<i>Road-based Culvert Inventory with Habitat Assessment at Barriers</i>	<i>1-6</i>
<i>Watershed-based Fish Passage and Diversion Inventory with Habitat Assessment</i>	<i>1-7</i>
<i>Existing Data</i>	<i>1-9</i>
<i>Field Gear and Safety Equipment.....</i>	<i>1-9</i>
<i>Field Forms.....</i>	<i>1-9</i>
<i>Obtaining Landowner Permission</i>	<i>1-9</i>
1.5 DATA SHARING AND COMMUNICATION	1-9
<i>Updating the FPDSI Database</i>	<i>1-9</i>
CHAPTER 2: SITE INFORMATION.....	2-1
2.1 SITE DESCRIPTION	2-1
<i>Activities.....</i>	<i>2-1</i>
<i>Data Collection.....</i>	<i>2-1</i>
<i>Photographing the Site</i>	<i>2-7</i>
<i>Safety.....</i>	<i>2-7</i>
<i>Instream Features That Do Not Require a Fish Passage or Screening Assessment</i>	<i>2-8</i>
2.2 QUICK REFERENCE TABLE	2-9
CHAPTER 3: CULVERTS.....	3-1
<i>Culverts in Tidal Areas.....</i>	<i>3-1</i>
3.1 CLASSIFICATION OF CULVERTS.....	3-2

<i>Bottomless Culverts in Contrast to Bridges</i>	3-2
<i>Culverts in Contrast to Dams</i>	3-2
3.2 CULVERTS – INVENTORY OVERVIEW	3-3
<i>Activities</i>	3-3
<i>Culvert Structural Definitions</i>	3-3
<i>Elevation Surveying Techniques</i>	3-4
3.3 LEVEL A CULVERT ASSESSMENT	3-4
<i>Header</i>	3-6
<i>Culvert Description</i>	3-7
<i>Channel Description</i>	3-22
<i>Plunge Pool Description</i>	3-23
<i>Barrier Status</i>	3-23
3.4 LEVEL B HYDRAULIC ANALYSIS	3-27
<i>Terminology</i>	3-27
<i>Elevation Calculations</i>	3-29
<i>Level B Elevation Locations</i>	3-29
<i>Applicability of Level B Hydraulic Analysis</i>	3-30
<i>Multiple Culvert Crossings</i>	3-31
<i>Header</i>	3-32
<i>Culvert Measurements</i>	3-32
<i>Downstream Control Cross-Section</i>	3-32
<i>Level B Barrier Determination</i>	3-35
<i>Level B Percent Passability</i>	3-35
3.5 INSTANTANEOUS FLOW RATE MEASUREMENTS	3-36
3.6 QUICK REFERENCE TABLES	3-37
CHAPTER 4: NON-CULVERT CROSSINGS	4-1
4.1 NON-CULVERT ROAD CROSSINGS – INVENTORY OVERVIEW	4-1
<i>Activities</i>	4-1
4.2 NON-CULVERT CROSSING ASSESSMENT AND BARRIER STATUS	4-3
<i>Bridges</i>	4-3
<i>Fords</i>	4-4
<i>Fill or Puncheon Crossings</i>	4-4
<i>Abandoned Crossings and Washouts</i>	4-4
4.3 QUICK REFERENCE TABLE	4-6
CHAPTER 5: DAMS	5-1
5.1 DAM - INVENTORY OVERVIEW	5-1
<i>Activities</i>	5-1
5.2 DAM ASSESSMENT	5-2
5.3 DAM BARRIER STATUS AND PERCENT PASSABILITY	5-7
5.4 QUICK REFERENCE TABLE	5-8

CHAPTER 6: MICELLANEOUS OBSTRUCTIONS.....	6-1
6.1 MISCELLANEOUS OBSTRUCTIONS – INVENTORY OVERVIEW	6-1
<i>Activities.....</i>	<i>6-1</i>
<i>Fish Passage</i>	<i>6-1</i>
6.2 MISCELLANEOUS OBSTRUCTION ASSESSMENT AND BARRIER STATUS.....	6-3
6.3 QUICK REFERENCE TABLE	6-11
CHAPTER 7: NATURAL BARRIERS	7-1
7.1 NATURAL BARRIERS – INVENTORY OVERVIEW	7-1
<i>Activities.....</i>	<i>7-1</i>
<i>Fish Passage Assessment for Natural Barriers</i>	<i>7-2</i>
7.2 GRADIENT.....	7-4
7.3 WATERFALLS	7-5
<i>Partial Barrier Waterfalls</i>	<i>7-7</i>
7.4 CASCADES.....	7-9
7.5 QUICK REFERENCE TABLES	7-13
7.6 REFERENCES	7-15
CHAPTER 8: FISHWAYS.....	8-1
8.1 FISHWAYS – INVENTORY OVERVIEW	8-1
<i>Fishway Definitions.....</i>	<i>8-1</i>
<i>Inventory Activities Overview.....</i>	<i>8-3</i>
8.2 FISHWAY ASSESSMENT.....	8-3
8.3 FISHWAY DESIGNS	8-4
<i>Baffled Culverts and Flumes.....</i>	<i>8-4</i>
<i>Weir Pool, Pool Chute, Vertical Slot, and Steeppass Fishways</i>	<i>8-5</i>
<i>Roughened Channel.....</i>	<i>8-7</i>
<i>Blasted Falls</i>	<i>8-8</i>
<i>Trap-and-Haul.....</i>	<i>8-8</i>
8.4 STREAMBED CONTROLS	8-8
<i>Assessing Culverts with Streambed Controls</i>	<i>8-9</i>
8.5 QUICK REFERENCE TABLES	8-11
CHAPTER 9: SURFACE WATER DIVERSIONS	9-1
9.1 DIVERSIONS – INVENTORY OVERVIEW	9-1
<i>Activities.....</i>	<i>9-1</i>
9.2 SURFACE WATER DIVERSION ASSESSMENT	9-3
9.3 SURFACE WATER DIVERSION ASSESSMENT - SCREENS.....	9-7
9.4 QUICK REFERENCE TABLE	9-16
9.5 ADDITIONAL READING	9-17

CHAPTER 10: HABITAT ASSESSMENT	10-1
10.1 HABITAT ASSESSMENT METHODS	10-1
<i>Threshold Determination.....</i>	<i>10-1</i>
<i>Physical Habitat Survey.....</i>	<i>10-2</i>
10.2 REDUCED SAMPLE FULL SURVEY OVERVIEW	10-3
<i>Data Collection for Reduced Sample Full Surveys.....</i>	<i>10-3</i>
<i>Fieldwork Considerations.....</i>	<i>10-4</i>
<i>Where to Begin the Assessment.....</i>	<i>10-4</i>
<i>Fish Access Check</i>	<i>10-4</i>
<i>Reaches</i>	<i>10-5</i>
<i>Naming Conventions.....</i>	<i>10-7</i>
10.3 UPSTREAM HABITAT SURVEY	10-8
<i>Header</i>	<i>10-9</i>
<i>Habitat Sample</i>	<i>10-10</i>
<i>Dry Reaches.....</i>	<i>10-14</i>
<i>Completing the Habitat Survey.....</i>	<i>10-14</i>
<i>Reach Data</i>	<i>10-14</i>
<i>Habitat Quality Modifiers.....</i>	<i>10-15</i>
<i>Comments and Photos</i>	<i>10-25</i>
<i>Landowner Denials.....</i>	<i>10-25</i>
<i>Terminating the Upstream Habitat Assessment.....</i>	<i>10-26</i>
10.4 WATERSHED SURVEYS OF ALL POTENTIALLY FISH BEARING WATERS	10-26
<i>Resident-Only Fish Habitat</i>	<i>10-27</i>
10.5 QUICK REFERENCE TABLES	10-28
10.6 ADDITIONAL READING	10-30
CHAPTER 11: HABITAT ASSESSMENT DATA ENTRY	11-1
11.1 HABITAT SURVEY DATA ENTRY	11-1
<i>Input Sheet</i>	<i>11-1</i>
<i>Data Analysis and Output Sheet</i>	<i>11-9</i>
<i>Fish Access Check and Upstream Comments.....</i>	<i>11-10</i>
<i>File Management and Printing.....</i>	<i>11-11</i>
11.2 ADDITIONAL BARRIERS.....	11-11
<i>File Management and Printing.....</i>	<i>11-12</i>
CHAPTER 12: PRIORITIZATION	12-1
<i>Why Prioritize?</i>	<i>12-1</i>
12.1 FISH PASSAGE BARRIER CORRECTION PRIORITY INDEX	12-1
<i>Barrier Correction Priority Index.....</i>	<i>12-1</i>
<i>Proportion of Passage Improvement</i>	<i>12-2</i>
<i>Annual Adult Equivalent Production Potential</i>	<i>12-2</i>
<i>Habitat Gain</i>	<i>12-2</i>
<i>Mobility Modifier.....</i>	<i>12-2</i>
<i>Species Condition Modifier.....</i>	<i>12-3</i>

<i>Cost Modifier</i>	12-3
12.2 SCREENING PRIORITY INDEX	12-3
<i>Screening Correction Priority Index</i>	12-4
<i>Flow</i>	12-4
<i>Annual Adult Equivalent Production Potential</i>	12-4
<i>Mobility Modifier</i>	12-4
<i>Species Condition Modifier</i>	12-5
<i>Cost Modifier</i>	12-5
12.3 ADDITIONAL CONSIDERATIONS	12-5

APPENDICES

APPENDIX A. GLOSSARY OF TERMS

APPENDIX B. SUMMARY OF MAJOR CHANGES

APPENDIX C. ESTIMATING FISH PASSAGE FLOWS

APPENDIX D. RECOMMENDED SURVEY EQUIPMENT

APPENDIX E. FIELD FORMS

APPENDIX F. PHOTOGRAPHY TIPS

APPENDIX G. MEASURING BANKFULL WIDTH

APPENDIX H. BASIC SURVEYING TECHNIQUES

APPENDIX I. HABITAT SURVEY SPREADSHEET EXAMPLE

APPENDIX J. INSTANTANEOUS FLOW RATE MEASUREMENTS

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 1

WELCOME TO FISH PASSAGE

Chapter 1 provides general information about the scope of this manual and the services provided by the Washington Department of Fish and Wildlife (WDFW) Fish Passage Program. It also introduces general fish passage inventory and assessment concepts and discusses project planning. A glossary of the words, terms, and abbreviations that are used in this manual can be found in Appendix A.

1.1 Introduction, Purpose, and Scope

The Fish Passage Inventory, Assessment, and Prioritization Manual (Manual) provides guidance for determining potential adult salmonid fish use at instream features, methods for determining whether an instream feature is an impediment to upstream adult salmonid migration, and a habitat evaluation protocol to prioritize fish passage barriers and poorly/un-screened diversions for correction. The methods described for determining potential adult salmonid fish use, and the criteria used for determining if an instream feature is a barrier to adult salmonids, have been used by WDFW and groups trained by WDFW for over 20 years. All other uses of these methods, e.g., determination of non-salmonid fish use, or to assess for juvenile fish passage, are outside of the scope of this manual.

Evolution of Manual

This manual was originally written in 1998 to provide standardized methods for evaluating fish passage conditions at water crossing structures. It has since been expanded to include evaluation protocols for additional instream features, including dams, fishways, surface water diversions, natural barriers, and miscellaneous obstructions. Revisions to the previous version of this manual (December 2009) are summarized in Appendix B.

Reasons for Updating the Manual

Since the publication of the 2009 fish passage manual, WDFW has solved numerous unforeseen challenges. Through the fish passage training program, WDFW has received insightful questions from participants, which have identified inadequacies in the 2009 protocols. Additionally, hydraulic analysis software has improved, allowing for the barrier determination of previously undeterminable crossings. The 2019 Manual provides data collection and analysis protocols for conditions that previously resulted in incomplete or incorrect barrier determinations.

Definition of ‘Adult Salmonid’

Consistent with earlier editions of the Manual, the term ‘adult salmonid’ is used to describe adults of the following species with a length \geq 6 inches: resident trout, sea run cutthroat trout, bull trout, steelhead, coho, sockeye, pink, chum, and Chinook.

‘Fish Use Potential’

Consistent with earlier editions of the Manual the term ‘fish use potential’ refers to the potential for adult salmonid use at an instream feature; a determination of ‘potential fish habitat’ is not intended to be an indicator of usability for all fish species and life stages. The criteria used for determining potential salmon habitat at an instream structure (‘biological’, ‘physical’, etc.) remain the same as those described in earlier editions of the Manual. Note that our criteria are similar to those used in Forest Practices, but should not be confused with Department of Natural Resources water typing.

Barrier Criteria

The successful upstream passage of adult salmonids continues to be the basis for barrier determinations. The criteria for velocity, depth, and water surface drop remain the same. A feature that is determined to be ‘passable’ using the methods described in the 2019 Manual, and earlier editions, is considered to be passable to adult salmonids and should not be construed to be passable for all salmonid species and life stages.

‘Culvert Case’ Injunction Implications

The permanent injunction regarding culvert correction, ordered 29 MAR 2013, states the Defendants shall use the barrier assessment methodologies in the Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual (WDFW 2000), or any later state barrier assessment standards, provided such standards are consistent with the terms of this injunction. WDFW affirms that the 2009 and 2019 editions of the Manual are consistent with the terms of the injunction.

Design Criteria

These methods were developed to provide technical guidance for the assessment of existing fish passage and diversion features and are NOT intended for design purposes. When a barrier to adult salmonid passage is discovered, a correction should be designed to pass all fish species at all mobile life stages, and meet the criteria described in applicable and current federal, state, and local regulations. Refer to WDFW’s Water Crossing Design Guidelines (2013) for information about the design of new water crossing structures. Be sure to check WDFW’s Fish Passage Program’s website periodically for any updates to the design manual.

1.2 WDFW Fish Passage Program Services

Training

WDFW provides formal training on the fish passage and habitat assessment protocols described in this manual. Course availability and registration are available on the WDFW fish passage training web-site. Please contact WDFW's Fish Passage training program coordinator directly by email at FishPassageTraining@dfw.wa.gov to register for training courses.

Technical Assistance

WDFW offers numerous fish passage and diversion screening services, including technical assistance for the information presented in this manual. The assessment methods described in this manual are applicative to most, but not all, situations you will encounter. For additional guidance, contact the WDFW Fish Passage Inventory, Assessment and Prioritization Section email address: FishPassageInventory@dfw.wa.gov.

Fish Passage Database

WDFW maintains the Fish Passage and Diversion Screening Inventory (FPDSI) database. The FPDSI database functions as a central repository for inventory data that has been collected throughout the state using the protocols described in this manual. It includes location and assessment data for fish passage and diversion features, salmonid use determinations, and habitat information. The FPDSI database can be used to identify and prioritize fish passage and screening projects that are vital to the recovery of Washington State salmonid.

1.3 Overview of Fish Passage Assessments and Prioritization

Fish Passage Features

This manual provides instructions to identify, assess, and prioritize human-made instream features that preclude or impede upstream fish passage. For the purpose of this manual and the FPDSI database, human-made fish passage features are classified as one of the following: culvert, non-culvert water crossing, dam, miscellaneous obstruction, or surface water diversions. Natural barriers may also be assessed for fish passage, however, they are not prioritized for correction.

Fishways may be attached to water crossing structures, dams, natural barriers, and other features to facilitate fish passage. If a fish passage feature has a fishway associated with it, both the primary feature and the fishway are evaluated together when assessing the site's fish passage conditions.

Fish Use

Fish passage and diversion assessments are only conducted on waterbodies with known or potential fish use by any anadromous or resident salmon or trout species. Chapter 2 provides

guidance for the determination of the potential fish utilization of habitat. For those waterbodies with known or potential fish use, physical measurements of the structure and adjacent watercourse are collected for analysis, as described in subsequent chapters.

Fish Passage Flows and Percent Passability

Barrier determinations are based on the ability of adult salmonids to migrate through, around, or over an instream feature. For the purpose of this manual, adult salmonids are defined as all salmonids ≥ 152 millimeters fork length.

For an instream feature to be considered a non-barrier, it should not obstruct upstream migration at any time between the low and high fish passage flows (Q_{fp}) at that location:

- Low fish passage flow is the 95% exceedance flow. The two-year, seven-day low flow may be used to determine the low fish passage flow.
- High fish passage flow is the 10% exceedance flow during the months of adult upstream migration.

Appendix C provides guidance for estimating fish passage flows in Washington State.

For features that are determined to be a fish passage barrier, a percent passability may be assigned that serves as a qualitative indicator of the barrier severity during fish passage flows. The percent passability of a barrier is a relative value that is frequently used for prioritizing barrier corrections. It is not a *quantitative* measure of the proportion of flows that allow fish passage through a feature, nor is it the percentage of fish that are able to successfully negotiate a feature.

Percent passability considers water surface drop, velocity, and/or depth, depending on the feature type and barrier criteria described in subsequent chapters. The water surface drop and velocity criteria are based on the swimming and leaping abilities of a 152 millimeter adult salmonid (including resident trout, searun cutthroat, etc). The depth criteria are based on the depth requirements of adult salmon. Therefore, the percent passability should not be interpreted as an absolute value for all salmonid species and life stages.

Percent passability estimates should be interpreted as follows:

- 0% passability indicates that the feature is a total barrier to some adult salmonids during a period within the range of fish passage flows.
- 33% passability indicates that the feature is a severe partial barrier to some adult salmonids during a period within the range of fish passage flows.
- 67% passability indicates that the feature is a moderate partial barrier to some adult salmonids during a period within the range of fish passage flows.
- 100% passability indicates that no adult salmonids should be impeded when attempting to pass through the feature during a period within the range of fish passage flows.

Prioritization

There are multiple ways to prioritize fish passage barriers and unscreened/insufficiently screened diversions for correction. The Priority Index (PI) for barriers and the Screening Priority Index (SPI) for diversions are prioritization models developed by WDFW that have been used statewide since the 1990s. The PI model factors the severity of the barrier (percent passability), species-specific production potential, the habitat obstructed by the barrier (quantity and suitability), species mobility (anadromous vs. resident), stock status (based upon Endangered Species Act-listing status), and the estimated cost of correction. The SPI model factors the amount of water diverted, species-specific encounter rates, species mobility, stock status, and the estimated cost of correction.

If an objective of the inventory effort is to generate PI and/or SPI values for a prioritized list of projects, it will be necessary to evaluate the habitat that is affected by each barrier or diversion. Chapter 10 describes a physical survey method that may be used to determine the estimated quantity and suitability of the affected habitat: the Reduced Sampling Full Survey (RSFS).

The PI and SPI are valuable tools when integrated with additional project considerations, such as funding availability, community support for the project, ongoing or recent restoration efforts within the watershed, the effects of upstream or downstream fish passage barriers, etc. The PI and SPI are described in more detail in Chapter 12.

1.4 Planning Fish Passage and Surface Water Diversion Inventories

Carefully planned inventories are the foundation of systematic fish passage correction and screening programs. Completing a comprehensive inventory and reporting priorities are crucial steps in developing salmonid recovery projects.

Defining the Goals and Scope of the Project

The first step to implementing a successful inventory and assessment program is to identify the goals of the project. For example, is the goal to inventory all transportation-related water crossing structures within a given jurisdiction? To identify all fish passage and surface water diversion features within an entire watershed? And/or to complete barrier assessments only in areas that are accessible to anadromous species?

When determining the geographical scope of your inventory project, be sure to consider your goals, priorities, budget, staffing, and other factors. If your goal is to conduct a thorough inventory of all instream features within a watershed, be sure to request enough funds to complete the work. If sufficient funds are not available, then scale-back your goal accordingly. Remember, inventories can be funded and completed over multiple years.

Table 1.1 shows a comparison of common inventory methods. The advantages and disadvantages of each method are described in the following subsections. WDFW recommends conducting the most comprehensive inventory possible to avoid having data gaps which may need to be filled

later. However, it is recognized that the scope of inventory efforts can be limited due to numerous factors, such as funding or property access constraints.

Road-based Culvert Inventory

Road-based inventories are most commonly implemented by entities interested in identifying barrier culverts within a particular jurisdiction or area of interest, e.g., a municipal public works department surveying all city streets within the Urban Growth Area.

Advantages

- Easy access by vehicle
- Quicker than conducting an inventory by foot
- Less costly than conducting a comprehensive watershed-based inventory

Disadvantages

- Missed water crossings at roads that are not accessible by vehicle
- No other instream features (human-made or natural) are inventoried and assessed if they are not within the target ownership or jurisdiction
- No habitat assessment
- Cannot prioritize barriers for correction using the PI model

Road-based Culvert Inventory with Habitat Assessment at Barriers

This project type is similar to the aforementioned inventory, but includes a habitat assessment at human-made barriers for the purpose of prioritization.

Advantages

- Can prioritize human-made barriers
- Can identify additional instream features, such as natural barriers to anadromous access, downstream and upstream of a barrier culvert during habitat survey
- Allow for the determination of potential species use upstream and downstream of a barrier.
- Less costly than conducting a comprehensive watershed-based inventory

Disadvantages

- Missed water crossings at roads that are not accessible by vehicle
- No other instream features (human-made or natural) are inventoried and assessed if no barrier culverts are identified

Watershed-based Fish Passage and Diversion Inventory with Habitat Assessment

Advantages

- Identify and assess all instream fish passage features and surface water diversions
- Can prioritize all human-made barriers and unscreened/insufficiently screened diversions in the watershed
- Can identify additional instream features, such as natural barriers to anadromous access, downstream and upstream of a barrier culvert during habitat survey
- Allow for the determination of potential species use upstream and downstream of a barrier.

Disadvantages

- Typically costs more than other inventory and assessment efforts

As part of the planning effort, estimate the number of stream kilometers that may be walked by map measuring stream distances. The Statewide Integrated Fish Distribution (SWIFD) map data is a good resource for identifying potentially fish-bearing streams. View the species distribution in your area of interest in the SWIFD map viewer: <https://geo.nwifc.org/swifd/>. Keep in mind that there are numerous unmapped drainages statewide, and potential salmonid use may extend upstream of the mapped distribution.

WDFW crews inventory an average of 1.6 linear stream kilometers per day. The distance surveyed depends on terrain, access, vegetation density, the number of instream features to inventory and assess, and various other factors. It generally takes 30-45 minutes to inventory and assess each fish passage and diversion feature. A mapping exercise should be used to plan routes, approximate travel time, and estimate the number of water crossings that may be encountered.

Estimating Time Requirements

Table 1.1. Comparison of common inventory efforts.

EFFORT	INVENTORIED & ASSESSED		
	Transportation-Related Water Crossing Structures	All Fish Passage & Surface Water Diversion Features	Prioritization of Human-made Barriers & Unscreened/Insufficiently Screened Diversions
Road-based Culvert Inventory	✓		
Road-based Culvert Inventory with Habitat Assessment at Barriers	✓	* ✓	* ✓
Watershed-based Fish Passage & Diversion Inventory with Habitat Assessment	✓	✓	✓

* if barrier discovered - other features may be identified & prioritized during habitat survey (Chapter 10)

Existing Data

Prior to conducting an inventory, contact WDFW to obtain reports from the FPDSI database. Having a copy of FPDSI reports in the field will speed up data collection. For previously inventoried features, field crews may only need to verify and update information. FPDSI reports can also be obtained through the Washington State Fish Passage Map Application - <http://apps.wdfw.wa.gov/fishpassage/>.

Field Gear and Safety Equipment

When developing your project's budget and scope of work, consider the recommended equipment items in Appendix D. WDFW crews regularly use this equipment when conducting inventories and can offer additional advice on selecting field gear.

Field Forms

Printable versions of all the field forms described in this manual are available in Appendix E. Field forms may be updated more frequently than the other sections of this manual. Visit WDFW's Fish Passage website to download this manual and ensure you are using the most updated field forms.

Obtaining Landowner Permission

Respect private property. Landowner permission needs to be secured to complete most inventories and habitat assessments. Prior to conducting fieldwork, always seek landowner permission to enter private property. County tax records and parcel maps may be reviewed to identify land ownership for the purpose of securing access. Document stream reaches where landowner permission is denied. It is important to report which areas of the watershed have not been inventoried.

1.5 Data Sharing and Coordination

Fish passage and screening inventories fill important data gaps in prioritization analyses, lead entity strategies, and species recovery plans. It is important to have a project manager provide inventory data to WDFW for incorporation into the FPDSI database, where it will be available to a variety of entities interested in salmonid recovery.

Updating the FPDSI Database

In general, due to the dynamic nature of the stream environment, barrier assessments have a limited life expectancy. Inventories should be updated as barriers are corrected, new culverts are installed, and previously passable culverts become barriers.

WDFW should be contacted whenever fish passage barriers are corrected and diversions are adequately screened so that the FPDSI database can be kept current. New data and corrections may be submitted via email: FishPassageInventory@dfw.wa.gov, or by using the data Edit Tool in the Washington State Fish Passage Map Application - <http://apps.wdfw.wa.gov/fishpassage/>.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 2

SITE INFORMATION

Whenever a human-made instream feature or natural barrier is encountered, basic information is collected to describe the site where the feature is located. This information includes a determination of the potential for fish utilization, geographic coordinates, classification of the feature type(s), and ownership. Try to collect as much information as possible while in the field. However, some information may be obtained back in the office, such as stream name, WRIA number, species utilization, and ownership information.

2.1 Site Description

Activities

The following is a summary of general activities conducted at each new fish passage site:

- Complete the Site Description Field Form (Figure 2.1) for each human-made or natural instream feature inventoried.
- Collect location information.
- Determine the type of instream feature(s) at the site.
- Determine the potential for salmonid fish use.
- Note the conditions in the vicinity of the feature(s).
- Record owner information.

Data Collection

Detailed explanations of the data fields in the Site Description Field Form (Figure 2.1) are provided in the following subsections and summarized in the Quick Reference Table (Table 2.2) in Section 2.2.

Site ID - The Site ID is a unique identifier used to distinguish individual sites in the FPDSI database and to relate multiple field forms when there is more than one associated feature, e.g., a dam with a fishway. Record the appropriate Site ID if one has already been assigned in the FPDSI database, or contact WDFW for a list of available Site IDs that may be assigned to sites not currently in the database.

Identifying Group - Record the name of the agency/organization responsible for the data collection.

SITE DESCRIPTION FIELD FORM (1/2/2018)

¹Site ID _____ ²Identifying Group _____

³Latitude _____ ⁴Longitude _____

⁵Road Name _____ ⁶Milepost _____

⁷County _____ ⁸WRIA # _____

⁹Stream Name _____ ¹⁰Tributary To _____

¹¹Location/Directions _____

¹²Feature Type Culvert Non-Culvert Crossing Dam
 Misc. Obstruction Natural Barrier Fishway Diversion

¹³Fish Use Potential Yes No Unknown

¹⁴Fish Use Criteria Biological Mapped Physical Other

¹⁵Species Chinook Chum Sockeye/Kokanee Coho Pink
 Steelhead Sea Run Cutthroat Bull/Dolly Varden Trout
 Resident Cutthroat/Rainbow Trout

¹⁶Site Comments _____

¹⁷OWNER INFORMATION

Type Federal State County City Tribal Private Other

Name _____

Street Address _____

Mailing Address _____

City _____ State _____

Zip Code _____ Phone (_____) _____ - _____

Contact Name _____

Contact Phone _____

Figure 2.1. Site Description Field Form. Superscript numbers correspond with superscript numbers in Table 2.2. A printable version of this field form is available in Appendix E.

Latitude/Longitude - Determine the geographic position of the site based upon the World Geodetic Survey 1984. It is best to retrieve geographic coordinate data in the field with a differentially correctable Global Positioning System unit to avoid confusion about the feature location. Coordinates should be collected at the most downstream end of the feature, e.g., the outlet of a culvert. Record the coordinates in decimal degrees using seven significant figures after the decimal.

Road Name - If a roadway is associated with the feature, record the name of the road. If the road is unnamed, provide a short description, e.g., 'private driveway'.

Milepost - If mileposts are present on a roadway associated with the feature, measure the distance between the fish passage site and the nearest milepost. Record to the nearest 0.01 mile.

County - Record the county in which the feature is located.

WRIA # - Record the Water Resource Inventory Area (WRIA) number and the stream catalogue number, if one is available. The WRIA number is a unique, two-digit watershed identifier within Washington State (1-62). Within each WRIA the streams are further categorized according to a system of four-digit stream catalogue numbers, e.g., "0012", which identify specific streams. If the stream is catalogued, record the WRIA number, followed by a decimal, followed by the stream catalogue number, e.g. "23.0012". If the waterbody is not catalogued, enter the two-digit WRIA number only.

Stream Name - Record the name of the waterbody where the feature is located. Use federally recognized names, if registered in the Geographic Names Information System. If not registered, a well-established local name may be used. If neither is available, record 'unnamed'.

Tributary To - Record the name of the downstream waterbody into which the waterbody described in 'Stream Name' flows. Apply the same naming convention described for recording 'Stream Name'. If the downstream waterbody is unnamed, record 'unnamed', followed by the name of the next downstream waterbody that *is* named, followed by the word, 'trib'. E.g., 'unnamed Pickle Cr trib'.

Location/Directions - Note landmarks, driving directions, and/or access information that assists with locating the feature.

Feature Type - Select all of the feature types assessed at the site.

Fish Use Potential - Fish Use Potential is a determination of the potential utilization of habitat by native trout or salmon. It may be difficult to determine fish use at a site based solely upon direct observations of fish due to poor visibility, low escapement levels, the existence of human-made barriers, or other factors. There are a number of methods that may be used to determine if a site has the potential to provide fish habitat. Satisfaction of one or more of the following Fish Use Criteria qualifies habitat as having the potential for fish use.

Note: fish use potential is potential habitat utilization absent any anthropogenic disturbance. Fish use potential is not restricted by man-made barriers, e.g., if a stream meets any of the fish use criteria below, then there is the potential for fish use.

Fish Use Criteria - Fish Use Criteria are the basis for the Fish Use Potential determination. For the purpose of this manual, there are four criteria used for determining whether a waterbody has the potential for salmonid fish use: biological, mapped, physical, and other.

- ‘Biological’ is the visual observation of trout or salmon during a site visit.
- ‘Mapped’ fish use refers to waterbodies listed as fish-bearing by a reliable mapping data source, such as SalmonScape: <http://wdfw.wa.gov/mapping/salmonscape/>
- ‘Physical’ is based on measurements of gradient and scour line width (SLW). A waterbody meets the physical criteria for potential salmonid fish use if the following condition is met immediately upstream of the feature, outside of culvert influence:
 - A sustained gradient does not exceed 20% for a distance greater than 160 meters. See Chapter 7 (Natural Barriers) for additional instruction on measuring gradients.
 - Average SLW is at least 0.61 meters in western Washington, or at least 0.91 meters in eastern Washington. See Figure 2.2 for a description and diagram of the SLW measurement in a typical stream channel. See Figure 2.3 for the delineation of eastern and western Washington.
- ‘Other’ may be used when other criteria do not apply, but there is a reliable data source available that confirms salmonid use, e.g., a published study or report from a local biologist that documents fish presence.

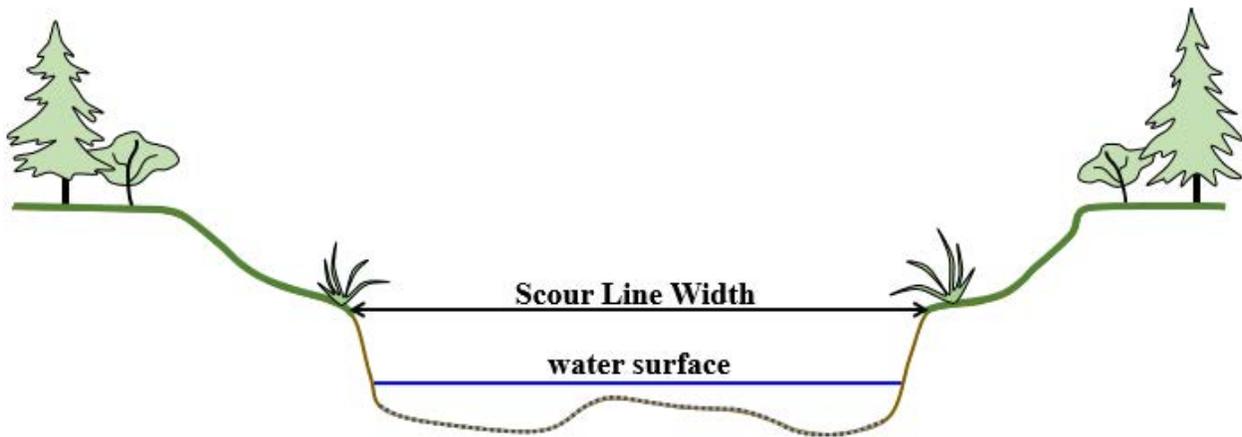


Figure 2.2. Diagram of the SLW measurement in a typical stream channel. The SLW includes everything within the active channel where stream flow is expected during winter flows. Scour lines are produced as a result of water action that occurs with enough frequency to leave a distinct mark upon the soil or vegetation. Look for indicators such as a line left by debris, pollen, or silt, and/or marks made by erosion or destruction of terrestrial vegetation. Measure SLW as the horizontal distance between the scour lines on both banks, perpendicular to the thalweg, and outside the area where normal stream function is influenced by an instream feature. Take several SLW measurements within representative channel segments to calculate an average.

Make every effort to determine the fish use potential while in the field. It is important to document any visual observation of fish use at a site. If you observe salmon or trout during your site visit, select Biological for Fish Use Criteria and comment on what species/age class was observed. Note: electrofishing or other fish surveying methods may be used to confirm fish presence, but not absence.

If no native salmonids are observed, apply the Physical criteria described in the previous section. Use professional judgment when applying physical criteria to determine the potential for salmonid fish use. Some waterbodies may not have scour marks, but still have the potential to support fish use; this is common in wetland conditions.

Map applications may support a field determination of potential fish according to physical criteria. Because map data are continually updated, WDFW recommends consulting more than one map application when verifying fish use. If you discover that a waterbody has mapped salmonid use, select 'Mapped' rather than 'Physical'. If you are still unsure about a site's potential to support fish use, you may select 'Unknown' for Fish Use Potential.

If active fish exclusion structures exist downstream, such as screened diversions, please make note of those structures, and, if available, provide supplementary info about those structures when submitting site data to WDFW. The presence of fish exclusion structures may influence the determination of fish use potential.

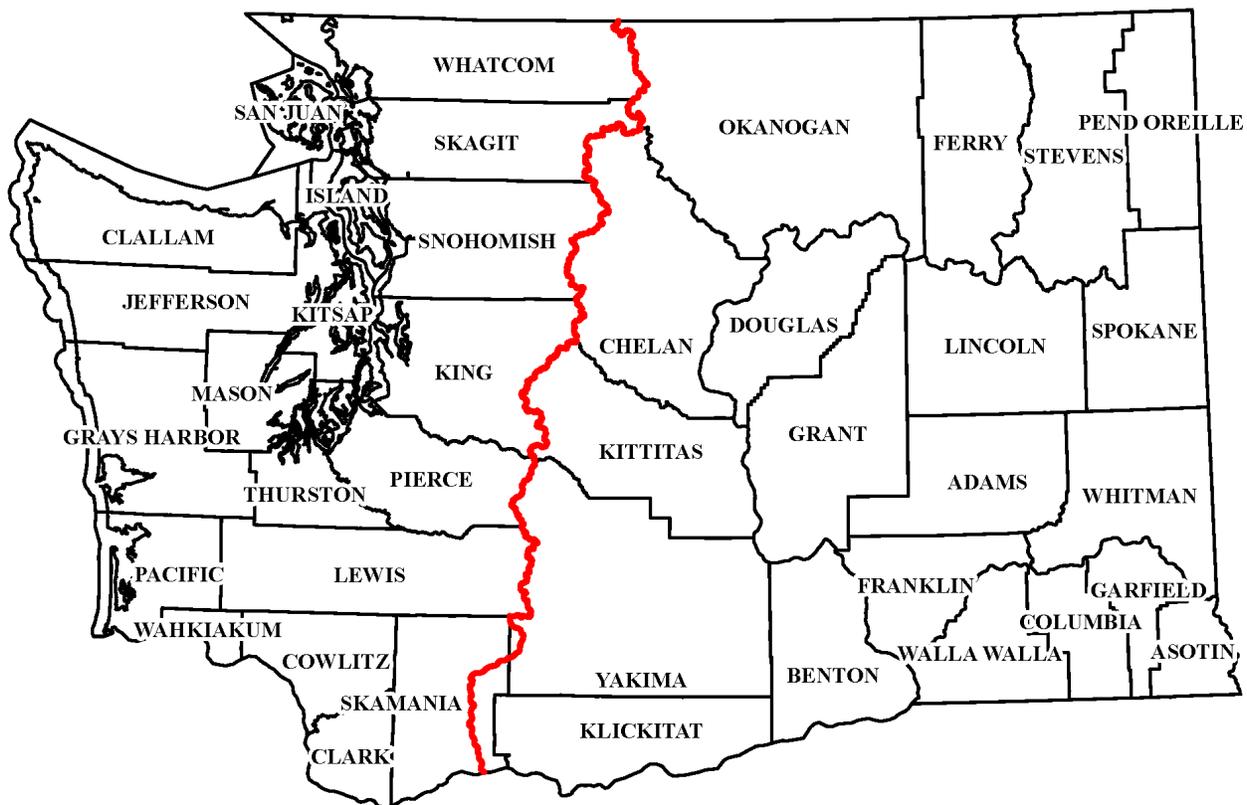


Figure 2.3. Western/Eastern Washington Divide Line. Eastern Washington is the geographic area east of the crest of the Cascade Mountains from the international border to the top of Mt. Adams (Washington Administrative Code 222-16-010, 2013).

Species - Determine which salmonid species can access the feature *and* potentially utilize the habitat upstream of the feature, assuming a lack of downstream human-made barriers. If potential species access or utilization is unknown, contact local biologists or consult online resources.

Online salmonid distribution resources include:

- SalmonScape - (<http://apps.wdfw.wa.gov/salmonscape/>) – An online, interactive, computer mapping system displaying the distribution of most Washington State salmonids, in addition to other species. Fish distribution is drawn from the Statewide Washington Integrated Fish Distribution database, and displayed according to species and run. The database includes a series of distribution types, such as documented, presumed, potential, and modeled use. Typically if a species has documented, presumed, or potential distribution it should be included in the list of species expected to benefit. If the distribution is modeled, take into account additional habitat observations, such as stream dimensions, downstream natural barriers, etc. when determining if that species can access the feature.
- Washington Stream Catalog - (http://www.streamnetlibrary.org/?page_id=95) – The online home of a large, comprehensive report, originally released in 1975. Divided into WRIAs, the catalogue provided a comprehensive view of present (as of 1975) and future fish status in Washington State.
- Washington State Fish Passage Map Application - (<http://apps.wdfw.wa.gov/fishpassage/>) – A centralized database of fish passage features throughout Washington State. The application has a number of helpful operational layers in the context of fish passage, including the fish distribution and ESA listing unit data from SalmonScape.

Fish distribution data from online resources is often spotty or incomplete, especially for smaller streams. Species known to be present in the main stem, are assumed to be present in the tributaries, providing the tributaries are accessible (or can be made accessible if all human-made barriers are removed) and do not exceed the normal upper gradient limits for the species (Table 2.1).

The upper gradient limit of salmonid species is used to determine habitat utilization upstream of a fish passage feature. Table 2.1 illustrates expected rearing and spawning utilization within different gradient ranges (solid green cells), and gradients that species may pass through (crossed-out yellow cells), even though they are not expected to exploit that habitat. Reaches that are neither usable nor passable are indicated by a blank box. For the purposes of assigning potential species use at a fish passage feature, only include species that can spawn or rear (i.e., “utilize”) the habitat upstream of the feature.

Table 2.1. Gradient ranges of anadromous salmonid utilization. Each cell of the table represents a specific gradient range. Solid green cells indicate that reaches with usable spawning and rearing gradients. Crossed-out yellow cells indicate that the species can pass through the reach with the gradient range, but do not utilize the habitat for spawning or rearing. Blank cells indicate that the reach is not usable and is impassable.

Species	Gradient (%)						
	0-3	3-5	5-7	7-12	12-16	16-20	20+
Chum		X					
Pink				X			
Coho				X	X		
Sockeye				X	X		
Chinook				X	X		
Steelhead					X	X	
Sea Run Cutthroat					X	X	

Resident trout and bull trout/Dolly Varden are expected to utilize habitat up to 20% for both rearing and spawning. While it is recognized that they may pass through gradients as high as 33%, for the purposes of this manual a 20% gradient threshold is considered the upper limit of spawning and rearing habitat, as well as fish passage for salmonids (See Chapter 7).

Site Comments - Record comments that describe conditions in the vicinity of the feature. Appropriate comments may include a note of beaver activity, land use, an observed head cut, fencing across stream, etc.

Owner Information - Record the type (e.g., county, city, private) and general contact information for the owner of the feature.

Photographing the Site

Photos of the site and feature provide useful supplementary data. Photograph the downstream and upstream ends of the feature, and stream habitat in the vicinity of the feature. Attempt to clear any vegetation or debris that may be obscuring the view. You may also photograph any notable conditions, fish that are observed, etc. It is useful to have a person or a stadia rod in the photo for scale. Appendix F provides more guidance for photographing a feature site.

Safety

Always use extreme caution when working around roadways and waterbodies. Do not take measurements or photos when it is unsafe to do so. High flows, deep plunge pools, and steep embankments are examples of conditions that may make it challenging to collect some or all of

the measurements and/or photos. Safety considerations always override data collection requirements.

Instream Features That Do Not Require a Fish Passage or Screening Assessment

You do not need to assess an instream feature's fish passage or screening conditions if there is no potential for salmonid fish use at the site. For example, a feature located in a non-natural drainage that meets the Physical criteria for potential fish use, but does not have a downstream connection and only contains flow for a short duration during flood events (a condition common with human-made roadside ditches), does not require a fish passage assessment. Another, less common, example is a feature located on a total natural barrier, e.g., a culvert or dam installed on a total barrier waterfall, as described in Chapter 7. If the natural barrier has historically precluded upstream fish migration, then correcting the human-made barrier will not benefit fish passage at that site, and therefore an assessment of fish passage is not necessary.

If you determine that the instream feature does not require a fish passage or screening assessment, select 'No' for Fish Use Potential on the Site Description Field Form and describe the conditions in the Site Comments. Include a description of any channel measurements (scour line widths, measurement interval, gradients, etc.) In the associated feature form (Appendix E) you may record the structural dimensions and a general description of the feature, but do not evaluate the site for fish passage or screening.

2.2 Quick Reference Table

Table 2.2 Data collection attributes for the Site Description Field Form (Figure 2.1; Appendix E). Superscript numbers correspond with superscript numbers in Figure 2.1. Predefined values are indicated in **bold** text.

Field	Description
¹ Site ID	Unique identifier used to distinguish individual sites in the database and to associate feature field forms with the Site Description Field Form.
² Identifying Group	Name of organization responsible for data collection.
³ Latitude	Northerly geographic position of feature in decimal degrees (WGS84) using 9 significant figures, e.g., 48.1234567.
⁴ Longitude	Westerly geographic position of feature in decimal degrees (WGS84) using 10 significant figures, e.g., -122.1234567.
⁵ Road Name	Name of road, if roadway associated with feature. If unnamed, provide short description, e.g., 'private driveway'.
⁶ Milepost	Milepost (to nearest 0.01 mile) where feature is located, if applicable.
⁷ County	County in which feature is located.
⁸ WRIA #	Enter the six-digit stream identifier when available. The first two digits are the WRIA number (1-62), the remaining four digits are the stream catalogue number. If there is no four-digit stream number, record the two-digit WRIA number at the least.
⁹ Stream Name	Name of the stream where the feature is located. If the stream is unnamed, record 'unnamed'.
¹⁰ Tributary To	Name of the downstream waterbody to which the stream (above) is connected. If the receiving waterbody is unnamed, record 'unnamed' followed by next downstream named waterbody, e.g., 'unnamed Pickle Cr trib'.
¹¹ Location/Directions	Location of feature relative to landmarks or driving directions.
¹² Feature Type	Type of feature(s) being assessed: Culvert, Fishway, Dam, Non-Culvert Crossing, Gravity Diversion, Pump Diversion, Natural Barrier, Other . More than one may be selected.

¹³ Fish Use Potential	Indicator of potential salmonid fish use in stream where feature is located. Values are Yes , No , and Unknown .
¹⁴ Fish Use Criteria	Basis for Fish Use Potential determination (above). Biological indicates that trout or salmon have been directly observed. Mapped indicates that the stream is mapped as fish-bearing in water type maps, <i>SalmonScape</i> , or other resource. Physical indicates the stream meets the minimum physical dimensions specified in Washington statutes pertaining to water typing. Other indicates that criteria other than those listed above were used to determine Fish Use Potential - explain in comments.
¹⁵ Species	Salmonid species that can access the feature <i>and</i> potentially utilize the habitat upstream of the feature, assuming a lack of downstream man-made barriers. Species include: Chinook, Chum, Sockeye/Kokanee, Coho, Pink, Steelhead, Resident Cutthroat/Rainbow Trout, Sea run Cutthroat, Bull/Dolly Varden Trout.
¹⁶ Site Comments	Concise comments describing the conditions in the vicinity of the feature.
¹⁷OWNER INFORMATION	
Type	General category of ownership: Federal, State, County, City, Tribal, Private, Unknown.
Name	Name of feature owner, e.g., "City of Olympia".
Street Address	Street address of feature owner.
Mailing Address	Mailing or secondary address of feature owner, if different than street address.
City	Name of city.
State	Two character abbreviation for state (e.g., WA).
Zip Code	Standard zip code, or zip plus 4-digit extension.
Phone	Ten-digit phone number in format (123) 456-7890.
Contact Name	Name of contact, if different than owner.
Contact Phone	Phone number for contact, if different than owner.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 3

CULVERTS

This chapter describes the inventory and assessment of culverts. For the purpose of this manual and the FPDSI database, culverts are differentiated from bridges and dams. Guidelines for the classification of culverts, bridges, and dams are described in Section 3.1.

For all culverts, regardless of fish use, information is collected to describe the structure (shape, material, dimensions). If the site is located within potential fish habitat (as described in Chapter 2), then data is collected to assess fish passage conditions through the structure. Barrier determinations are based on the ability of adult salmonids to migrate through a culvert during fish passage flows (as described in Chapter 1).

This chapter describes two methods for assessing fish passage through culverts: Level A culvert assessment (Section 3.3) and Level B hydraulic analysis (Section 3.4). The Level A may be used to make barrier determinations on culverts that are obviously barriers or obviously non-barriers. If the barrier status of a culvert cannot be determined by the Level A, then proceed to collect Level B data. The Level B is a more advanced hydraulic evaluation, used to determine whether a culvert meets velocity and depth criteria for fish passage.

For additional assistance evaluating the barrier status of culverts, collect the measurements described in this chapter and any additional relevant information, then contact the WDFW Fish Passage Program for technical assistance: FishPassageInventory@dfw.wa.gov

Culverts in Tidal Areas

There are numerous information gaps regarding the effects of culvert hydraulics on fish behavioral in tidal areas. A provisional framework for assessing fish passage at culverts in areas with tidal influence is currently in development. These technical guidelines, titled 'Draft Guidance for Evaluating Fish Passage at Tidally-Influenced Culverts', are expected to be updated as new information emerges and fish passage analysis methods are subsequently revised to apply the best available science. Periodically visit the Fish Passage web-site to review developments in this draft guidance, and to ensure you are applying the most updated protocols.

If culvert hydraulics are affected by tidal activity, complete the Level A data collection described in Section 3.3 and refer to the tidal protocol for the most current information in regards to making a barrier determination. The Level A flowchart (Figure 3.19), multiple culvert key (Box 1), and Level B hydraulic analysis (Section 3.4) are not applicable to tidal culverts.

3.1 Classification of Culverts

Fish passage structures come in a multitude of designs. Classifying a structure as either a culvert or alternate feature type is often ambiguous, requiring presumptions about the purpose of the structure.

Bottomless Culverts in Contrast to Bridges

The criteria for classifying a water crossing structure as a bridge or culvert varies throughout federal, state, and local regulations, design guidelines, inspection manuals, etc. For the purpose of this manual, all four-sided structures are classified as culverts. Bottomless culverts are differentiated from bridges by comparing the span of the structure to the bankfull width. If the span of a bottomless water crossing structure is greater than the bankfull width, classify the structure as a bridge and refer to Chapter 4 for data collection. If you have specific knowledge that a structure was permitted as a culvert, then it should be inventoried and assessed as a culvert, even if the span is greater than BFW. Instructions for measuring span and bankfull width are described in Section 3.3.

Culverts in Contrast to Dams

For the purpose of this manual, a culvert designed for water detention, water impoundment, or to elevate the upstream water surface is classified as a dam.

A culvert that functions as a dam may be equipped with a hydraulic control structure such as a vertical standpipe, flow control gate, flashboards or stoplogs, etc. (see Chapter 5 for more information). However, not every culvert with a hydraulic structure is considered a dam. Some examples of culverted structures that are not classified as dams include:

- A culvert with a tide gate designed primarily to prevent saltwater intrusion to the upstream end.
- A culvert with a floodgate, or other flood protection structure, designed primarily to prevent backflow into an agricultural area during high flows.
- A culvert with an attached riser, with or without a trash rack or debris cage, designed primarily to prevent sediment and floating debris from plugging the culvert.
- A culvert with a sediment sump designed primarily to retain sediment.

These are not classified as dams because their primary purpose is not to detain or impound water, or to elevate the upstream water surface.

A culvert may also function as a dam without any associated hydraulic structure or flow control device. For example, a culvert may be deliberately undersized or installed at a higher elevation than the channel for the primary purpose of detaining water at the upstream end. In this situation, the culvert is acting as the hydraulic control structure, and is classified as a dam. However, a culvert that unintentionally impounds water is not classified as a dam. For example, an undersized or failing culvert that slows water conveyance, inadvertently raising the water surface elevation on the upstream end, is not classified as a dam.

If a culverted structure is determined to be a dam, collect the Level A culvert assessment data as described in this chapter, and refer to Chapter 5 for the descriptive information, physical measurements, and barrier evaluation for a dam.

3.2 Culverts - Inventory Overview

Activities

The following is a summary of the general activities conducted at each culvert site with the potential for salmonid fish use:

- Complete the Site Description Field Form in Appendix E (instructions for this form are provided in Chapter 2).
- Record descriptive information and physical measurements using the applicable field forms in Appendix E:
 - Level A Culvert Assessment Field Form (Figure 3.2).
 - Level B Hydraulic Analysis Field Form (Figure 3.22).
 - Fishway Description Form (Chapter 8).
- Evaluate the feature for barrier status and percent passability.
 - Use the Level A flowchart (Figure 3.19) or multiple culvert key (Box 3.2), if applicable.
 - Use the percent passability tables (Table 3.1 and 3.2).
- Photograph the inlet and outlet of the culvert structure, as well as any peculiarities at the site. Stand at a distance from the structure so that the photos provide environmental context. Appendix F provides guidance for photographing a culvert.
- If the culvert is a fish passage barrier and correction prioritization is desired, then conduct a habitat assessment (Chapter 10).

Culvert Structural Definitions

The Level A culvert assessment and Level B hydraulic analysis require measurements at specific locations of the culvert. At any given cross section of the culvert, the invert is the lowest elevation point inside of the culvert, the soffit is the highest elevation point inside of the culvert, and the crown is the highest elevation point on the outer edge of the culvert (example in Figure 3.1).

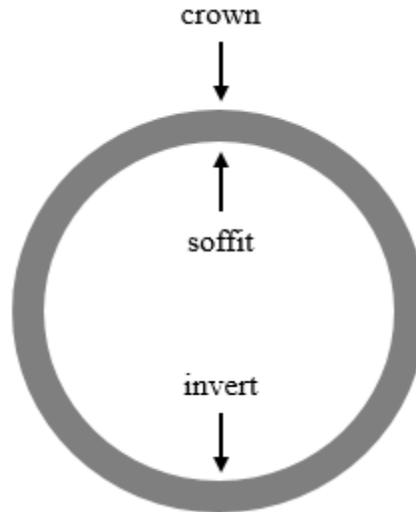


Figure 3.1. Cross section diagram of a round culvert. The invert and soffit are referenced in multiple Level A and Level B measurement descriptions.

Elevation Surveying Techniques

The elevation measurements required for the Level A culvert assessment and Level B hydraulic analysis do not need to be absolute elevations, i.e., not from sea level; rather, elevations need only be relative and referenced to a local, temporary datum.

There are multiple types of surveying equipment available for collecting elevation data. Surveying equipment must have the precision and accuracy to measure vertical distances to the nearest centimeter (0.01 meter).

This chapter provides general information for setting up surveying equipment and basic instructions for calculating relative elevations. The actual calculation formulas will vary based on the type of surveying equipment used. Appendix H provides detailed information on surveying techniques, using a variety of elevation surveying equipment.

3.3 Level A Culvert Assessment

The purpose of the Level A culvert assessment is to collect basic information about culverts in potentially fish bearing waters (e.g., structural dimensions), and to make a barrier determination on culverts that are obviously barriers or the most obvious non-barriers. The majority of culverts can be classified as barriers or non-barriers using just the Level A culvert assessment.

It generally takes about 20 minutes to complete the Level A data collection in the field. Site-specific factors that may increase the time needed for a Level A assessment include high traffic volume, deep road fill, multiple non-overflow culverts at a single water crossing, long culverts, dense vegetation, and other conditions that require moving the elevation surveying equipment or limit accessibility to the structure.

LEVEL A CULVERT ASSESSMENT FIELD FORM (5/22/2018)

¹Site ID _____ ³Crew _____
²Culvert Number _____ ⁴Date _____

CULVERT DESCRIPTION

⁵Material PCC CPC CST SST CAL SPS
 SPA PVC TMB MRY OTH

⁶Span _____ ⁷Rise _____ ⁸Water Depth in Culvert _____

⁹Shape RND BOX ARCH SQSH ELL OTH

¹⁰WS Drop _____ ¹¹Drop Location Outlet Inlet Interior

¹²Apron None US DS Both ¹³Total Length _____

¹⁴Culvert Slope _____ ¹⁵Road Fill Depth _____

¹⁶Countersunk Yes No ¹⁷Backwatered Yes No Unk

¹⁸Gate Yes No ¹⁹Rack Yes No ²⁰Fishway Yes No

CHANNEL DESCRIPTION

²¹Bankfull Width _____ ²²Span/Bankfull Width _____

²³Tidal Influence Yes No Unk

PLUNGE POOL DESCRIPTION

²⁴Pool Length _____ ²⁵Pool Maximum Depth _____

²⁶Pool Scour Line Width _____

BARRIER STATUS

²⁷Barrier Yes No Unk

²⁸Method LA LB Fishway Other

²⁹% Passability 0 33 67 100 Unk

³⁰Significant Reach Yes No Unk

³¹Comments _____

Figure 3.2. Level A Culvert Assessment Field Form. The superscript values in the field form correspond to the superscript values in Table 3.3. **Note:** Field forms are updated frequently; visit WDFW’s Fish Passage website to download this manual and to ensure you are using the most updated field forms.

Detailed explanations of the data fields in the Level A field form are provided in the following subsections and summarized in the Quick Reference Table (Table 3.3) in Section 3.6.

Header

For each culvert, record the FPDSI Site ID, observers, and the date of inventory. Fields in the header resemble the Site Description Field Form (Chapter 2). See Table 3.3 for brief header field descriptions.

Culvert Number - When there are multiple culverts at a single water crossing, you must determine which culverts to assess for fish passage and which culverts, referred to as “overflow culverts”, function solely for relief during high flow events. Overflow culverts are not assessed for passability, and are not assigned a culvert number.

To identify any overflow culverts, go to the upstream end of the site and determine which culvert within the main channel (i.e., the watercourse with the majority of the flow) has the lowest inlet invert elevation; this is the primary culvert. If any culvert has an inlet invert elevation that is higher than the vertical midpoint elevation of the primary culvert, then that culvert is considered an overflow culvert (examples in Figures 3.3 & 3.4). If the primary culvert is nearly or completely buried, contact WDFW Fish Passage division for inventory and assessment guidance.

Culverts that are not within the same bankfull of the primary culvert are also considered overflow culverts, regardless of invert elevations. Refer to Appendix G for information about determining bankfull.

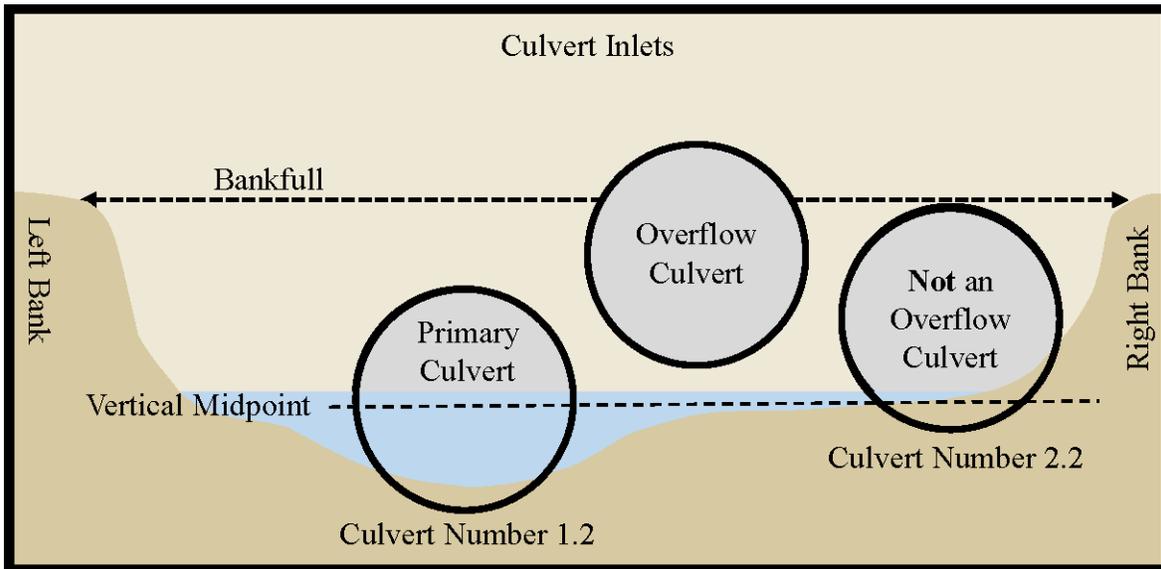


Figure 3.3. Overflow culvert diagram. The primary culvert has the lowest inlet invert elevation in the main channel. Any other culvert that is within the same bankfull, and has an inlet invert elevation below the vertical midpoint of the primary culvert, is assigned a culvert number and assessed for fish passage. Any other culvert that is not within the same bankfull, or has an inlet invert elevation above the vertical midpoint of the primary culvert, is considered an overflow culvert and should not be assessed for fish passage.

The 'Culvert Number' field on the Level A Field Form is used to distinguish between the non-overflow culverts. The non-overflow culvert closest to the left bank (on your left when looking downstream) is assigned Culvert Number 1.X, where X is the total number of non-overflow culverts at the water crossing. Working from the left to right bank, increase the culvert number sequentially, i.e., 2.X, 3.X, and so on for each non-overflow culvert (see Figure 3.3). When there is only a single culvert at a site, the Culvert Number is '1.1'.



Figure 3.4. Photo examples of multiple culverts at a single water crossing. A) three non-overflow culverts. The culvert number for the culvert nearest the left bank is 1.3, the middle culvert number is 2.3, and the culvert number for the culvert nearest the right bank is 3.3. **B)** two non-overflow culverts and one overflow culvert. The culvert number for the culvert nearest the left bank is 1.2 and the culvert number for the culvert nearest the right bank is 2.2. The top middle culvert's size, shape, and material are described in the comments, e.g., '0.61 m round corrugated steel overflow culvert', and is not assessed for fish passage.

Multiple-cell culverts have central vertical wall stretching the length of a box culvert, dividing it into parallel cells. Multiple-cell culverts should be evaluated as multiple culverts, and numbered according to the conventions described above.

Complete only one Site Description Field Form (Chapter 2) for all culverts at a single water crossing; they will all have the same Site ID. Complete separate Level A field forms (Figure 3.2; Appendix E) for each non-overflow culvert. The span, rise, and material of any overflow culverts are recorded in the comments section of culvert 1.X.

Culvert Description

Material - Determine the construction material of the culvert interior (Figure 3.5).

Precast Concrete (**PCC**) culverts come in all shapes and are typically manufactured in uniform sections that can be fit together during installation. PCC culverts may have a flange or collar on the end that is used to fit into the abutting section.

Cast-in-Place Concrete (**CPC**) culverts are typically bottomless or box shape and constructed at the installation site. Look for evidence of the forms that were used to shape and pour the concrete structure, e.g., seams at the ends of form boards, or woodgrain impressions.

Corrugated Steel (CST) and Corrugated Aluminum (CAL) are differentiated based upon what material provides for the structure of the crossing. Look for rust, or use a magnet to differentiate between steel and aluminum material; steel can rust and is magnetic. If a steel culvert is coated with bitumen, tar, zinc or aluminum (“aluminized”), and/or its invert is paved with concrete or asphalt, the material type should still be ‘steel’.

Structural Plate Steel (SPS) and Structural Plate Aluminum (SPA) culverts are constructed by fastening steel or aluminum plates together at the installation site. Bolted seams are the best indicator of a structural plate culvert. If a steel culvert lacks both corrugation and plates, then it is classified as Smooth Steel (SST).

For the purpose of this manual any form of plastic culvert is classified as PVC, with or without corrugations. Timber (TMB) culvert are constructed from wood. Masonry (MRY) culverts are constructed from materials such as brick, blocks, or stone.

If the culvert material cannot be categorized using this guidance, or there are differing materials at the inlet and outlet, classify the culvert material as Other (OTH) and describe in the comments, e.g., a culvert constructed of CST material at the inlet and PCC at the outlet.



Figure 3.5. Examples of culvert construction materials. A) Precast concrete (PCC), **B)** Cast-in-place concrete (CPC), **C)** Corrugated Steel (CST), **D)** Smooth Steel (SST)



Figure 3.5 (Continued). Examples of culvert construction materials. E) Corrugated Aluminum (CAL), F) Structural Plate Steel (SPS), G) Plastic (PVC), H) Timber (TMB), I) Masonry (MRY), J) Other (OTH)

Span - Measure the horizontal culvert dimension inside the culvert at a point that is perpendicular to the streamflow. Consider the following conditions when measuring span:

- If the widest point of the culvert is embedded below the surface of the streambed, measure span at the widest point possible above the streambed and describe in the comments.
- If the span measurements are different at the outlet and inlet, record the smaller of the two measurements and describe in the comments.
- If the inlet or outlet of a culvert is skewed, remember to measure perpendicular to stream flow, and not directly across the culvert inlet or outlet (Figure 3.6).

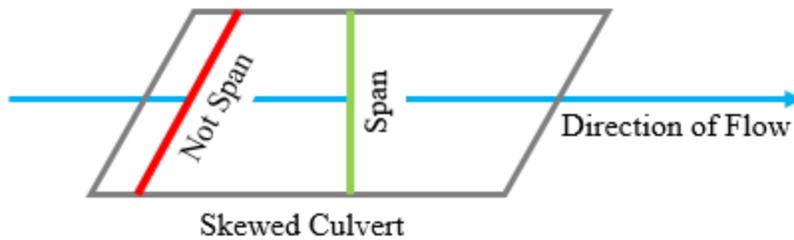


Figure 3.6. Where to measure span in a skewed culvert. For a skewed culvert span is measured perpendicular to flow, not directly across the inlet or outlet.

Rise - Just inside the culvert outlet and inlet, measure the vertical culvert dimension from the invert to the soffit. If streambed material is present, use a probe to reach the invert. If the invert is rusted-out/missing, or the invert cannot be accessed due to the presence of deep bed material within the culvert, measure from the soffit to the streambed and explain in the comments. For bottomless arch culverts, measure from soffit to the streambed directly below the soffit. If the rise measurements are different at the outlet and inlet, record the smaller of the two measurements and describe in the comments.

Shape - Use the measured span and rise to determine the shape of the culvert. Figure 3.7 contains photographic examples of different culvert shapes.

Round (**RND**) culverts have a circular shape where the span is equal, or nearly equal, to the rise. Note: Round metal culverts often become damaged and may appear elliptical at the inlet, outlet, and/or at a collapsing section in the interior of the culvert. Record the actual measured span and rise dimensions at the ends of the culvert and select the original shape of the culvert, i.e., the shape during initial installation. Do not attempt to enter a culvert to measure span or rise at a damaged section. Describe any culvert damage in the comments.

Box (**BOX**) culverts are any square or rectangular culvert with four main sides. Box culverts may have haunch corners for reinforcement.

Arch (**ARCH**) culverts are any bottomless culverts, including bottomless 3-sided box structures.

Squash (**SQSH**) culverts are constructed or mechanically reshaped to create a lower profile so that the widest horizontal cross-section of the culvert is near the invert. Squash culverts are often referred to as 'pipe arch'.

Elliptical (**ELL**) culverts are oval-shaped and may be horizontally or vertically elongated. The major and minor axes of an elliptical culvert should transect the geometric center.

For all other culvert shapes (e.g., pear, semi-circle, polygonal), or for culverts that consist of 2 or more shapes throughout, classify the shape as 'Other' (**OTH**) and describe in the comments.



Figure 3.7. Examples of culvert shapes. A) Round (RND). B) A four-sided box (BOX). C) Bottomless Arch (ARCH). D) Mechanically reshaped squash (SQSH). E) Elliptical (ELL) that is horizontally elongated. F) Elliptical (ELL) that is vertically elongated. G) Other (OTH) culvert with one curved and three straight sides. Note: this configuration is not considered squash shaped

because the vertical walls have the same span from top to bottom, rather than widening near the invert. **H)** Other (OTH) culvert that transitions from round to arch shaped.

Water Depth in Culvert - Measure the maximum water depth inside the culvert at the downstream end, approximately 0.15 meters upstream of the culvert outlet. Depth should be measured at the culvert invert, or the thalweg if the culvert is bed-loaded. If you are unable to fit the measurement tool into the culvert, measure as far into the outlet as possible.

Water Surface Drop - A water surface drop is an abrupt change in water surface elevation, requiring a fish to leap into a feature. If water surface drops occur at any point within a culvert, at the inlet, or at the outlet (including the apron), measure the vertical distance from the water surface above each drop to the water surface below each drop if you can do so safely. If there are multiple drops, record the maximum drop in the Water Surface Drop field, and record any additional drops in the culvert comments.

If there is a water surface drop from the culvert outlet, measure the vertical distance from the water surface at the culvert outlet to the water surface of the first resting water downstream; this may be a plunge pool immediately below the culvert outlet, or a resting pool farther downstream that does not directly receive the drop. For example, if the outlet flow drops onto road fill before entering a resting pool, measure the vertical distance from the resting pool surface to the water surface at the culvert outlet (Figure 3.8).

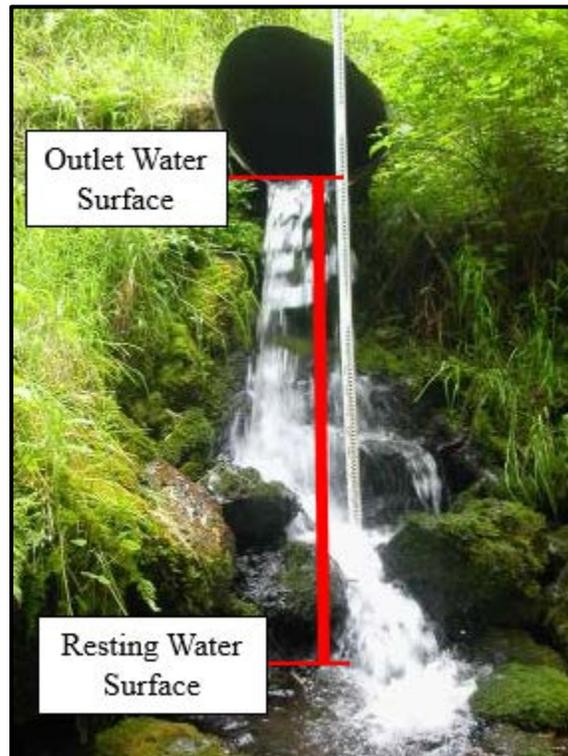


Figure 3.8. Water surface drop measurement when the culvert outlets onto rip rap, boulders, etc. Measure the vertical distance between the outlet water surface and the surface of the first resting pool below.

Water surface drops at the inlet or in the interior of a culvert are often caused by debris accumulations. Although you may be able to remove the debris by hand, this will only temporarily mitigate the blockage, as the culvert is too small for expected debris to pass. Measure water surface drops without altering the debris jam, and provide a comment about the presence of debris.

It may be unsafe to measure water surface drops that occur within a culvert or at the outlet of a culvert with a deep plunge pool. If it is unsafe to access a drop, visually estimate the water surface difference and describe it in the comments. If you are certain that the water surface drop is ≥ 0.24 meters, the culvert is a barrier; refer to the Level A Percent Passability subsection later in this chapter for assigning an estimate of passability.

Drop Location - Note the location of the largest culvert water surface drop.

Apron - An apron is a flat surface that extends from the base of a culvert's inlet or/and outlet (examples in Figure 3.9). Aprons are considered part of the culvert structure, and must be included in the measurement of culvert length. Culvert slope should be measured from the invert at the ends of any aprons. You may need to use a probe to locate the end of an apron if it is covered with streambed material. Record the location of any aprons.



Figure 3.9. Examples of aprons. Locate the ends of any aprons to include in the measurements of total length and culvert slope. The left image illustrates an apron at downstream end of a box culvert. The right image illustrates an apron at upstream end of a round culvert.

Use the overall slope of the culvert, including aprons, in the Level A flowchart (Figure 3.19) or multiple culvert key (Box 1). If there is an obvious slope break (change in culvert slope) where the aprons meet the culvert structure, then also measure the slope of the culvert itself. If any length of the culvert/apron invert is a slope barrier, then the entire site is considered a slope barrier. You may also be able to determine if the culvert is a barrier using the Level B as described in the 'Applicability of Level B Hydraulic Analysis' section later in this chapter.

Total Length - Measure the distance from the inlet to the outlet of the culvert. Include any aprons in your measurement, but do not include bottomless wing walls as part of the structure length.

Culvert Slope – Culvert rise divided by run. Calculating the culvert slope requires surveying equipment capable of measuring relative elevations to the nearest centimeter. Slope is recorded to the nearest hundredth of a percent and expressed as a positive or negative value. Slope is measured from downstream to upstream; therefore, a culvert where the inlet is *higher* than the outlet has a positive slope value, and a culvert where the inlet is *lower* than the outlet has a negative slope value.

$$\% \text{ Slope} = [(\text{USI Elevation} - \text{DSI Elevation}) / \text{Length}] * 100$$

Appendix H provides detailed information on surveying techniques using various types of elevation surveying equipment and formulas for calculating slope.

For enclosed culverts (i.e., culverts with all four sides), slope is calculated as the difference in invert elevations at the most upstream end of the structure and the most downstream end of the structure, divided by the total length. If an enclosed culvert has streambed material covering either invert, use a probe to locate the culvert invert. Place the stadia rod on top of the probe to measure the invert elevation. Remember to include the length of the probe in the calculations.

For bottomless culverts, slope is calculated as the difference in the thalweg elevations at the upstream and downstream ends of the structure, divided by the total length.

Sometimes circumstances make it difficult to measure the culvert invert elevations. If you cannot locate the upstream or downstream invert with a probe due to excess bed material, coarseness of substrate, etc., or if the invert is damaged or missing, measure the slope from the culvert inlet and outlet soffits and record the measurements in the comments. Note: the purpose of the Level A slope calculation is to measure the incline that fish encounter along the *bottom* of the structure. The slope along the top of the structure may vary greatly from the bottom, especially if the culvert is damaged; therefore, measuring slope from the soffit or crown is generally not preferred.

Culverts may have an internal grade break, i.e., a slope change within the culvert. These are referred to as ‘broken back’ culverts. Figure 3.10 illustrates two broken back culverts. Grade breaks often occur when a culvert has been extended or when a section of the culvert has shifted or collapsed. A water surface drop inside of a culvert is also considered a grade break.

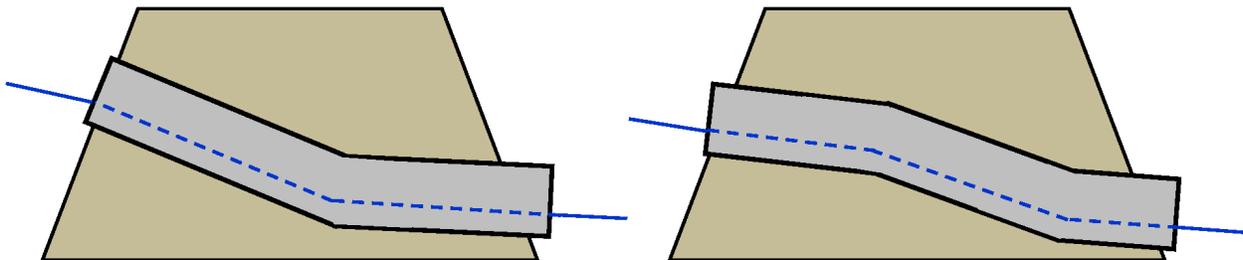


Figure 3.10. Examples of culverts with internal grade breaks. Left diagram illustrates a single internal grade break. Right diagram illustrates two internal grade breaks.

If a broken back culvert has an interior water surface drop, measure the overall slope as described above, but do not use the slope in the Level A flowchart (Figure 3.19) or multiple culvert key (Box 3.2) to determine the barrier status. If it is possible to measure the height of the water surface drop, that can be used to assign a barrier status. Otherwise, the barrier status is “unknown”.

If a broken back culvert does not have an interior water surface drop, measure the overall slope as described above. This slope may be used in the Level A flowchart or multiple culvert key to identify whether the site is a barrier. If assessed as a slope barrier, and the calculated passability is 0%, then the site is a total barrier. If the overall slope results in a partial barrier (33% or 67% passable), then the site is still a slope barrier, but the percent passability is unknown.

Road Fill Depth - Measure the vertical distance from the culvert *invert* to the top of the road prism (Figure 3.11). The depth of the road fill is used to estimate the amount of fill material that would need to be removed if the culvert is replaced.

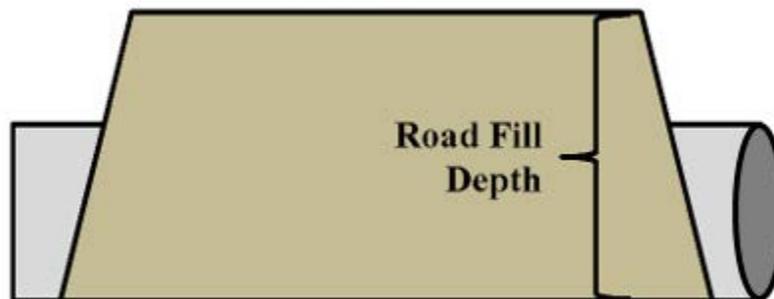


Figure 3.11. Road fill depth measurement.

Countersunk - For the purpose of this manual, an enclosed culvert is considered countersunk if the depth of bed material at the outlet invert is $\geq 20\%$ of the total culvert rise, and streambed material covers the invert throughout the entire length of the culvert. Bottomless arch culverts are always considered to be countersunk.

If an enclosed culvert has streambed material at the outlet, use a probe to locate the culvert invert (Figure 3.12). Measure the bed depth as the vertical distance from the streambed surface to the culvert invert. For box culverts, measure to the invert from the channel thalweg if present (i.e., low-flow channel).

Note: The definition of ‘countersunk’ and the embedment depth measurements prescribed above are solely for the purpose of the barrier assessment methods described in this manual. The meaning of these terms and their associated measurements vary across agencies, principles, and practices. When working on other projects, such as research or engineering design, ensure that you are using the appropriate definitions and measurements of embedment depth.



Figure 3.12. Countersunk culvert. A tile probe is used to determine if the culvert outlet invert is embedded at a depth $\geq 20\%$ of the culvert rise.

Sometimes the substrate within a culvert becomes too deep, reducing the culvert clearance and creating a potential hindrance to fish passage (examples in Figure 3.13). If the headroom of the culvert (vertical distance from surface of the streambed to the culvert soffit) is < 0.30 meters, then the culvert should be considered a barrier, and the percent passability is unknown. If the headroom is ≥ 0.30 meters, but you believe that the culvert may exceed the velocity requirements for fish passage due to the reduction in hydraulic capacity, then use the Level B hydraulic analysis to calculate the velocities between the low and high fish passage flows.



Figure 3.13. Culverts with excess bed material. When there is a substantial loss of hydraulic capacity and headroom, the Level A flowchart (Figure 3.19) and multiple culvert key (Box 3.2) may not be applicable to the barrier determination. **A)** if there is a significant loss in hydraulic capacity but the headroom is still ≥ 0.30 meters, use the Level B hydraulic analysis to estimate velocity. **B)** if headroom < 0.30 meters, then the culvert is considered a barrier due to lack of headroom.

Backwatered - A culvert is considered to be backwatered if either of the following conditions apply:

- the average velocity throughout the entire length of the culvert is visibly slower than the average velocity in the adjacent channel, or
- there is very little or no visible flow throughout the entire length of the culvert

Note: while culvert submersion is a good indicator of backwatering, it is not a requisite. A culvert may be backwatered with only shallow depth throughout the entire length.

Gate - A culvert may be equipped with a flow control gate, e.g., a tide gate or floodgate (examples in Figure 3.14). Gates may function to prevent saltwater intrusion, control water levels and flow rates, divert flow into a bypass or detention basin, or even stop flow entirely. For the purpose of this manual, gated culverts that function to impound and elevate the surface of the water at the upstream end are classified as dams (Chapter 5). However, gated culverts designed to prevent water from flowing upstream, e.g., tide gates or floodgates, are classified as culverts. If a culvert has any form of gate attached, then fill out as much of the Level A field form as possible, select 'Yes' for the Gate field, and describe the gate in the comments. If the structure is classified as a dam, also complete the Dam Assessment Field Form (Figure 5.2; Appendix E).



Figure 3.14. Examples of culverts with gates. A) Flap gate, B) Screw gate, C) Swing gate, D) Slide gate.

If access to the culvert inlet or outlet is blocked by a gate, some Level A data may be difficult to collect. If you need to deviate from the protocols specified in this chapter, e.g., you can only

measure the water depth in the culvert at the inlet, or slope from the culvert crown due to the presence of a gate, then describe the measurements in the comments.

Box 3.1 provides guidance for the assessment of culverts with flow control gates. Note: Box 3.1 is based on the theoretical deduction that the position of a gate may change between the conditions observed during the field assessment, and other periods within the range of fish passage flows, affecting the passability of the culvert. If there are multiple culverts with gates at the crossing, use Box 3.1 to determine the passability of each culvert, and Box 3.2 to determine the passability of the site.

If you are able to contact the owner/operator of the structure, inquire about the purpose, operational timing, and maintenance of the gate and describe in the comments. Please forward gate assessments to WDFW for final review.

1. Is the gate intended to prevent the upstream flow of water?
 - a. Yes, The crossing is a barrier. Assign passability according to the criteria below:
 - i. If the gate is self-regulating style – percent passability is 33%
 - ii. All other gate styles – percent passability is 0%
 - b. No, The gate is intended to impound water, and acts as a dam. Go to 2
2. Is gate fully closed?
 - a. Yes, Site is a barrier - percent passability is unknown
 - b. No, Go to 3
3. Are you able to conduct full Level A culvert assessment?
 - a. Yes, Go to 4
 - b. No, Barrier status is unknown
4. Is culvert a barrier using Level A culvert assessment?
 - a. Yes, Go to 5
 - b. No, Go to 6
5. Is culvert 0% passable according to Level A culvert assessment?
 - a. Yes, Site is a barrier - passability is 0%
 - b. No, Site is a barrier - percent passability is unknown
6. Is culvert a non-barrier using Level A assessment?
 - a. Yes, Barrier status is unknown
 - b. No, Go to 7
7. Is gate fully open?
 - a. Yes, Go to 8
 - b. No, Barrier status is unknown
8. Is Level B applicable, and are you able to conduct full Level B hydraulic analysis?
 - a. Yes, Go to 9
 - b. No, Barrier status is unknown
9. Is culvert a barrier using Level B hydraulic analysis?
 - a. Yes, Go to 10
 - b. No, Barrier status is unknown
10. Is culvert 0% passable according to Level B hydraulic analysis?
 - a. Yes, Site is a barrier - percent passability is 0%
 - b. No, Site is a barrier - percent passability is unknown

Box 3.1. Gated culvert assessment key.

Rack - A culvert may be equipped with a rack, screen, cage, or various types of guards (examples in Figure 3.15 and illustrated in Figure 3.16). These structures are often used to reduce the accumulation of debris and sediment within a culvert. Common examples include trash racks, debris cages, and beaver deceivers. Screens are also commonly used at hatchery facilities, lake

outlets, and diversion canals for fish exclusion. For the purpose of this manual, these structures are classified as ‘racks’.



Figure 3.15. Examples of culverts with racks. Note: stadia rods are in the pictures for scale only. They do not illustrate where to measure rack dimensions.

When a rack is present, perform the full Level A assessment, and then determine if the horizontal and vertical openings are adequate to allow for fish passage. All rack measurements should be taken within the area of the culvert opening at locations where fish are expected to attempt passage during fish passage flows. Measure the horizontal distance between adjacent vertical bars, and vertical distance from the bottom of the culvert - or the surface of the streambed (if bed material is present) - to the bottom of the lowest exposed lateral bar. Record the maximum horizontal and vertical openings in the comments.

If adult Chinook salmon are potentially present in the stream, a rack is a barrier if the horizontal or vertical measurements are ≤ 0.30 m. If adult Chinook are *not* potentially present, a rack is a barrier if horizontal or vertical measurements are ≤ 0.24 m. If the culvert is a total barrier according to the Level A, then record a passability of ‘0%’, otherwise we do not currently have a passability scale for racks, so the percent passability is ‘unknown’.

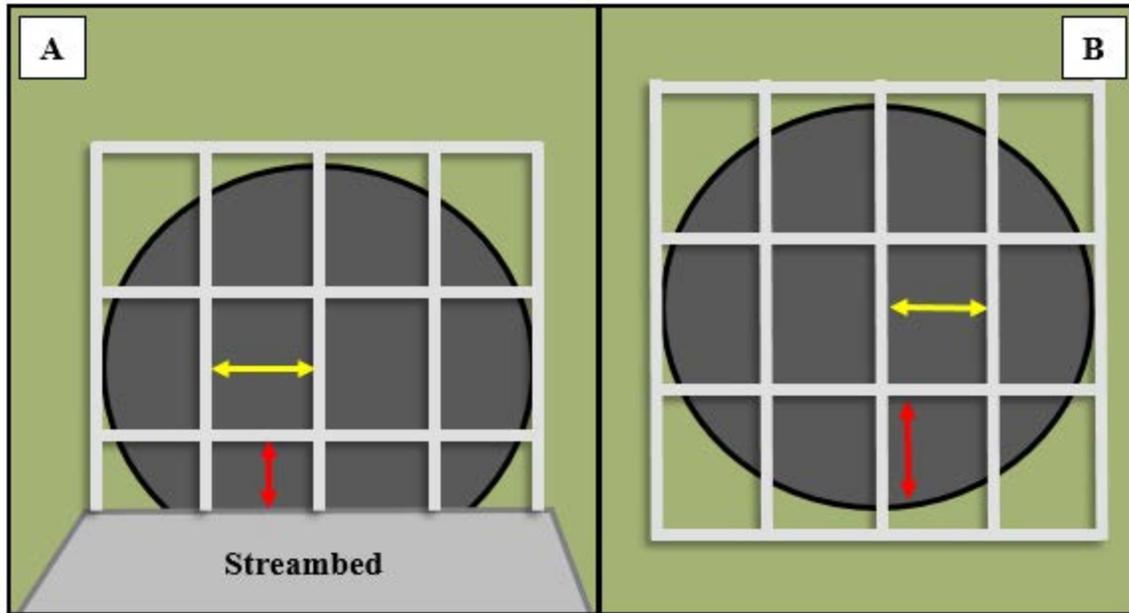


Figure 3.16. Where to measure horizontal and vertical rack openings. Measure the horizontal opening between adjacent vertical bars, as illustrated by the yellow lines in figures A and B. When streambed material is present, measure the vertical opening between the streambed surface and the lowest lateral bar as illustrated by the red line in figure A. When the culvert invert is bare, measure the vertical opening between the culvert invert and the first lateral bar, as illustrated by the red line in figure B.

Fishway - A fishway is a human-placed structure designed to facilitate fish migration through, over, or around a human-made or natural feature. Fishways can increase water depth, slow velocity, and reduce water surface drops through a culvert. They may be located in the interior of a culvert (e.g., baffles), at the upstream end, or at the downstream end (examples in Figure 3.17). For culverts equipped with a fishway, collect all Level A culvert assessment data, select 'Yes' for Fishway on the Level A Assessment Field Form, and proceed to fishway data collection (Chapter 8). The fish passage barrier determination is based on the fishway evaluation, Level A, and/or Level B results, as described in Chapter 8.



Figure 3.17. Examples of culverts with fishways. Fishways may be located upstream, downstream, or within a culvert and are intended to facilitate fish passage up to, through, and away from the structure. **A)** A rock streambed control fishway at downstream end of dual culverts. **B)** Culvert with interior metal baffles. **C)** Weir pool fishway at downstream end of culvert. **D)** Log streambed control fishway at upstream end of culvert.

Channel Description

Bankfull Width - Bankfull width is a description of the width of the channel that contains most stream flows. It is measured perpendicular to the thalweg. Measure bankfull width horizontally from the point on the bank where water begins to overflow into the active floodplain perpendicularly across the channel to a point at the same elevation on the opposite bank. If there is no floodplain, measure the width of the waterbody at the stage of dominant channel forming flow, using bankfull indicators such as vegetation, soils, material deposition, etc.

Bankfull width can be measured upstream or downstream of the culvert, outside of the area of culvert influence. If feasible, take multiple measurements and record the average. Refer to Appendix G for more detailed information about measuring bankfull width.

Span/Bankfull Width - Divide the measured culvert span by the bankfull width. If there is more than one non-overflow culvert at the crossing, use the sum of the spans of all non-overflow culverts. Use the span/bankfull width ratio to determine if the structure(s) potentially constrict the streamflow.

Tidal Influence - Determine if the culvert hydraulics are affected by tidal activity. Refer to the 'Draft Guidance for Evaluating Fish Passage at Tidally-Influenced Culverts' for making this determination and assessing barrier conditions through tidally-influenced culverts.

Plunge Pool Description

For the purpose of this manual, a plunge pool refers to the pool downstream of a culvert with a water surface drop at the outlet. Figure 3.18 illustrates a culvert with a plunge pool and some of the required measurements. Measure the following plunge pool dimensions *only if* the culvert has an outfall drop.

Pool Length - Measure the horizontal distance from culvert outlet to downstream control. The downstream control is the geomorphic feature at the pool's tail-out which controls the outlet pool water surface elevation (See Figure 3.18).

Pool Maximum Depth - Measure the depth of the plunge pool at its deepest point. Note: plunge pools can be very deep, even on small streams - use caution.

Pool Scour Line Width - Measure the width of the plunge pool scour line at its widest point. See Chapter 2 for more information about SLW.

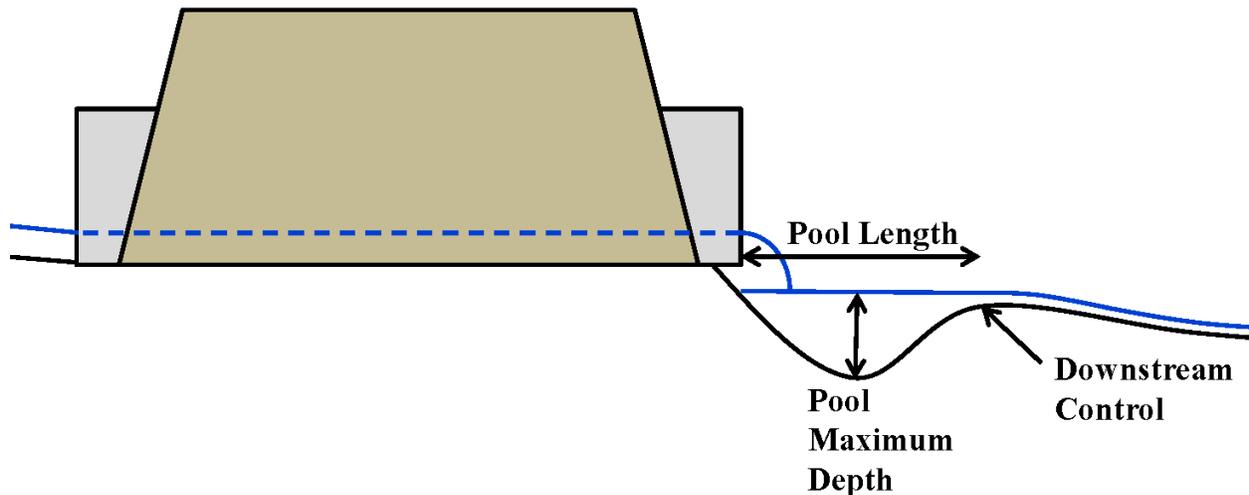


Figure 3.18. Example of a culvert with a plunge pool. This figure illustrates some of the plunge pool description measurements and the downstream control.

Barrier Status

Barrier - After collecting Level A data, use the Level A flowchart (Figure 3.19) for a single culvert, and the Level A multiple culvert key (Box 3.2) for more than one non-overflow culvert, to determine if the site is a barrier to fish passage. Also, refer to the applicable guidance provided

throughout this chapter (e.g., in sections describing tidal culverts, gates, fishways, and Level B hydraulic analysis) to make the final barrier determination.

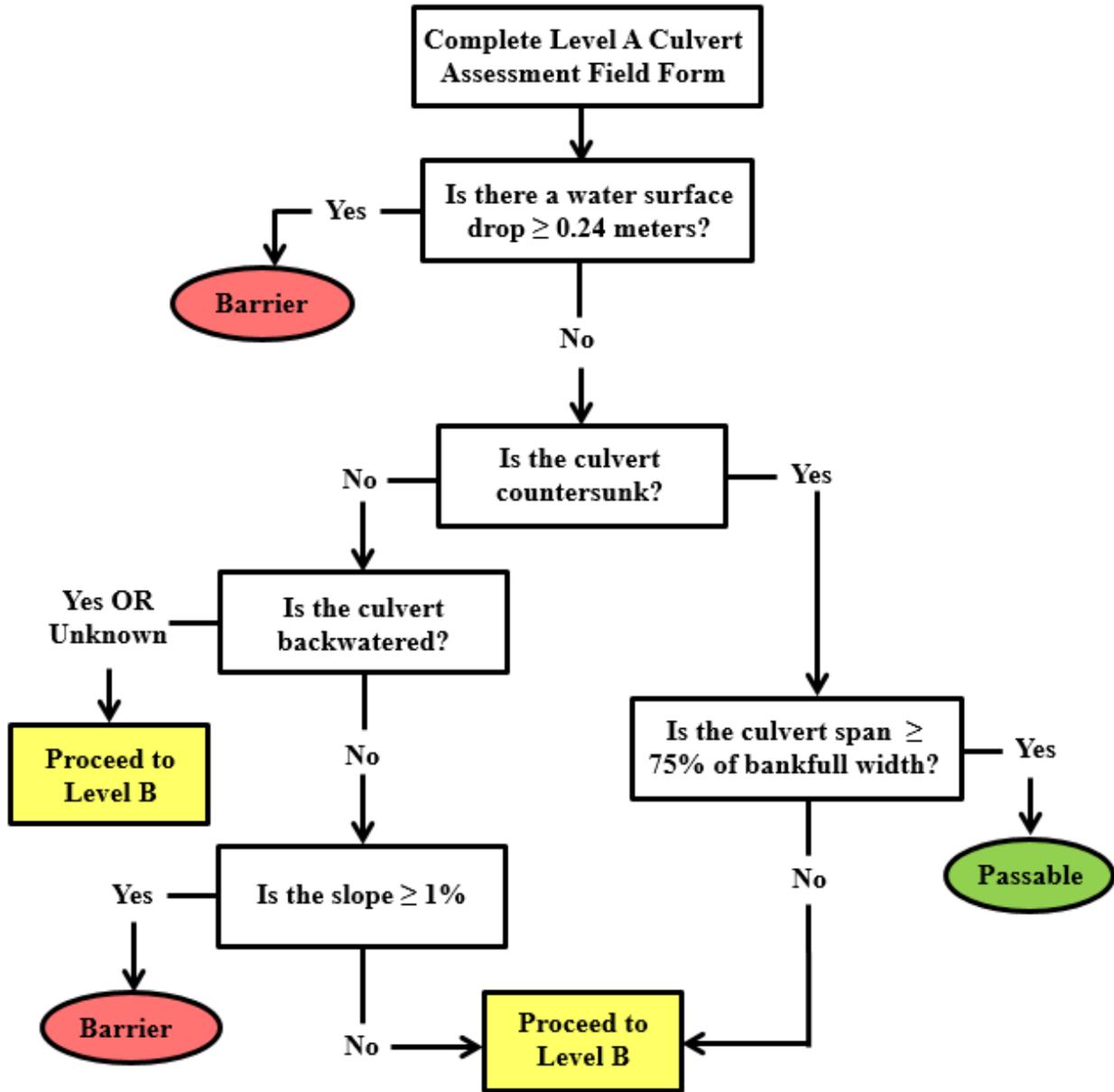


Figure 3.19. Level A flowchart to determine culvert barrier status.

1. Do all culverts have a water surface drop ≥ 0.24 meters?
 - a. Yes, Site is a barrier – percent passability based on the culvert with the highest passability
 - b. No, Go to 2
2. Does any culvert have a water surface drop ≥ 0.24 meters?
 - a. Yes, Go to 5
 - b. No, Go to 3
3. Are all culverts countersunk?
 - a. Yes, Go to 4
 - b. No, Go to 5
4. Is the sum of the spans of all culverts $\geq 75\%$ of the bankfull width?
 - a. Yes, Site is a non-barrier
 - b. No, Proceed to Level B
5. Are any of the culverts countersunk?
 - a. Yes, Go to 6
 - b. No, Go to 7
6. Is the sum of the spans of only the countersunk culverts $\geq 75\%$ of the bankfull width?
 - a. Yes, Site is a non-barrier
 - b. No, Proceed to Level B
7. Are any of the culverts backwatered?
 - a. Yes or Unknown, Proceed to Level B
 - b. No, Go to 8
8. Do all of the culverts have a slope $\geq 1\%$?
 - a. Yes, Site is a barrier – percent passability based on the culvert with the highest passability
 - b. No, Proceed to Level B

Box 3.2. Level A multiple culvert key to determine barrier status when there is more than one non-overflow culvert.

The Level A flowchart and Level A multiple culvert key are accurate most of the time. If you believe that a culvert is inaccurately categorized as a Level A barrier or non-barrier, you may proceed to the Level B hydraulic analysis, if applicable, to confirm the barrier determination. For example, you assess a box or squash culvert that is embedded only 18% below the streambed at the outlet, but the widest cross-section is fully covered with bed material throughout the entire length of the culvert, and the span is greater than the bankfull width. The measured culvert slope is 1.5%. This culvert would be assessed as a barrier using the Level A flowchart. However, it may be more appropriate to evaluate passability using the Level B hydraulic analysis since the culvert is maintaining a sufficient amount of bed material, and the slope is low enough that the structure may not be creating excessive velocity conditions.

Method - Record the method that was used to make the final barrier determination.

% Passability – If the Level A flowchart (Figure 3.19) or multiple culvert key (Box 3.2) categorizes the culvert as a fish passage barrier, an estimated percent passability value may be assigned using Table 3.1. Barrier determinations based on the presence of a gate or other obstruction, culvert failure, or any condition not listed in Table 3.1 will be classified as barriers, but with an “unknown” percent passability. For more information about the percent passability value, refer to Chapter 1.

Table 3.1 Assignment of percent passability to culverts determined to be barriers using the Level A flowchart (Figure 3.19) or multiple culvert key (Box 3.2).

Criterion	Culvert Length	Value	Range	% Passability
Water Surface Drop	N/A	≥ 0.24 m	0.24 m - 0.49 m	0.67
			0.5 m - 0.99 m	0.33
			≥ 1.00 m	0
Slope	< 18.3 m	≥ 1.0%	1.01 % - 1.99 %	0.67
			2.00 % - 3.99 %	0.33
			≥ 4.00 %	0
Slope	≥ 18.3 m	≥ 1.0%	1.01 % - 1.99 %	0.33
			≥ 2.00 %	0

If there is only one culvert at the crossing, and more than one barrier criterion apply, then assign the lowest percent passability. For example, a 10-meter long culvert with a water surface drop of 0.30 meters and a slope of 2.5% would be assigned a percent passability value of 33% because the barrier severity of the slope is greater than that of the water surface drop.

If there is more than one non-overflow culvert at the crossing, then the entire site will be assigned the percent passability of the most passable culvert. This is based on the assumption that fish will migrate through the most passable culvert.

If you are unable to measure one of the culvert attributes, but have collected enough data to assign a passability of 0% based on one of the Level A measurements, then it is acceptable to enter a passability of 0%. For example, a culvert with a > 1 m water surface drop, but an inaccessible inlet to measure a slope, is still 0% passable.

It is important to emphasize that a site may be a barrier, but the passability is unknown. For example, a site may have multiple partial barrier conditions, but some attribute that prevents the assignment of the percent passability, such as a gate. In those situations the culvert record will indicate that the site *is* a barrier, but the severity of the barrier is unknown.

Significant Reach - For the purpose of this manual, a significant reach is defined as a section of stream having at least 200 linear meters of usable habitat without a gradient or natural barrier, both upstream and downstream of the fish passage feature.

Comments - Record useful comments about the structure, including information that wasn't captured in the data fields (e.g., more than one water surface drop) and descriptions for any attributes where 'other' or 'unknown' was selected.

3.4 Level B Hydraulic Analysis

Terminology

Level B hydraulic analysis may be required to determine the barrier status of a culvert. The Level B is an advanced analysis used to determine if a culvert meets the velocity and depth requirements for fish passage between low and high fish passage flows. It generally takes about 30 minutes to complete the Level B field data collection and an additional 30 minutes of data analysis in the office.

The following subsections provide basic surveying terminology, and describe the values required to measure the elevations used in Level B analysis. See Appendix D for examples of surveying equipment, and Appendix H for more detailed information about surveying techniques.

Datum Elevation - A datum, or temporary benchmark, is arbitrarily assigned by the field crew. The datum is the reference point from which all Level B elevations are measured.

Backsight - A measurement directed backward to a known elevation.

Foresight - A measurement directed forward to an unknown elevation.

Rod Height - The rod height (RH) is the vertical distance from a point of interest (a point of known or unknown elevation) to a target height measurement on a stadia rod, as read using survey instruments. The RH may be the position indicator on an electronic receiver, a location on a non-powered reflective target, a tick mark on the stadia rod, etc., depending on the type of surveying equipment used.

Vertical Distance +/- - Some surveying instruments can measure inclination to calculate vertical distance (VD). The VD is the difference between the instrument height (IH) and the RH, and can be positive or negative. For surveying levels that do not measure incline, such as rotary laser levels, the VD value is null.

Instrument Height - Instrument height is the elevation of the surveying instrument. IH is calculated relative to the datum elevation.

To calculate instrument height, set up the surveying instrument in a location where you can see the datum and, if possible, all of the elevation points to be measured (Figures 3.20 & 3.24). Place

a stadia rod on the reference datum and backsight from the instrument to the datum. The IH is calculated as the vertical difference between the instrument and reference datum (example using rotary laser level in Figure 3.20). Appendix H contains information about the use of turning points to recalculate IH when the surveying level needs to be relocated.

Use the appropriate formula below for calculating IH:

For surveying equipment that measures incline

if VD is positive, $IH = \text{Datum Elevation} + RH - VD$

if VD is negative, $IH = \text{Datum Elevation} + RH + |VD|$

Note: | | Denotes absolute values

For surveying equipment that does not measure incline (i.e., VD is null)

$IH = \text{Datum Elevation} + RH$

Note: example in Figure 3.20

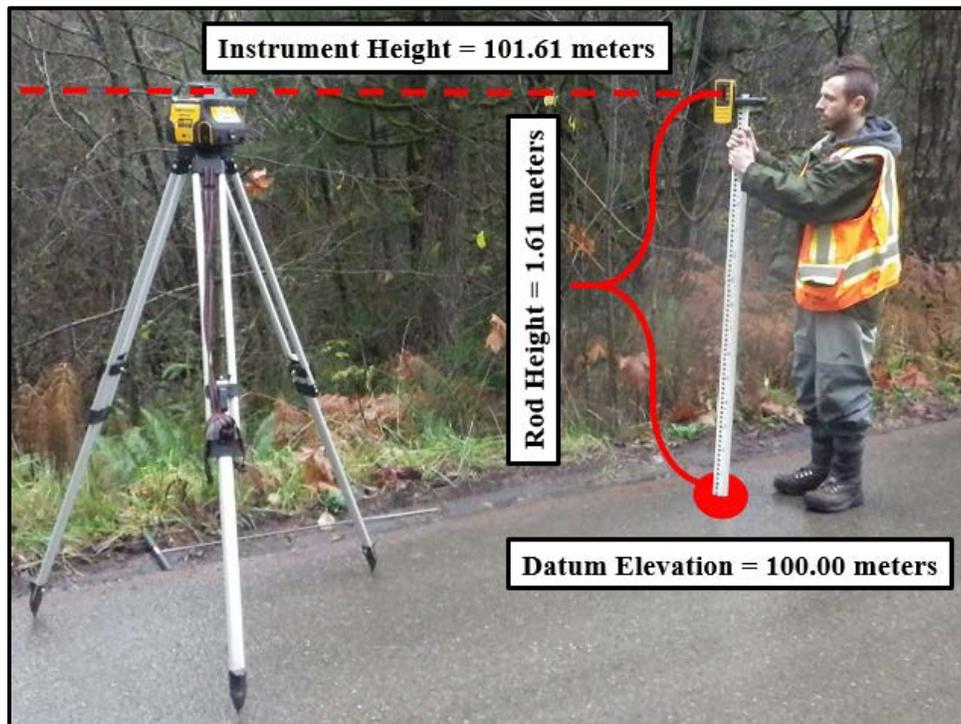


Figure 3.20. Establishing a reference datum and calculating instrument height (IH) with surveying equipment that does not measure incline. In this example, a rotary laser level has been set up in a location with a line of site to the Level B elevations (shown in Figures 3.20 & 3.24). The rotary laser level quickly spins, projecting a 360-degree horizontal plane. A reference datum (red circle) has been set at a stable location on the roadway that is easy to relocate. The datum has been arbitrarily assigned an elevation of 100.00 meters. An electronic receiver is secured to the top of a stadia rod and extended vertically until the receiver beeps continuously at 1.61 meters (this is the rod height (RH) value) from the datum to the instruments projected

horizontal plane. The IH is calculated as the Datum Elevation (100.00) plus RH (1.61) = 101.61 meters.

Elevation Calculations

Elevation (ELEV) is calculated relative to the instrument height. Take foresight readings from the instrument to a position of unknown elevation using the survey instrument and stadia rod.

Use the appropriate formula to calculate ELEV:

For surveying equipment that measures incline

if VD is positive, $ELEV = IH - (RH - VD)$

Note: Do math in parentheses first

if VD is negative, $ELEV = IH - RH - |VD|$

Note: | | Denotes absolute value

For surveying equipment that does not measure incline (i.e., VD is null)

$ELEV = IH - RH$

Level B Elevation Locations

The Level B hydraulic analysis requires elevation measurements at the following locations (Figure 3.21):

- upstream and downstream ends of the culvert, including the:
 - invert of the inlet and outlet of the culvert, and invert of any aprons (if present)
 - culvert bed elevation (if streambed material is present) in the thalweg at the culvert inlet and outlet
- downstream control cross-section
- water surface below the downstream control

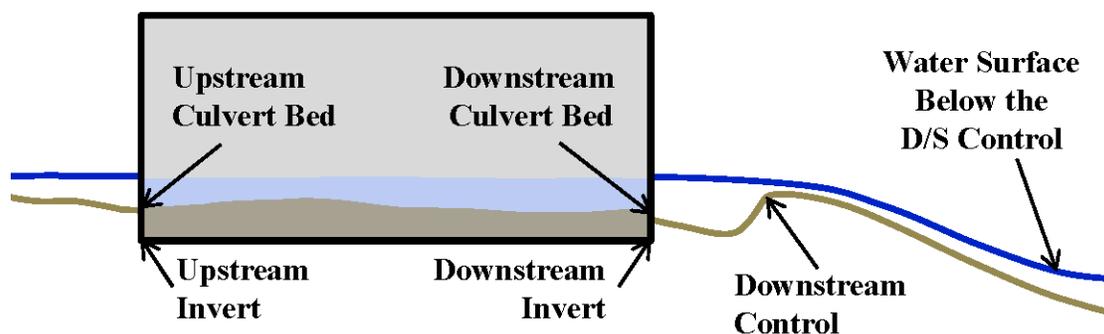


Figure 3.21. Longitudinal view showing the general locations of elevation data required for the Level B hydraulic analysis. See Figure 3.24 for a cross-sectional view of the downstream control elevations.

Applicability of Level B Hydraulic Analysis

There are a number of conditions that impede the ability to determine barrier status using the Level B hydraulic analysis. These conditions often require an engineer review, leaving the barrier status as 'unknown' until the review is complete. The following list provides some common examples of conditions that preclude a Level B. Do not collect Level B data if you encounter any of the following conditions, and contact WDFW for assistance.

The Level B hydraulic analysis may not be applicable when the following conditions occur:

- A significant amount of the flow at the downstream control did not pass through the culvert. If >30% of the total flow at the downstream control was not conveyed through the entire length of the culvert, then the Level B is not applicable. This may occur in the following conditions:
 - One or more watercourses enter the channel between the culvert outlet and downstream control.
 - Culverts that receive water from another source in the interior (e.g., a stormwater pipe that connects to the middle of the culvert).
 - Culverts that discharge directly into a larger stream or a river.
- The culvert discharges into a waterbody that lacks an accessible control. This is common in lakes, reservoirs, and some wetlands. Note: if there is an outlet stream, look for a control at that location. If a control exists, and is accessible, collect Level B data.
- The presence of fishways other than streambed controls (see Chapter 8). Fishways alter culvert hydraulics in ways that are not captured in the Level B hydraulic analysis. If the fishway type is a streambed control, then collect Level B data. Note: a streambed control near the culvert outlet can function as the downstream control.
- The size or shape of the culvert varies significantly from one end to the other. The Level B works on the assumption that the culvert has a similar shape and uniform volumetric capacity through the entire length of the pipe.
- Inverts are partially missing or water is flowing beneath the culvert structure. The Level B works on the assumption that the same volume of water entering the culvert inlet is exiting through the culvert outlet. If there is a loss of >30% of flow from the culvert inlet to outlet, the Level B is not applicable. Note: this does not apply to bottomless arch culverts.

If the damaged or missing invert is fully embedded in streambed material, it may be possible to approximate a hydraulic analysis. Collect the Level A, and Level B data. If the invert is missing, collect the soffit or crown elevation (record the elevation locations in the culvert comments). Contact WDFW for assistance with the hydraulic analysis.

- Another culvert is functioning as the downstream control. If there is a culvert immediately downstream, contact WDFW for assistance with the hydraulic analysis.
- The presence of a flow control structure obstructing any part of the culvert inlet or outlet, e.g., a closed or partially open gate. If the gate is fully open collect Level B data.
- An enclosed culvert with a grade break. \Note: this does not apply to bottomless arch culverts.

LEVEL B HYDRAULIC ANALYSIS FIELD FORM (3/18/2019)

¹Site ID _____

²Culvert Number _____

⁵Datum Elevation _____

⁶Datum Location _____

³Crew _____

⁴Date _____

⁷CULVERT MEASUREMENTS

	IH	RH	VD +/-	ELEV
Upstream Invert				
Upstream Culvert Bed				
Downstream Invert				
Downstream Culvert Bed				

IH = Instrument Height; RH = Rod Height; VD = Vertical Distance (for equipment that measures incline); ELEV = Elevation (relative to Datum Elevation). Formulas on reverse side.

⁸Culvert Roughness concrete smooth paved invert
 corrugation: 0.5" x 2.67" 1" x 3" 2" x 6" other _____

⁹Sediment Through Length of Pipe? yes no unknown

¹⁰DOWNSTREAM CONTROL CROSS-SECTION

	STA	IH	RH	VD +/-	ELEV	DEP	WSE	SUB
Top LB	0.00							
Toe LB								
Bed 1								
Bed 2								
Bed 3								
Toe RB								
Top RB								

¹⁰Avg. WSE _____

STA = Station; DEP = Water Depth; WSE = Water Surface Elevation; SUB = Dominant Substrate (F = Fines, C = Gravels/Cobbles/Bedrock, B = Boulders, W = Wood)

	IH	RH	VD +/-	WSE
¹² Water Surface Downstream of X-Section;				

¹³Distance from X-section _____

Figure 3.22. Level B Hydraulic Analysis Field Form. Superscript numbers on the field form correspond with superscript numbers in Table 3.4.

Multiple Culvert Crossings

The header info and ‘Culvert Measurements’ section of the Level B field form must be completed separately for each culvert at the crossing, including overflow culverts. Although not assessed for fish passage, overflow culverts can provide relief during high flow events and reduce velocities through non-overflow culverts. If an overflow culvert is present, record ‘overflow’ for the Culvert Number, and record the length of the overflow culvert on the Level B field form.

The ‘Downstream Control Cross-Section’ portion of the field form only needs to be completed once for the entire site. Detailed explanations of the data fields in the Level B field form are provided in the following sections and summarized in the Quick Reference Table (Table 3.4) in Section 3.6.

Header

For each culvert, record the FPDSI Site ID, Culvert Number (as described earlier in this chapter), observers, and the date of inventory.

Datum Elevation - Assign an elevation to the datum. The datum elevation will be used to calculate the relative elevation data necessary for the Level B hydraulic analysis. Setting the datum elevation to 100.00 meters is recommended to ensure that none of the calculated ELEV values are less than 0.00 meters.

Datum Location - The location of the assigned datum, e.g., ‘upstream culvert crown’ or ‘top of roadway’. Establish the datum at a fixed point that is stable and easy to relocate. Do not set the datum on the streambed, or on any feature that may shift during the survey. You may set the culvert inlet or outlet as the datum, in which case the elevation for that location will just be the datum elevation that you assigned. For example, if you designated the culvert inlet as the datum location the elevation of the culvert inlet will equal the assigned datum elevation (e.g., 100 m).

Culvert Measurements

Culvert Elevations – Measure and record IH, RH, and VD to calculate ELEV for each culvert’s upstream and downstream inverts. If streambed material is present at the culvert inlet or outlet, measure and calculate the ELEV at the streambed thalweg. If the culvert is a bottomless arch, measure the streambed thalweg elevation -invert elevations will be null.

Culvert Roughness - Culvert boundary roughness affects velocity distributions and depth throughout the length of a culvert. An increase in roughness can cause a reduction in velocity and an increase in depth. A Manning’s roughness coefficient for the culvert is applied to the flow calculations in the Level B hydraulic analysis. Common surface descriptors and corrugation sizes are provided on the Level B field form (Figure 3.22).

Sediment Through Length of Culvert? - Does bed material cover the low-flow channel (i.e., thalweg) throughout the entire length of the culvert? If there is substrate missing, or culvert corrugations are exposed, it does *not* have sediment through the length of the culvert.

Downstream Control Cross-Section

The downstream control (also referred to as the tailwater control) is a feature downstream of the culvert that controls the water surface elevation at the culvert outlet. The downstream control is typically a geomorphic feature located at the head of the first riffle below the culvert. However, the downstream control may also be a streambed control feature that has been designed to increase water depth, slow velocity, and reduce water surface drops through the culvert.

Occasionally there may be more than one control downstream of the culvert, each controlling the flow of water at varying flows. In which case, set up the cross-section at the control with the greatest potential to backwater the culvert. When it is difficult to determine which control is backwatering the culvert, measure both and perform the hydraulic analysis using both controls.

Some watercourses are heavily modified through anthropogenic use, resulting in uniform channels without an obvious downstream control. In these conditions, collect the downstream control cross-section data at a representative transect within a few meters of the culvert outlet.

The Downstream Control Cross-Section data is derived from seven elevation locations across the control. Stretch a measuring tape from the top of the left bank (Top LB) to the top of the right bank (Top RB) across the downstream control (example in Figure 3.23 & 3.24). For the purpose of this manual, the left bank is on your left while looking downstream.



Figure 3.23. Setting up Downstream Control Cross-Section for Level B hydraulic analysis. Looking upstream toward the control and culvert, the left bank is on the right side of the photo. Secure the zero end of a measuring tape at the top of left bank (Top LB) and stretch to the top of right bank (Top RB), across the downstream control.

Locate seven stations (STA) across the downstream control: Top LB and Top RB, toe of left and right bank (Toe LB and Toe RB), and three bed elevations (Bed 1, Bed 2, and Bed 3) between the Toe LB and Toe RB. The Top LB and Top RB are located on top of each bank and may have different elevations. The Toe LB and Toe RB are located at the points where the streambed elevation begins to increase sharply toward the top of the bank. Between the Toe LB and Toe RB, select three locations for Bed 1, Bed 2, and Bed 3 that reflect the elevation changes across the downstream control (example in Figure 3.24).

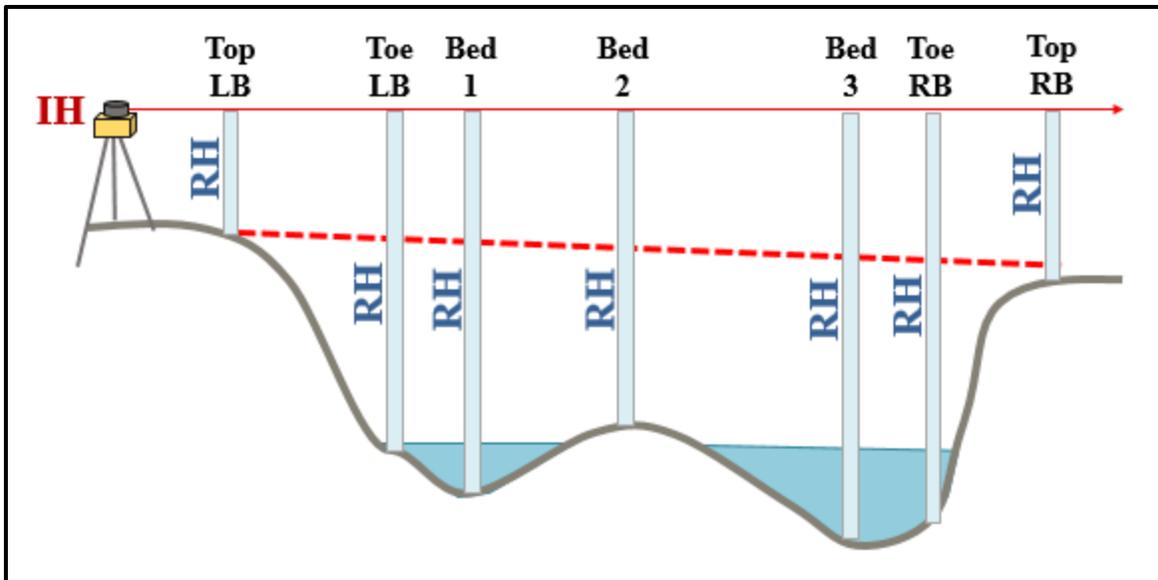


Figure 3.24. Diagram example of a downstream control cross-section. Looking downstream from the culvert outlet toward the control, the vertical light blue bars represent a stadia rod placed at each station (STA) of the cross-section. The dashed red line represents the cross-sectional measuring tape used to measure STA from the top of left bank (Top LB) (0.00 meters on the tape) to the top of right bank (Top RB). Between the toe of left bank (Toe LB) and toe of right bank (Toe RB), one of the bed elevation locations is placed in the thalweg (Bed 3), one is placed at the highest elevation (Bed 2), and one captures a grade break (Bed 1).

At each elevation location across the downstream control, record STA, IH, RH, and VD (if applicable) to calculate ELEV. Formulas for calculating ELEV are provided earlier in this section. Also record the dominant substrate (SUB) at the base of the stadia rod at each elevation location. Substrate records are used to assign Manning's roughness coefficients to the downstream control. Abbreviations for SUB categories are provided on the Level B field form (Figure 3.22).

At each STA between the Toe LB and Toe RB, inclusive, record the water depth (DEP). For each STA with a non-zero DEP value, calculate water surface elevation (WSE) as the sum of ELEV plus DEP. If a STA has a DEP value of zero, leave the WSE cell blank.

Average WSE - The water surface elevation across the downstream control is primarily used to calculate the water surface slope moving downstream from the control. Calculate and record the average of the values in the WSE column.

Water Surface Downstream of X-Section; Distance from X-Section - The water surface elevation downstream of the control cross-section is measured to calculate downstream channel slope. The downstream channel slope can affect velocities and depths through the channel, and consequently through the culvert. Measure 15 meters downstream of the control cross-section following the channel thalweg. Place the base of the stadia rod at the water surface, and record IH, RH, and VD (if applicable) to calculate WSE.

Sometimes it is not possible to measure the WSE 15 meters downstream of the control. In that case, measure as near to 15 meters as possible following the channel thalweg, record the downstream distance from the control, and measure the IH, RH, and VD from the water surface.

If there is a flow pattern change in the 15 meters downstream, measure to the upstream end of the change. For example, if there is a water surface drop, measure to the upstream end of the drop and note the distance downstream from the control.

Level B Barrier Determination

WDFW recommends downloading and filling out the 'Hydraulic Analysis Spreadsheet' then forwarding to WDFW with the Site Description Field Form and Level A Culvert Assessment Field Form. WDFW will complete the analysis and send you the results. The Hydraulic Analysis Spreadsheet is available on the Fish Passage web-site.

Any commercially available software capable of culvert hydraulic computations can be used with the Level A and B data to complete the Level B analysis. Refer to Chapter 1 for information about fish passage flows, the range of flows at which fish passage criteria must be satisfied, and Appendix C for estimating fish passage flows in Washington State.

Level B Percent Passability

Compare the calculated velocity and depth values from the hydraulic analysis results to those in Table 3.2 to determine if a culvert is a barrier. Table 3.2 provides an estimated percent passability for culverts that do not meet the fish passage parameters for one or more of the criteria. For more information about this value, refer to the Percent Passability section in Chapter 1. Note: culverts with bed material throughout the entire length are exempt from the depth criterion.

If there is only one culvert at the crossing and more than one barrier criterion apply, then assign the lowest percent passability. If there is more than one non-overflow culvert at the crossing, then the entire site will be assigned the percent passability of the most passable culvert. This is based on the assumption that fish will choose to migrate through the most passable culvert.

Table 3.2 Assignment of percent passability to culverts determined to be barriers using the Level B hydraulic analysis.

Criterion	Culvert Length	Value	Range	% Passability
Velocity	≤ 30.4 m	≥ 1.22 mps	1.22 mps – 1.82 mps	67
			≥ 1.83 mps	33
Velocity	30.5 – 61 m	> 0.91 mps	0.92 mps – 1.52 mps	67
			≥ 1.53 mps	33
Velocity	> 61 m	≥ 0.61 mps	0.61 mps – 1.21 mps	67
			≥ 1.22 mps	33
Water Depth	N/A	≤ 0.30 m	0.15 m – 0.30 m	67
			0.05 m – 0.14 m	33
			≤ 0.04 m	0

3.5 Instantaneous Flow Rate Measurements

In situations where the Level A culvert assessment, or Level B hydraulic analysis do not apply, or are inconclusive, you may be able to determine if the culvert is a velocity barrier given current flow conditions by using a flowmeter. When using a flowmeter, it is highly recommended to visit the site as close to the 10% exceedance flow as possible; this is the most likely period in the hydrograph for the site to have excessive velocities during the range of fish passage flows. Generally, 10% exceedance flows are most likely during January.

If using a flowmeter, calculate the average cross-sectional velocity at whichever end of the culvert has the highest velocities. Compare that velocity to the values in Table 3.2, however do not use the percent passability ratings in this table; the average cross-sectional velocity can only be used to verify that the culvert exceeds the velocity barrier threshold, but cannot be used to assign a percent passability or to verify that a culvert is 100% passable.

If the average cross-sectional velocity exceeds the velocity values in Table 3.2, then measure instantaneous discharge in the channel to determine if the discharge is within the range of fish passage flows. If the discharge is outside of the range of fish passage flows, the barrier status is unknown and you should reassess during fish passage flows. If the flow velocity is greater than the maximum velocity criteria, and the discharge is within fish passage flows, then the site is a barrier with unknown passability.

See Appendix J for additional guidance on measuring cross-sectional mean velocities and stream discharge.

3.6 Quick Reference Tables

Table 3.3 Data collection attributes for the Level A Culvert Assessment Field Form (Figure 3.2; Appendix E). Superscript numbers correspond with superscript numbers in Figure 3.2. Predefined field values are indicated in **bold** text.

Field	Description
¹ Site ID	Unique identifier for each site. Used to associate the feature field forms with the Site Description Field Form.
² Culvert Number	Used to distinguish between non-overflow culverts at a water crossing. Format X.Y, where X represents an individual culvert and Y is the total number of culverts at the crossing. For example, at a triple culvert crossing, the Culvert Numbers would be 1.3, 2.3, and 3.3. Overflow culverts are not assigned a Culvert Number.
³ Crew	Last names of individuals responsible for field data collection. Separate names with a semicolon, e.g., Barrett; Zweifel.
⁴ Date	Date of field data collection. Use MM/DD/YYYY format.
⁵ Material	Construction material of culvert: PCC = pre-cast concrete, CPC = cast-in-place concrete, CST = corrugated steel, SST = smooth steel, CAL = corrugated aluminum, SPS = structural plate steel, SPA = structural plate aluminum, PVC = plastic, TMB = timber, MRY = masonry (usually stone, brick, or block), OTH = other. Select CST or SST for aluminized steel. Select OTH if there is more than one material. If OTH is selected, describe in the comments.
⁶ Span	Horizontal culvert dimension. Measure at the widest point of culvert outlet and inlet; if different, record the smaller of the two measurements and describe in the comments. If streambed material is present, measure span at the widest point possible above the streambed and describe in the comments. Record to the nearest centimeter (0.01 meters).
⁷ Rise	Vertical culvert dimension. Measure from the invert to the soffit at culvert outlet and inlet; if different, record the smaller of the two measurements and describe in the comments. For bottomless arch culverts, measure from soffit to the streambed directly below the soffit. If the invert is rusted-out/missing or the invert cannot be accessed due to the presence of bed material within the culvert, measure from soffit to streambed and explain in the comments. Record to the nearest centimeter (0.01 meters).

Field	Description
⁸ Water Depth In Culvert	Depth of water inside culvert. Measure at the downstream end, approximately 0.15 meters from outlet. Record to the nearest centimeter (0.01 meters).
⁹ Shape	Shape of culvert: RND = round, BOX = rectangular or square, ARCH = bottomless, SQSH = squash (pipe arch), ELL = elliptical, OTH = other. See examples in Figure 3.7.
¹⁰ Water surface drop	Vertical distance from the water surface above a water surface drop and the water surface below a water surface drop. Measure all drops and record only the largest water surface drop in this field. Record additional water surface drop measurements in the comments. Record to the nearest centimeter (0.01 meters).
¹¹ Drop Location	Location of the water surface drop recorded in the Water surface drop field: Outlet = water surface drop at culvert outlet, Inlet = water surface drop at culvert inlet, Interior = water surface drop inside culvert. Record additional water surface drop locations in the comments.
¹² Apron	Presence and location of apron: None = not present, US = upstream, DS = downstream, Both = both ends. See examples in Figure 3.9.
¹³ Total Length	Distance from inlet to outlet of the culvert. Include aprons if present. Describe wing walls, or any other vertical structures at the ends of a culvert, in the comments but do not include in Total Length. Record to the nearest tenth of a meter (0.1 meters).
¹⁴ Slope	The difference in invert elevations from the most upstream end of the structure to the most downstream end of the structure, divided by the Total Length. For ARCH culverts, the difference in streambed elevations in the thalweg from the upstream end of the structure to the downstream end of the structure, divided by the Total Length. May be positive or negative. Record as a percentage to the nearest hundredth of a percent, e.g., +4.37%.
¹⁵ Road Fill Depth	Vertical distance from the culvert invert to the top of the road prism. See Figure 3.11. Record to the nearest half of a meter (0.5 meters).
¹⁶ Countersunk	Embedment of the culvert invert below the streambed. To be countersunk, the outlet invert must be buried below the streambed for a vertical distance $\geq 20\%$ of the total culvert rise, and streambed material must cover the invert for the entire length of the culvert. Example in Figure 3.12. All ARCH culverts are considered to be countersunk. Yes = countersunk, No = not countersunk.

Field	Description
17 Backwatered	Little or no visible flow throughout the entire length of the culvert: Yes = backwatered, No = not backwatered, Unk = unable to determine at time of assessment (describe in the comments).
18 Gate	Presence of a gate, e.g., tide gate or floodgate: Yes = gate present, No = gate not present. If purpose of gate is to impound water, complete the Dam Assessment Field Form (Chapter 5).
19 Rack	Presence of a rack that is associated with the culvert: Yes = rack present, No = rack not present.
20 Fishway	Presence of a Fishway: Yes = fishway present, No = fishway not present. If Yes , complete the Fishway Assessment Field Form (Chapter 8).
21 Bankfull Width	Outside of the area of culvert influence, bankfull width is measured horizontally, and perpendicular to flow from the point on the bank where water begins to overflow into the active floodplain. If there is no floodplain, it is the width of the waterbody at the dominant channel forming flow, which typically has a recurrence interval between one and two years. Record the width to the nearest centimeter (0.01 meters).
22 Span/Bankfull Width	Divide Span by Bankfull Width and record to the nearest whole number percentage, e.g., 67%. If there is more than one non-overflow culvert at the crossing, divide the sum of the spans of all non-overflow culverts by the Bankfull Width.
23 Tidal Influence	Determination of whether tidal conditions affect culvert hydraulics at any time between the low and high fish passage flows: Yes = tidal influence on culvert hydraulics present, No = tidal influence on culvert hydraulics not present, Unk = unable to determine at time of assessment (describe in the comments).
24 Pool Length	If there is a water surface drop at the outlet, measure the horizontal distance from culvert outlet to downstream control (the geomorphic feature at the pool's tail-out which controls the outlet pool water surface elevation). Record to the nearest centimeter (0.01 meters).
25 Pool Maximum Depth	If there is a water surface drop at the culvert outlet, measure the depth of the plunge pool at its deepest point. Record to the nearest centimeter (0.01 meters).
26 Pool Scour Line Width	If there is a water surface drop at the culvert outlet, measure the width of the plunge pool scour line at its widest point. Record to the nearest centimeter (0.01 meters).

Field	Description
²⁷ Barrier	Barrier determination using Level A culvert assessment: Yes = barrier, No = not a barrier, Unk = barrier status is unknown and more information is needed (describe in the comments).
²⁸ Method	Assessment method used to determine barrier status: LA = Level A culvert assessment, LB = Level B hydraulic analysis, Fishway = fishway assessment (Chapter 8), Other = barrier status determined by another assessment method (describe in the comments).
²⁹ % Passability	An estimate of the proportion of flows, between the low and high fish passage flows, which allow the majority of adult salmonids to successfully pass through the instream feature(s): 0 = 0%, 33 = 33%, 67 = 67%, 100 = 100% of fish passage flows, Unk = percentage of fish passage flows that allow passability through the structure is unknown and more information is needed. See Table 3.1 for assigning percent passability.
³⁰ Significant Reach	Is there a section of stream having at least 200 linear meters of usable habitat without a gradient or natural barrier, both upstream and downstream of the culvert? Yes = present, No = not present, Unk = unable to determine at time of assessment.
³¹ Comments	Concise comments about the culvert. Includes description for any field where Other or Unknown was selected.

Table 3.4 Data collection attributes for the Level B Hydraulic Analysis Field Form (Figure 3.22; Appendix E). Superscript numbers correspond with superscript numbers in Figure 3.22. Predefined field values are indicated in **bold** text.

Form Field Name	Description
¹ Site ID	Database unique identifier for each site used to associate feature field forms with the Site Description Field Form.
² Culvert Number	Refer to 'Culvert Number' in Table 3.3. The header info and 'Culvert Measurements' section of the Level B Hydraulic Analysis Field Form must be completed for each non-overflow culvert at the crossing. The 'Downstream Control Cross-Section' portion of the field form only needs to be completed once for the entire site.
³ Crew	Last names of individuals responsible for field data collection. Separate names with a semicolon, e.g., "Barrett; Zweifel"
⁴ Date	Date of field data collection. Use MM/DD/YYYY format.

Form Field Name	Description
5 Datum Elevation	Elevation that is assigned to a temporary benchmark (datum) that is used as a reference point from which Level B elevations are measured. Record to the nearest centimeter (0.01 meters).
6 Datum Location	Location of reference datum, e.g., culvert inlet invert.
7 Culvert Measurements	Data used to calculate relative elevations at the culvert inlet and outlet. Refer to Figure 3.21 for locations of culvert elevation data. At each location, record Instrument Height (IH), Rod Height (RH), and Vertical Distance (VD) if using surveying equipment that measures incline, to calculate Elevation (ELEV). If a probe is used to locate the invert, add the length of the probe to the Rod Height. Measure culvert bed elevation (if applicable) at a location on top of the bed material that represents the average elevation of the bed. Formulas for calculating the Elevation field are on the back of the Level B Hydraulic Analysis Field Form in Appendix E. Record all values to the nearest centimeter (0.01 meters).
8 Culvert Roughness	Data used to determine the frictional resistance caused by the internal roughness of the culvert: concrete, smooth = even, regular surface, paved invert = reinforced invert. If corrugated, dimensions are recorded as depth (top of corrugation to bottom of corrugation) x width (top of corrugation to top of adjacent corrugation): 0.5" x 2.67" , 1" x 3" , 2" x 6" , other . If other is selected, describe.
9 Bed Material Throughout	Does bed material cover the low-flow channel throughout the entire length of the culvert (i.e., no missing substrate or exposed corrugation)?
10 Downstream Control Cross-Section	Data used to calculate relative elevations and determine hydraulic roughness across the downstream control. Refer to Figure 3.24 for locations of downstream control elevations. The STA is the horizontal distance from the Top of Left Bank, read from the measuring tape. Moving horizontally from Top of Left Bank to Top of Right Bank, record IH, RH, and VD (if using surveying equipment that measures incline), to ELEV at each STA. Record SUB at the base of the stadia rod at every STA. Except at Top LB and Top RB, record the DEP. For only those elevation locations that have a non-zero DEP measurement, record the WSE as the sum of ELEV + DEP. Formulas for calculating Elevation are on the back of the Level B Hydraulic Analysis Field Form in Appendix E. Record all numerical values (IH, RH, VD, ELEV, DEP, and WSE), to the nearest centimeter (0.01 meters).

Form Field Name	Description
¹¹ Avg. WSE	Water surface elevation at the downstream control. Calculate the Avg. WSE using only the downstream control cross-section elevation locations with a non-zero DEP measurement. Record to the nearest centimeter (0.01 meters).
¹² Water Surface Downstream of X-Section; Distance from x-section	Data used to calculate relative elevation at the water surface downstream of the control. Place the base of stadia rod at the water surface and record IH, RH, and VD (if using surveying equipment that measures incline), to calculate WSE. Record the distance of this calculated WSE from the downstream control, measured along the thalweg. Record all values to the nearest centimeter (0.01 meters).

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 4

NON-CULVERT CROSSINGS

This chapter describes the inventory and assessment of non-culvert water crossings. Common types of non-culvert crossings include bridges, fords, fill or puncheon crossings, abandoned crossings, and washouts. Non-culvert crossings are frequently encountered in the field, especially as barrier culverts are replaced or removed.

For additional assistance evaluating the barrier status of non-culvert crossings, collect the measurements described in this chapter and any additional relevant information, then contact the WDFW Fish Passage Program for technical assistance: FishPassageInventory@dfw.wa.gov

4.1 Non-culvert Road Crossings – Inventory Overview

Non-culvert crossings should be designed and built for the purpose of supporting motorized traffic. Non-motorized crossings, such as footbridges, hiking trail fords, etc., are not inventoried unless they are suspected obstructions. If the crossing creates a fish passage barrier condition, then it should be inventoried according to the appropriate feature classification protocol described in this manual. Examples include:

- A footbridge with a span less than the bankfull width. The narrow footbridge constricts the channel, resulting in possible velocity conditions, and should be inventoried and assessed as a three-sided culvert (Chapter 2).
- A cattle crossing built on fill material should be inventoried and assessed as a fill/debris miscellaneous obstruction (Chapter 6).

Activities

The following is a summary of the general activities conducted at each non-culvert crossing site with the potential for salmonid fish use:

- Complete the Site Description Field Form in Appendix E (instructions for this form are provided in Chapter 2).
- Record descriptive information and physical measurements using the Non-Culvert Crossing Evaluation Form (Figure 4.1; data attributes described in Table 4.1). Comment on all potential barrier conditions at the site.
- Evaluate the feature for barrier status and percent passability (Section 4.2).
- Photograph the inlet and outlet of the feature, and any peculiarities. Stand at a distance from the feature so that the photos illustrate the environmental context. Appendix F provides guidance for photographing a fish passage feature.
- If the non-culvert crossing is a fish passage barrier and correction prioritization is desired, then conduct a habitat assessment (Chapter 10).

Detailed explanations of selected data fields in the Non-Culvert Crossing Evaluation Field Form (Figure 4.1) are provided in the following subsections and summarized in the Quick Reference Table (Table 4.3) in Section 4.3.

NON-CULVERT CROSSING EVALUATION FORM (07/6/2017)

¹Site ID _____

²Crew _____

³Date _____

⁴Crossing Type

Bridge Ford

Fill / Puncheon Abandoned

Washout Undefined

⁵Bankfull Width _____ ⁶Span _____

⁷Fishway Attached Yes No

⁸Barrier Yes No Unk

⁹Barrier Criteria WS Drop Slope Depth Debris

Failed Other Unspecified Tidegate

¹⁰%Passability 0 33 67 100 Unk

¹¹Significant Reach Yes No Unk

¹²Description _____

¹³Comments _____

Figure 4.1. Non-Culvert Crossing Evaluation Field Form. The superscript values in the field form correspond to the superscript values in Table 4.1.

4.2 Non-Culvert Crossing Assessment and Barrier Status

The assessment and barrier determination of non-culvert crossings depends on the type of feature present. When evaluating passability consider the criteria for water surface drop, slope, velocity, and depth outlined in Chapter 3. A flow meter may be used to measure velocity through a non-culvert crossing structure. See Appendix J for information about the applicability and use of flow meters. Level B hydraulic analysis will not be possible with most non-culvert crossings. If a structure physically blocks stream flow then it should be classified as a barrier.

Bridges

Differentiating between a bridge and three-sided culvert structure is often ambiguous. For the purpose of this manual, a bridge is defined as a *bottomless* structure with a span greater than the bankfull width. If you have specific knowledge of how the structure was permitted, defer to the structure definition in the permit. E.g., a structure with a span greater than bankfull width, which was permitted as a culvert, should be inventoried and assessed as a culvert.

When feasible measure and record the span of the bridge feature and the associated bankfull width. Measure span as the distance between the inside of the abutment on one bank to the inside of the abutment on the opposite bank. If the footings are exposed and/or piers are present, describe in the comments. Refer to Appendix G for information about measuring bankfull width.

Note: If you have previous knowledge that a structure was designed and permitted as a culvert, but it meets the aforementioned definition of a bridge, it should still be evaluated as a culvert for the purpose of this manual and consistency in the fish passage database



Figure 4.2. Photographic examples of bridge non-culvert crossings.

Fords

A ford is a shallow instream crossing. Fords commonly have a hardened foundation, such as concrete, or compacted rock. Fords are permitted for use during periods of no or low stream flow to minimize sediment delivery.

When assessing ford features record the foundation material and depth of water at the site in the comments. Observations of sediment delivery, or evidence of crossings outside of low-flow conditions, should also be included in the comments.



Figure 4.3. Photographic examples of ford non-culvert crossings.

Fill or Puncheon Crossings

Fill crossings are typically constructed with an assortment of large debris (logs, rocks, rubbish, etc.). Fill crossings allow water to pass through permeable material below a crossing, but usually restrict fish passage.

Puncheon crossings are lumber or wood decked crossings that are nearly level with the water surface elevation, or lie directly below it. They are typically found in wetland conditions.

When assessing fill or puncheon crossings comment on the construction materials and the dimensions of any potential passageways through the feature. For example, in a puncheon culvert the clearance between the streambed and the crossing feature, i.e., the headroom, should be measured and recorded.

Abandoned Crossings and Washouts

Observe general site conditions to differentiate between a washed-out crossing and an intentionally abandoned road crossing.

A washed-out road crossing is the result of a destructive event or the unintended failure of an aging structure. Remnants of a washed-out structure often remain within the stream channel, streambanks are disturbed, and the channel may be eroded and incised.

When a road is formally decommissioned (e.g., a forest practices road abandonment), it is inventoried as an abandoned crossing. Abandoned water crossings are designed and permitted to entirely remove the crossing structure and associated road fill. Typically, in a road abandonment project, the adjacent banks and channel are stabilized and restored. Removed barrier structures, such as decommissioned dams, should also be noted when performing fish passage inventories, so that the record can be corrected in the fish passage inventory database, but they are not classified as a non-culvert crossing.



Figure 4.4. Photo examples of fill/puncheon, washout, and abandoned non-culvert road crossings.

4.3. Quick Reference Table

Table 4.1. Field descriptions for the Non-Culvert Crossing Evaluation Form. Predefined field values are indicated in **bold** text.

Field Form Name	Description
¹ Site ID	Unique database identifier, must be identical to the Site ID for the site.
² Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon, e.g., “Paulus; Rains”
³ Field Review Date	Field review date. MM/DD/YYYY
⁴ Type	Type of non-culvert crossing feature. Values include: Bridge, Ford, Fill/Puncheon, Abandoned, Washout, Undefined
⁵ Bankfull Width	Outside of the area of bridge influence, bankfull width is measured horizontally, and perpendicular to flow from the point on the bank where water begins to overflow into the active floodplain. If there is no floodplain, it is the width of the waterbody at the dominant channel forming flow, which typically has a recurrence interval between one and two years. Record to the nearest centimeter (0.01 meters).
⁶ Span	Horizontal bridge dimension. Measure at the widest point of bridge outlet and inlet; if different, record the smaller of the two measurements and describe in the comments. Measure span at the widest point possible above the streambed and describe in the comments. Record to the nearest centimeter (0.01 meters).
⁷ Fishway Present	Indicates whether a fishway is associated with the feature. Yes = fishway is present, No = fishway is not present.
⁸ Barrier	The barrier determination using applicable assessment method: Yes = feature is a barrier, No = feature is not a barrier, Unk = barrier status is unknown and more information is needed (describe in the Comments).
⁹ Barrier Criteria	The reason that the feature was determined to be a barrier. Select all that apply: WS Drop, Slope, Depth, Debris, Failed, Other, Unspecified, Tidegate.
¹⁰ Percent Passability	An estimate of the proportion of flows, between low and high fish passage flow, which allow the majority of adult salmonids to successfully pass through the non-culvert crossing. Values are 0, 33, 67, 100, and Unk.

Field Form Name	Description
¹¹ Significant Reach	Indicates the presence of a significant reach of habitat. Defined as a section of stream having at least 200 linear meters of usable habitat without a gradient or natural barrier, both upstream and downstream of the fish passage feature. Values are Yes , No , and Unk .
¹² Description	A brief description of the feature. Record any feature dimensions or hydraulic measurements used to determine the passability of the site.
¹³ Comments	Concise comments. Provide an explanation of any attribute where “Other” or “Unknown” was selected.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 5

DAMS

A dam is any human-made structure built with the intent to impound or divert water, and elevate the upstream water surface. Water may be impounded for numerous purposes, including: hydroelectric power, irrigation, recreation, flood control, water quality, and wildlife habitat. Dams may be permanent or seasonal structures. For example, a vertical structure with seasonally installed flashboards or stoplogs is considered a dam.

Temporary natural features that dam the channel, such as beaver dams, debris jams, landslides, etc. are not inventoried as a dam.

The definition of dams, as outlined in this manual, should be used for the purposes of fish passage inventory and assessment only. It is not intended as a legal definition, nor is it intended to supplement or supersede the Washington State Department of Ecology definition of dams.

For additional assistance evaluating the barrier status of dams, collect the measurements described in this chapter and any additional relevant information, then contact the WDFW Fish Passage Inventory, Assessment, and Prioritization section: FishPassageInventory@dfw.wa.gov.

5.1 Dam – Inventory Overview

Activities

The following is a summary of the general activities conducted at each dam site with the potential for salmonid fish use.

- Complete the Site Description Field Form in Appendix E (instructions for this form are provided in Chapter 2).
- Record descriptive information and physical measurements using the Dam Evaluation Form (Figure 5.2; data attributes described in Table 5.2). If additional features are present, complete applicable field forms in Appendix E:
 - Culvert Level A (see Chapter 3)
 - Fishway Evaluation Form (see Chapter 8)
 - Diversion Evaluation Form (see Chapter 9)
- Evaluate the feature for barrier status and percent passability (Section 5.3).
- Photograph the inlet and the outlet of the feature and any peculiarities. Stand at a distance from the feature so that the photos illustrate the environmental context. Appendix F provides guidance for photographing a fish passage feature.
- If dam is a fish passage barrier and correction prioritization is desired, then conduct a habitat assessment (see Chapter 10).

As discussed in Chapter 3, culverts designed for water detention, water impoundment, or to elevate the upstream water surface, should be evaluated as dams. Water may be detained or

impounded by flow control devices, or the elevation of the pipe above the stream bed. Some examples of structures that may function as flow control devices include vertical standpipes, flashboard risers, and flow control gates. *Note: the presence of a vertical pipe does not automatically indicate that the site is a dam (example in Figure 5.1). If the vertical pipe is not elevated above the channel in order to retain or impound water, it should be inventoried as a culvert, and evaluated using the Level A culvert assessment described in Chapter 3.*



Figure 5.1. Photographic examples of dam standpipe, and non-dam vertical stormwater inlet. The dam standpipe on the left was designed for water detention, allowing debris and sediment to settle, and to constrain stormwater runoff. The non-dam stormwater inlet on the right was not installed to impound water. It was likely installed to access previously existing, underground stormwater management infrastructure; its primary purpose is water conveyance.

5.2 Dam Assessment

The purpose of the dam assessment is to collect basic information about the structure and make a barrier determination. Dams can be constructed from many different materials and have a variety of functions (Figure 5.3).

Check structures are classified as dams for inventory purposes. Check structures are small seasonal dams constructed of rocks, gravel bags, sandbags, fiber rolls, or other materials. Check structures are placed within a waterway to temporarily impound or redirect flow to a water diversion. When check structures are encountered complete the Dam Evaluation Form (Figure 5.2), and describe the check structure in the comments.

DAM EVALUATION FORM (07/10/2017)

¹Site ID _____

⁴Dam Name _____

⁵Reservoir Name _____

⁶Material Type CN EF MS
MT RF TB OT

⁷Primary Purpose FldCtrl Debris Elec Irr Nav Oth
StockPd WQual Rec WSup Tail FshProp WildHab

⁸Outlet Type Spillway Standpipe Flashboard Riser Culvert

⁹Span Full Partial

¹⁰Operation Timing Year-round Seasonal

¹¹Length _____ ¹²Height _____

¹³Water Surface Difference _____ ¹⁴Plunge Pool Depth _____

¹⁵Fishway Yes No ¹⁶Gate Yes No

¹⁷Barrier Yes No Unk

¹⁸Barrier Criteria WS Drop Depth Other

¹⁹%Passability 0 33 67 100 Unk

²⁰Significant Reach Yes No Unk

²¹Description _____

²²Comments _____

Figure 5.2. Dam Evaluation Form. The superscript values in the field form correspond to the superscript values in Table 5.2



A full span concrete dam with a flashboard riser outlet type.



A full span earthen fill dam with culvert outlet. The culvert is intentionally perched on the upstream end to impound water.



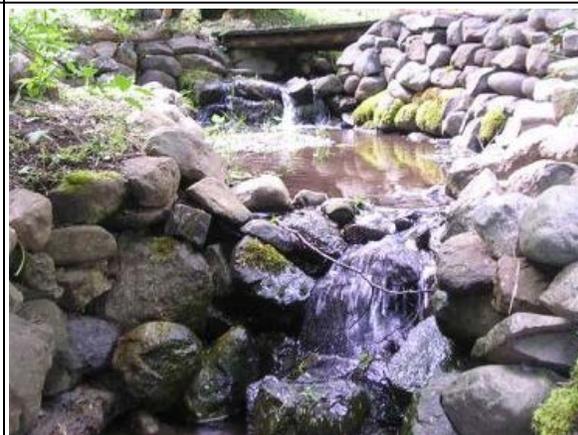
A partially spanning dam with an abandoned water surface diversion and no outlet type.



A screw gate at the upstream end of a culvert, resulting in a dam feature.



A full span seasonal dam (check structure) for irrigation.



A full span recreational rock fill dam.

Figure 5.3. Photo examples of dam structures.

Detailed explanations of the data fields in the Dam Evaluation Form (Figure 5.2) are provided in the following subsections and summarized in the Quick Reference Table (Table 5.2) in Section 5.4

Dam and Reservoir Names – Record if the dam or reservoir have an official or local name.

Material Type – Record the primary construction material of the dam. If the dam is constructed of multiple materials, such as a timber structure with concrete supports, describe the additional materials in the “Description” field.

Primary Purpose – Record the primary purpose of the dam. This may be difficult to determine during a field evaluation. If landowners or administrators are present, inquire as to why the dam was built. Otherwise rely on contextual clues.

Outlet Type – If present, select the type of outlet structure controlling the water surface elevation above the dam. If an outlet control structure is not present, e.g., water is just seeping through fill, leave this field blank. Outlet types include:

- **Spillway** – Spillways are structures that allow the passage of surplus water over the crest of a dam. The spillway outlet may include notches in the crest, spillway chutes, or side-channel spillways.
- **Standpipe** – Standpipes are vertical pipes with the inlet elevated above the stream channel. Standpipes retain water at a desired elevation, allowing excess water to spill over into an underground water conveyance (i.e., culvert).
- **Flashboard Riser** – For the purpose of this manual, “flashboards” and “stoplogs” are synonymous. Flashboard risers are vertical half pipes, walls, or boxes with channel guide slots on each side. The channel guides allow the installation or removal of flashboards that control the upstream water surface elevation.
- **Culvert** – Culvert outlets are installed at a near horizontal orientation. They may be deliberately undersized to impound water, and/or perched on the upstream end so that flow is only conveyed when the upstream water surface reaches a desired elevation. With culvert outlet types, collect Level A assessment data, if possible, in addition to the dam evaluation data (see Chapter 3).

There is often more than one feature transporting water from a dam. In the ‘Outlet Type’ field in the Dam Evaluation Form, record the feature controlling the upstream water surface elevation. For example, a site may have flashboard risers at the inlet of a culvert. The flashboard risers control the upstream water surface elevation, and water flowing over there risers is then conveyed through a culvert. The flashboard risers are the outlet type of this structure, because they are the outlet control structure. Describe any additional features in the Description field.

Span – Determine if the dam fully or partially spans the stream channel at normal flow.

Operation Timing – Determine if the dam detains or impounds water year-round or seasonally. If the dam operates seasonally, discuss the water control management plan with the facility owner to determine the time periods when the dam would be in use and could pose a complete or partial barrier to fish passage. For example, inflatable dams may be easily deflated on a seasonal basis to allow fish passage.

Dams with flashboards that are completely removed during high flow periods would also be considered “seasonal”. However, if the flashboards are only partially removed during high flows and the dam still controls the upstream water surface elevation, then the operation timing would be “Year-Round”.

Length – Length is the total measurement of the structure or fill that acts to impound water. Measure the length of the dam from the points where the structure or fill (e.g., an earthen berm) meets either bank. Length is typically measured perpendicular to the flow (Figure 5.4).



Figure 5.4. Photographic examples of dam length measurements.

Height – Measure the dam height from the lowest point at the base of the structure vertically to the crest of the dam.

Water Surface Difference – If water is flowing over the crest of the dam or into a standpipe, measure the vertical distance from the water surface above the dam to the water surface below

the dam. If there is no abrupt change in water surface elevation, leave this field blank, e.g., water flowing through an alternate outlet type, such as a culvert outlet or seeping through fill.

Plunge Pool – If a plunge pool is present, measure the maximum depth of the pool.

Fishway – Indicate whether a fishway is present. If yes, complete the Fishway Evaluation Form (Chapter 8).

If a fishway is present, the barrier status of the dam will depend upon the status of the fishway.

Gate – Indicate whether a gate is present. Remember that gated culverts that function to retain and elevate the surface of the water on the upstream end are classified as dams. Describe the gate in the comments.

5.3 - Dam Barrier Status and Percent Passability

Water Surface Difference – The difference in the water surface elevations above and below the dam may be used to determine the barrier status and assign percent passability. Water surface difference measurements are only taken when water is flowing over a crest of the dam, creating a water surface drop. If water *is not* flowing over the crest during fish passage flows, and there is no other outlet which fish can pass through, the site is a barrier with a passability of “0%”. If the water surface difference is greater than 0.24 meters, it is a barrier. Remember to account for launching and landing conditions at any water surface drop, and measure from the upstream water surface to the resting water below. Table 5.1 provides guidance on making passability estimates at dams that are barriers.

Table 5.1. Guidance for estimating barrier status based on water surface difference.

Water Surface Difference	≥ 0.24 m	0.24 m - 0.49 m	Yes	0.67
		0.5 m – 0.99 m		0.33
		≥ 1.00 m		0

Additional Features – When multiple fish passage features are present, consider all potential barrier conditions. If the dam has a culvert outlet, the fish passage barrier status may be determined by measuring the culvert’s Level A parameters. For example, if the dam has a culvert outlet with a slope barrier condition, then the barrier status and percent passability of the feature may be based on the Level A results.

The barrier status of a dam may also be influenced by an associated fishway. See Chapter 8 for guidance on evaluating fishways and determining the passability of a dam with a fishway.

Seasonal Features – Dams may impound water year-round, or seasonally. If a dam appears to be temporarily breached during the site visit, then the barrier status is ‘unknown’. If the seasonal

dam is in place at the time of assessment, evaluate the passability and barrier status as described in this chapter. For example, if a dam has a flashboard in place, and there is a ≥ 0.24 -meter water surface drop, then the structure is considered a barrier. If flashboard risers are present, but the boards are not in place during the site visit, then the barrier status is ‘unknown’.

Gates – The assessment method for a gated culvert acting as a dam depends on whether the gate is open or closed. Evaluate the site according to the gated culvert instructions in Chapter 3.

5.4 Quick Reference Table

Table 5.2. Data collection attribute descriptions for the Dam Evaluation Form (Figure 5.2). Predefined field values are indicated in **bold** text.

Form Field Name	Description
¹ Site ID	Unique identifier, must be identical to the Site ID for the site.
² Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon, e.g., “Holowatz; Wilson”
³ Field Review Date	Field review date. MM/DD/YYYY
⁴ Dam Name	Recorded legal name or local name.
⁵ Reservoir Name	Recorded legal name or local name.
⁶ Material Type	Type of dam, referencing the type of material that the dams is constructed from: CN = Concrete, EF = Earth Fill, MS = Masonry, MT = Metal, RF = Rock Fill, TB = Timber, or OT = Other.
⁷ Primary Purpose	The primary purpose of the dam: FldCtrl – Flood Control, Debris -Debris Control, Elec - Hydroelectric, Irr - Irrigation, Nav - Navigation, Oth - Other, StockPd - Stock or Farm Pond, WQual - Water Quality, Rec - Recreation, WSup - Water Supply, Tail - Tailings, FshProp - Fish Propagation, WildHab - Wildlife Habitat.
⁸ Outlet Type	Describes the outlet control structure at the dam. Options include: Spillway , Standpipe , Flashboard Riser , or Culvert
⁹ Span	Does the dam completely or partially span the stream channel?
¹⁰ Operation Timing	Is the dam in operation year-round or seasonally?
¹¹ Length	Length of the dam. Record to the nearest 0.1 meters.

Form Field Name	Description
12Height	The height of the dam from the base to the crest. Record to the nearest 0.01 meters.
13Water Surface Difference	If water is flowing over the crest of the dam, give the difference between the water surface elevations above and below the dam. Record to the nearest 0.01 meters.
14Plunge Pool Depth	Plunge pool maximum depth (if present). Record to the nearest 0.01 m.
15Fishway	Is there a fishway present?
16Gate	Is a gate present?
17Barrier	The barrier determination using applicable assessment method: Yes = feature is a barrier, No = feature is not a barrier, Unk = barrier status is unknown and more information is needed (describe in the Comments).
18Barrier Criteria	Factor that determined barrier status. Values include WS Drop, Depth, and Other.
19Percent Passability	An estimate of the proportion of flows, between low and high fish passage flow, which allow the majority of adult salmonids to successfully pass through the miscellaneous obstruction. Values are 0, 33, 67, 100, and Unk.
20Significant Reach	Indicates the presence of a significant reach of habitat. Defined as a section of stream having at least 200 linear meters of usable habitat without a gradient or natural barrier, both upstream and downstream of the fish passage feature. Values are Yes, No, and Unk.
21Description	A concise description of the physical structure.
22Comments	Concise comments and explanations of any attribute where 'Other' or 'Unknown' was selected.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 6

MISCELLANEOUS OBSTRUCTIONS

Human-made features that are not water crossing structures, fishways, dams, or water diversions are classified as miscellaneous obstructions. Examples include: artificial waterfalls, dikes/levees, erosion control structures, fill/debris, flumes, hatchery racks, lake screens, pipeline crossings, roughened channels, streambed controls, or other miscellaneous obstructions. Photographic examples and brief descriptions of miscellaneous obstructions are found in Figure 6.1.

For additional assistance evaluating the barrier status of miscellaneous obstructions, collect all relevant measurements and additional information, and then contact the WDFW Fish Passage Program for technical assistance: FishPassageInventory@dfw.wa.gov

6.1 Miscellaneous Obstructions - Inventory Overview

Activities

Conduct the following:

- Complete the Site Description Form in Appendix E (instructions for this form are provided in Chapter 2).
- Record descriptive information and physical measurements using the Miscellaneous Obstructions Evaluation Form (Figure 6.1; data attributes described in Table 6.2). If additional features are present, complete applicable field forms in Appendix E.
- Evaluate the feature for barrier status and percent passability (Table 6.1).
- Photograph the obstruction, and any peculiarities. Stand at a distance from the feature so that the photos illustrate the environmental context. Appendix F provides guidance for photographing a fish passage structure.
- If the feature is a fish passage barrier and correction prioritization is desired, then conduct a habitat assessment (Chapter 10).

Detailed explanations of selected data fields in the Miscellaneous Obstruction Evaluation Form (Figure 6.1) are provided in the following subsections and summarized in the Quick Reference Table (Table 6.2) in Section 6.2.

MISCELLANEOUS OBSTRUCTION EVALUATION FORM (05/24/2018)

¹Site ID _____

⁴Type _____

Artificial Waterfall
 Dike/Levee
 Erosion Control
 Fill/Debris
 Flume
 Hatchery Rack
 Lake Screen
 Pipeline
 Roughened Channel
 Streambed Control
 Other Miscellaneous Obstruction

²Crew _____

³Date _____

⁵Fishway Yes No

⁶Barrier Yes No Unk

⁷Barrier Criteria WS Drop Slope Velocity Depth

Debris Rack Failed Other N/A

⁸% Passability 0 33 67 100 Unk

⁹Significant Reach Yes No Unk

¹⁰Description _____

¹¹Comments _____

Figure 6.1. Miscellaneous Obstructions Evaluation Form. The superscript values in the field form correspond to the superscript values in Table 6.2.

6.2 Miscellaneous Obstruction Assessment and Barrier Status

Determining the barrier status of miscellaneous obstructions depends on the type of structure, and its measurable attributes. Due to the variable hydraulics of miscellaneous obstructions, professional judgement may often be used to assess passability. Consider the fish passage criteria for other human-made features, such as water crossing structures and dams (Chapters 3, 4, and 5). Evaluate any water surface drops, slope, depth, velocity, racks, and any other potential obstructions to help determine passability through the site (Table 6.2).

Velocity - Velocity measurements of Miscellaneous Obstructions can only be collected for features with a confined channel, such as a flume. To obtain velocity measurements, use a flow meter to measure the average cross-sectional velocity (See Appendix ##). Level B hydraulic analysis will not be possible with miscellaneous obstructions.

Depth - To estimate whether a site is a depth barrier, take direct measurements of the water depth. The water depth in or over the structure must be 0.30 m during fish passage flows. Features with natural bed med material throughout the length of feature cannot be classified as a depth barrier.

Racks - A miscellaneous obstruction may be equipped with a rack, screen, cage, or various types of guards. Common examples include trash racks and debris cages. If a rack is present at either end of an obstruction, measure and assess the clearance between bars according to the instructions in Chapter 3. Table 6.1 provides guidance on estimating barrier status when racks are present.



Artificial Waterfall – A human-made waterfall, or a waterfall that is reinforced to prevent erosion.



Dike/Levee – An embankment built to prevent flooding from other waterbodies. Jetties that act as barriers are also classified as a Dike/Levee.



Erosion Control Structure – Human-made structures or modified channels that are intended to protect streambeds, control grade or head cutting, reduce sedimentation, or function for other erosion control purposes.



Fill/Debris – Fill or debris of human origin that acts as a potential obstruction. Can include rubbish, rip-rap, rubbish etc.



Flume – An artificial stream channel built to transport water, or transport materials using flowing water. Flumes include aqueducts and canals.



Hatchery Rack – A weir that functions to block, divert, or trap fish, for hatchery or other use.



Lake Screen – Screen at the inlet or outlet of a lake or pond, typically intended to prevent fish migration.



Pipeline – Sites where pipelines intersect waterbodies. Pipeline may be above or below the streambed.



Roughened Channels – A channel constructed from boulder sized roughness elements placed in a pattern to increase roughness. Roughened channels control gradient, reduce velocity, or serve other restoration purposes.



Streambed Controls – Grade control features embedded in the channel that are not intended to improve fish passage through a human-made structure.



Other Miscellaneous Obstructions –Human-made structures, or obstructions of human origin, that do not fit the other feature type descriptions in this manual.

Figure 6.2. Examples of miscellaneous obstructions. Photographs and a brief description.

Table 6.1. General guidance for estimating percent barrier status and passability for miscellaneous obstructions.

Water Surface Drop	≥ 0.24 m	0.24 m - 0.49 m	Yes	0.67
		0.5 m – 0.99 m		0.33
		≥ 1.00 m		0
Slope (for near horizontal structures ≤ 18.3 meters in length)	$\geq 1.0\%$	1.01 % - 1.99 %	Yes	0.67
		2.00 % - 3.99 %		0.33
		≥ 4.00 %		0
Slope (for near horizontal structures ≥ 18.4 meters in length)	$\geq 1.0\%$	1.01 % - 1.99 %	Yes	0.33
		≥ 2.00 %		0
Velocity (culverts ≤ 30.4 meters in length)	≥ 1.22 mps		Yes	Unknown
Velocity (culverts 30.4 – 61 meters in length)	≥ 0.92 mps		Yes	Unknown
Velocity (culverts ≥ 61.1 meters in length)	≥ 0.61 mps		Yes	Unknown
Depth in/over Structure (during fish passage flows)	≤ 0.30 m		Yes	Unknown
Rack Present (horizontal and vertical minimum clear space between bars)	< 0.30 m	Chinook salmon potentially present in the stream	Yes	See Rack subsection in Chapter 3.
Rack Present (horizontal and vertical minimum clear space between bars)	< 0.24 m	Fish bearing streams without potential Chinook presence.	Yes	See Rack subsection in Chapter 3.

6.3 Quick Reference Table

Table 6.2. Miscellaneous Obstructions Form data collection attributes. Predefined field values are indicated in **bold** text.

Field Form Name	Description
¹ Site ID	Unique identifier, must be identical to the Site ID for the site.
² Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon, e.g., “Fleming; Phinney”
³ Field Review Date	Field review date. MM/DD/YYYY
⁴ Type	Type of miscellaneous obstruction feature. Values include: Artificial Waterfall, Dike/Levee, Erosion Control, Fill/Debris, Flume, Hatchery Rack, Lake Screen, Pipeline Crossing, Roughened Channel, Streambed Control, or Other Miscellaneous Obstruction.
⁵ Fishway Present	Indicates whether a fishway is associated with the barrier. Yes = fishway is present, No = fishway is not present.
⁶ Barrier	The barrier determination using applicable assessment method: Yes = feature is a barrier, No = feature is not a barrier, Unk = barrier status is unknown and more information is needed (describe in the Comments).
⁷ Barrier Criteria	The reason that the culvert was determined to be a barrier. See Table 6.1. Select all that apply: Water Surface Drop, Slope, Velocity, Depth, Debris, Rack, Failed, Other, N/A
⁸ Percent Passability	An estimate of the proportion of flows, between low and high fish passage flow, which allow the majority of adult salmonids to successfully pass through the miscellaneous obstruction. Values are 0, 33, 67, 100, and Unk.
⁹ Significant Reach	Indicates the presence of a significant reach of habitat. Defined as a section of stream having at least 200 linear meters of usable habitat without a gradient or natural barrier, both upstream and downstream of the fish passage feature. Values are Yes, No, and Unk.
¹⁰ Description	A brief description of the feature. Record any feature dimensions or hydraulic measurements used to determine the passability of the site.
¹¹ Comments	Concise comments. Provide an explanation of any attribute where “Other” or “Unknown” was selected.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 7

NATURAL BARRIERS

Natural barriers are defined as permanent or long-term naturally occurring features that impede fish passage, such as waterfalls or high gradient stream sections. Features such as beaver dams, log jams, and landslides are considered transitory, and are not inventoried or assessed for fish passage. A complete inventory of natural barriers is important to determine which salmonid species potentially inhabit upstream habitat.

The natural barrier criteria presented in this manual are for the purpose of identifying the upstream limits of adult salmonid migration only, and do not supersede fish typing guidelines published by other state or federal organizations.

If a natural barrier is encountered which cannot be evaluated according to criteria presented in this manual, collect all relevant measurements (plunge and step-pool dimensions, horizontal and vertical distances between grade breaks, dominant substrate size, scour line elevation relative to water surface elevation, channel width and depth, etc.), take photos, and then contact the WDFW Fish Passage Program for technical assistance: FishPassageInventory@dfw.wa.gov

7.1 Natural Barriers - Inventory Overview

A thorough contextual understanding is important when determining whether to inventory and assess a natural barrier feature. The following subsections provide guidelines for the evaluation of natural features, but ultimately professional judgment plays a significant role in determining whether the site is a barrier. For example, direct observations of salmonids upstream of an expected barrier, especially anadromous species expected to be blocked by the barrier, should supersede these guidelines.

Activities

Conduct the following:

- Complete the Site Description Field Form in Appendix E (instructions are provided in Chapter 2).
- Record descriptive information and physical measurements using the Natural Barrier Evaluation Form (Figure 7.1; data attributes described in Table 7.1). If additional features are present, complete applicable field forms in Appendix E.
- Evaluate the feature for barrier status (Sections 7.2 and 7.3).
- Note the date, time, and flow conditions during the assessment.
- Photograph the feature, and any peculiarities of the site. Stand at a distance from the feature so that the photos illustrate the environmental context. Appendix F provides guidance for photographing a fish passage structure. Note: natural features are often

much more complex than human-made features; multiple photos of any plunge and step-pools, grade breaks, substrate, etc., are very useful for barrier analysis.

Occasionally a fishway may be present to facilitate the passage of fish through or around a natural barrier. If a fishway is present, refer to Chapter 8 for data collection attributes and evaluation protocols for fishways.

Fish Passage Assessment for Natural Barriers

Natural barriers that are the upper limit of adult salmonid upstream access are defined as:

- Gradient - a stream reach with a sustained gradient of $\geq 20\%$ for ≥ 160 meters without resting areas
- Waterfall - a single, near vertical drop > 3.7 meters in height

Natural barriers should be evaluated, or visualized at a variety of flows. Salmonids may wait for more favorable hydrological conditions that provide navigable paths around barriers, such as re-watered side channels with smaller drops or steps, or more traversable main channel margins (Reiser et al., 2006). Measuring an assumed depth of water at bankfull conditions (bankfull depth), may help to envision passage conditions at higher flows.

NATURAL BARRIER EVALUATION FORM (7/20/2017)

¹Site ID _____

²Site Name _____

³Crew _____

⁴Date _____

⁵Barrier Type Gradient
 Waterfall
 Cascade

GRADIENT

⁶Length _____ ⁷Slope (%) _____

WATERFALL

⁸Water Surface Drop _____ ⁹Plunge Pool Depth _____

CASCADE

¹⁰Horizontal Length _____ ¹¹Slope (%) _____

¹²Vertical Height _____ ¹³Base Pool Depth _____

BARRIER STATUS

¹⁴Fishway Present Yes No

¹⁵Blockage Total Partial Unknown

¹⁶Description _____

Figure 7.1. The Natural Barrier Evaluation Form. The superscript values in the field form correspond to the superscript values in Table 7.1.

Detailed explanations of the data fields in the Natural Barrier Evaluation Form (Figure 7.1) are provided in the following subsections and summarized in the Quick Reference Table (Table 7.1) in Section 7.5.

7.2 Gradient

For a stream reach to be considered a gradient barrier, a water surface slope of 20% or greater should be sustained for a minimum length of 160 meters. While it is recognized that different species have various swimming and leaping abilities, e.g., bull trout are often found above 30% gradient (Cannings and Ptolemy 1998) and cutthroat trout have been found in gradients up to 33% (Jauquet 2002), for the purpose of this manual the 20% gradient threshold is used as the upper limit for most adult salmonids.

Professional judgment is important when determining whether a stream reach is a gradient barrier. Segments of stream that drop below the 20% threshold may act as a velocity refuge, allowing salmonids to rest and continue further upstream (see Figure 7.2). Consider the lengths of lower gradient segments, and their utility for migrating fish. Calm step-pools, with sufficient depth and length to allow fish to submerge their gills and rest, may provide relief within a high gradient reach, and should be considered breaks in the 160-meter segment length.

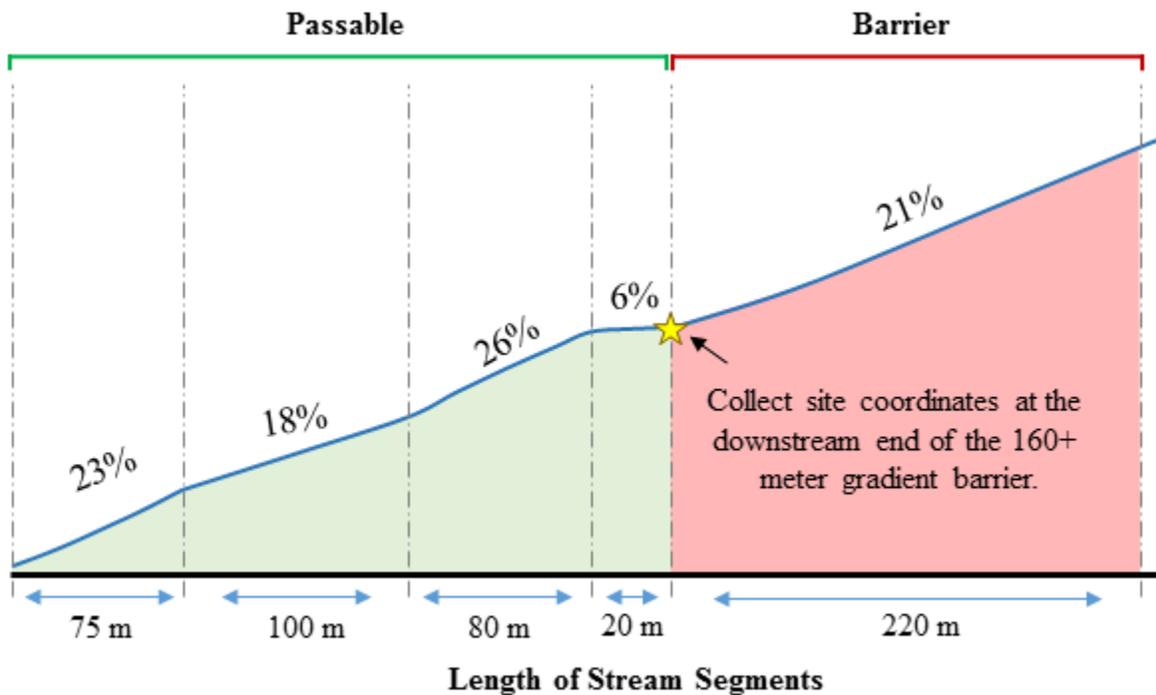


Figure 7.2. Gradient barriers. Diagram illustrates a series of stream segments, their length and gradient measurements, and whether those segments create barrier conditions. Also displayed is the point at which the barrier site coordinates should be collected.

Use a laser rangefinder or clinometer to measure gradients. Gradients should be measured along a straight segment of stream at least 15 meters long. Measurements should be taken from water surface at similar stream habitat types (e.g., riffle crest to riffle crest). For each gradient barrier, record the following data:

Length - The measured length of the gradient barrier to the nearest meter. The length should be greater than 160 meters for gradient barriers.

Slope - The average water surface slope of the gradient barrier to the nearest 0.01%. The slope should be greater than 20% for gradient barriers.

When documenting the location of gradient barriers, the site coordinates should be recorded at the downstream end of the gradient feature.

7.3 Waterfalls

For the purpose of this manual, a vertical, or near vertical, water surface drop is classified as a waterfall. Water surface drops should be measured as the vertical distance from the pool at the base of the waterfall to a velocity and depth refuge at the landing site; for example, if there is high velocity sheet flow at the top of the falls, then the vertical height should be measured to the first resting pool above the crest of the falls.

In addition to measuring the total water surface drop from the base to the landing site, account for the following conditions that may influence the ability of salmonids to successfully negotiate a waterfall:

- Launching conditions at the base of the waterfall, and any step-pools that may be used to circumvent a barrier water surface drop (Figure 7.4). Measure all drops and pool dimensions individually. Pools should have a depth, length, and width greater than the length of target species that can reasonably be expected to be present in the stream. Excessive turbulence that reaches the bottom of pools may present orientation difficulties and affect a fish's swimming and leaping abilities.
- Obstructions in step-pools or at the landing site. Large boulders or overhanging crests are examples of potential obstructions that can affect a fish's ability to physically reach the landing site.
- The horizontal distance between launching and landing sites. Depending on the angle of leap, different species reach the asymptote of their leap at different heights (See Figures 7.5 and 7.8).
- Velocity, turbulence, and depth at the landing site - to successfully pass a natural feature, a fish must be able to swim upstream and away from the landing site. Depths less than the body of the fish, and turbulent flows with suspended air impede the swimming ability of fish.
- Could higher flows potentially reduce the water surface drop? Note whether the tail out is controlling the pool depth at the time of assessment. Look for signs of scour on the banks (Figure 7.3).



Figure 7.3. The same natural fish passage feature at September low-flow conditions (A) and May high-flow conditions (B). Note evidence of high flow conditions when assessing waterfalls for barrier status. *Images used with permission from Powers (2008).*

For each waterfall barrier (total or partial) record the following information:

Water Surface Drop - The vertical water surface elevation difference between the landing water at the top of the falls and the launching pool at the base of the falls. Record the height to the nearest 0.01 m. If there are step-pools present, record the largest water surface drop in the “Water Surface Drop” field and record the height of any additional drops in the comments.

Plunge Pool Depth - The maximum depth of the plunge pool at the base of the waterfall recorded to the nearest 0.01 m. If there are step-pools present, record the pool depths in the comments.

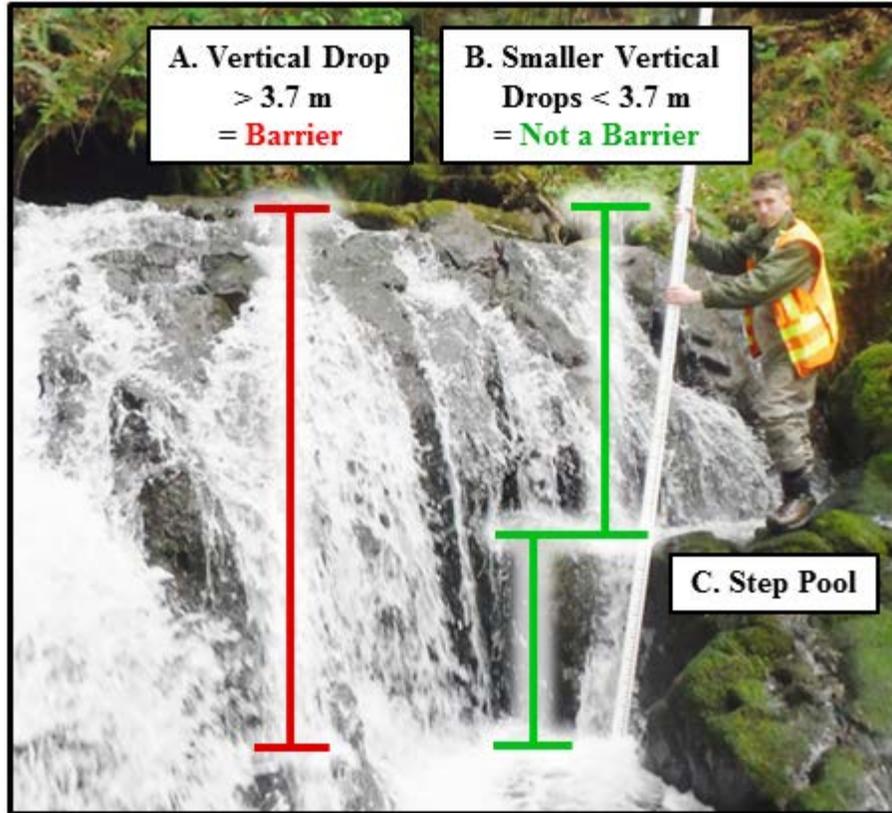


Figure 7.4. Step-pools. A) The water surface drop where the main channel spills over the waterfall, creating a barrier condition. B) Water surface drops between the plunge pool, step pool (C.), and the resting water above, creating a passable natural feature.

Partial Barrier Waterfalls

During the course of an inventory you may encounter waterfalls that are not total barriers, but do block anadromous access for species with weaker leaping abilities. Figure 7.5 illustrates the leaping abilities of Pacific salmonids (Powers and Orsborn 1985). The leap heights illustrated in the graph represent the modeled leaping abilities of healthy fish at the beginning of their migration, leaving the water at an 80° leap angle. For the purpose of this manual, natural features should be evaluated as if they are encountered by healthy fish.

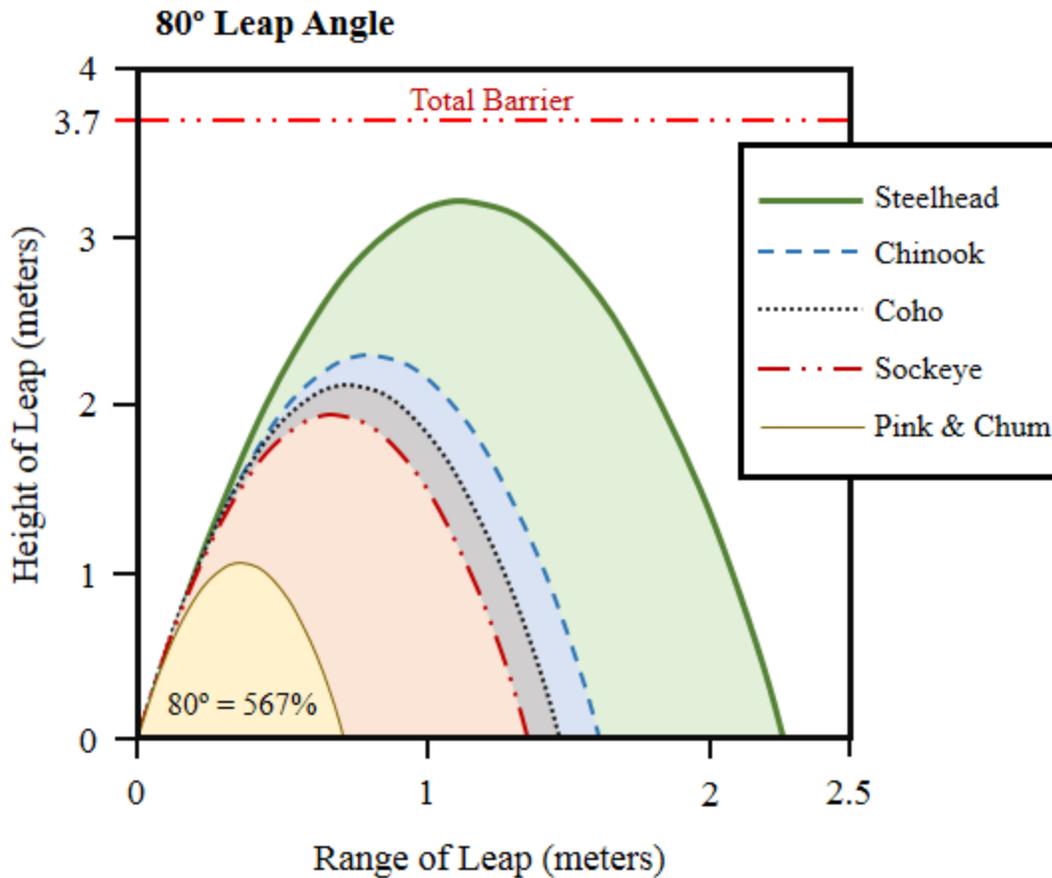


Figure 7.5. Washington State salmon leaping abilities. Illustrates the leap height and range of healthy fish leaving the water at an 80° leap angle (or 567% slope). Figure adapted from Ruggerone (2006) and Powers and Orsborn (1985).

When a waterfall is evaluated as a partial barrier (i.e., a barrier to some, but not all species), determine which species potentially inhabit the stream and which species are potentially blocked by the waterfall. See Chapter 2 for instructions on determining potential species utilization. Only inventory waterfalls that block anadromous species that may encounter the barrier. The following narrative describes when partial barrier sites should be inventoried and when they should not:

A habitat survey is conducted on a stream with potential chum, coho, steelhead, cutthroat trout, and resident trout use. While surveying upstream, a waterfall is encountered with a height of 1.5 meters. Referring to Figure 7.4, the waterfall would block chum salmon access to the upstream channel. This partial barrier site should be inventoried. Continuing upstream, a 2nd waterfall with a height of 1.5 meters is encountered. Since chum are no longer expected to be in the channel due to the 1st waterfall that was encountered, and because the remaining species in the stream have a leap height greater than 1.5 m, this 2nd waterfall should not be inventoried. Continuing farther upstream, a 3rd waterfall with a height of 2.5 meters is encountered. The maximum leap height of a healthy coho salmon is approximately 2.1 meters, so this 3rd waterfall should be

inventoried as a partial barrier. Any additional waterfalls encountered farther upstream which block only chum or coho salmon should not be inventoried.

7.4 Cascades

Cascades are chutes, or a series of small waterfalls, with steep, non-vertical slopes that require a combination of burst swimming, or horizontal and vertical leaps to access upstream habitat (See Figure 7.6 for examples of cascades). Site coordinates should be collected at the base of a cascade.



Figure 7.6. Photographs of chutes and cascades as defined in this manual. At the chute on the left, fish may attempt to burst swim up the face, resorting to leaping if there is excessive turbulence, or water depths less than the fish body depth. The feature on the right requires a combination of burst swimming and leaping to access upstream habitat.

To determine the barrier status of cascades or chutes record the following measurements:

Vertical Height - Measure the vertical distance between the launching point at the base of the cascades, and the landing point at the top. Record values to the nearest 0.1 meters.

Slope - Measure the water surface slope through the cascade and record to the nearest 0.5%. Use the water surface slope to determine if fish may burst swim to navigate the feature or determine the appropriate leap angle (Figure 7.5 & 7.8). Excessive turbulence or sheet flows may trigger leaping attempts, but there is little empirical data for when a fish will burst swim up a cascade or jump. Barrier assessments of cascade features should refer to the most recent scientific literature.

Length - Measure the horizontal distance between the launching point at the base of the cascades, and the landing point at the top. Record values to the nearest 0.1 meters.

Base Pool Depth - Measure the maximum depth of any plunge pools that are at the base of the cascade. Record values to the nearest 0.01 m. If there are step-pools present, record the pool depths in the comments.

Determining whether a cascade or chute is a barrier requires a detailed evaluation of the feature. Consider seasonal conditions, noting channel depths and the presence of potential refuge. For example, complex features such as boulders may create velocity refuge at high flows. Inversely, sheet flow or excessive turbulence during higher flows may block passage. Entrained air in turbulent water, and water depths less than the body depth of a fish hinder the fish's ability to realize their propulsive potential, resulting in barrier conditions. Figures 7.5 and 7.8 provide guidance as to whether adult salmonids could potentially achieve the burst speeds, or leap height and range necessary to traverse a barrier. Figure 7.7 provides additional decision support when evaluating the barrier status of a cascade. Because of the many extenuating circumstances found at cascades and chutes, a thorough assessment of the site, combined with professional judgment, is necessary to determine whether the feature is a partial or total barrier. When in doubt, it is better to presume that there is potential fish passage.

Remember that natural barriers must be permanent or long-term features. If a chute or cascade appears to be created to temporary events, such as woody debris build-up or seasonal erosion, it should not be assessed as a natural barrier to upstream anadromous access.

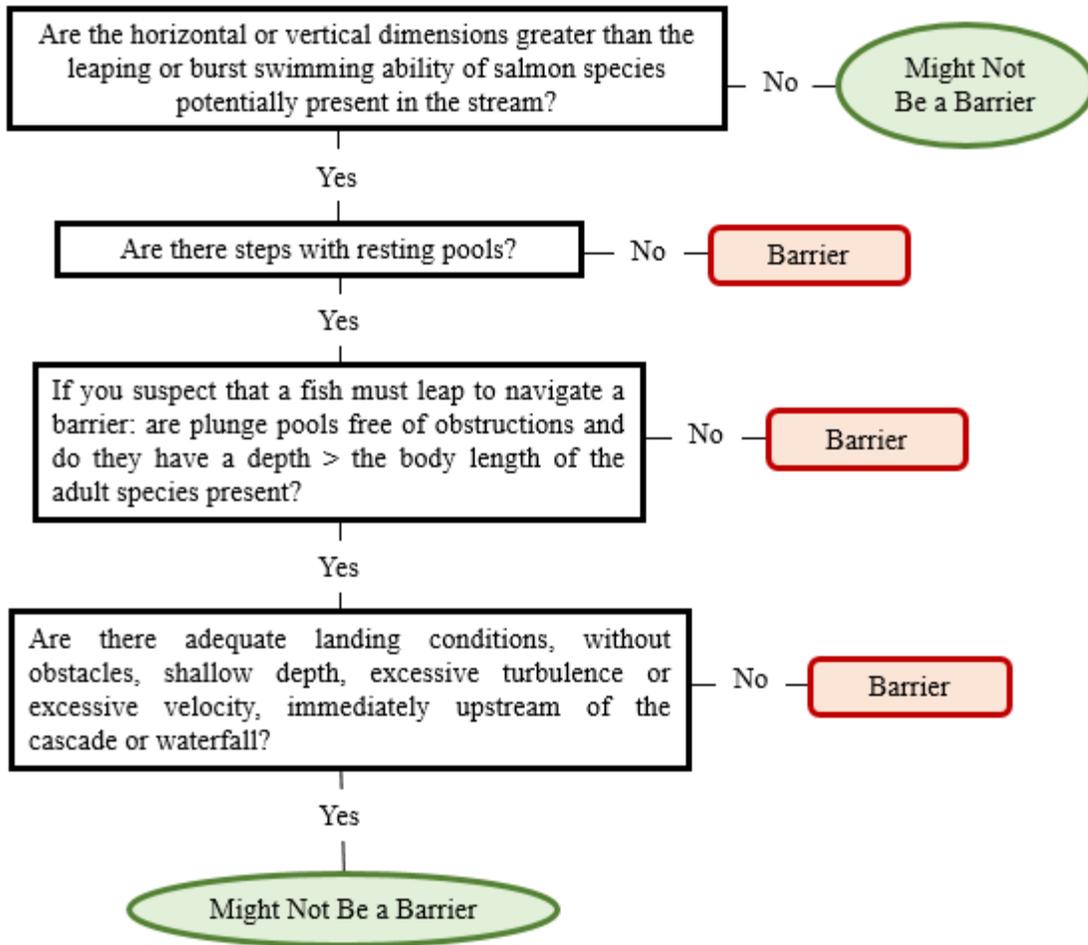


Figure 7.7. Cascade barrier determination. This flowchart provides guidance for determining whether a cascade is a barrier. Remember to consider the range of flows that occur at the site when evaluating the barrier status of a cascade.

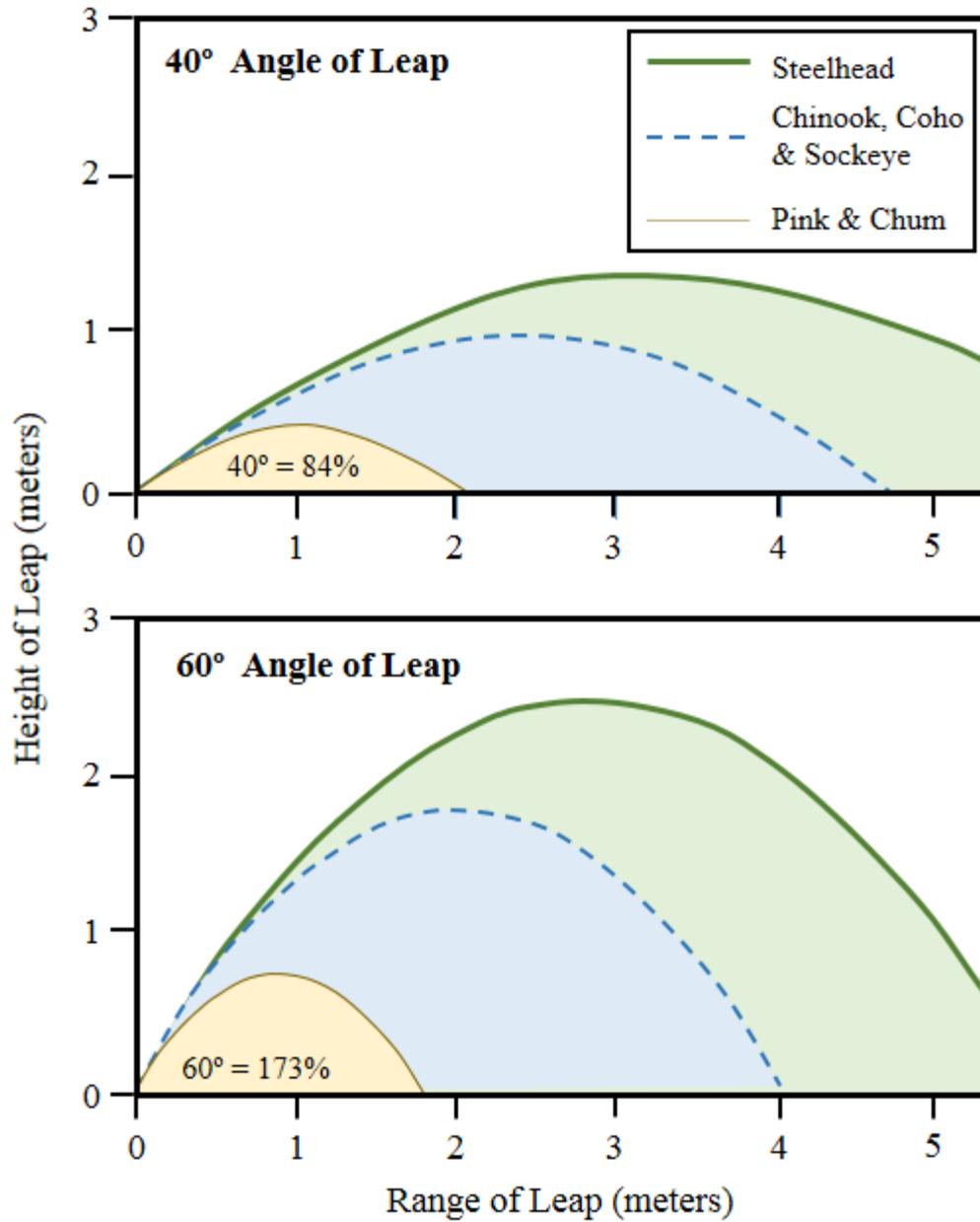


Figure 7.8. Vertical and horizontal leap distances in relation to angle of leap, as applied to assessing cascade barrier status (Powers and Orsborn 1985).

7.5 Quick Reference Table

Table 7.1. Natural Barriers Form data collection attributes. Predefined field values are indicated in **bold** text.

Field Form Name	Description
¹ Site ID	Unique database identifier used to associate the barrier feature with the Site Description Field Form.
² Site Name	Common name of the barrier used by local residents, resource managers, or as it appears on maps.
³ Field Crew	Last names of individuals responsible for field data collection. Separate names with a semicolon, e.g., “Fredley; Moore”.
⁴ Field Review Date	Field review date. MM/DD/YYYY
⁵ Barrier Type	Type of natural barrier feature. Valid entries include: Gradient or Waterfall .
⁶ Gradient Length	The length of the stream segment exceeding a 20% gradient. Record to the nearest meter.
⁷ Gradient Slope	Water surface slope of the gradient barrier stream segment. Report as a percentage.
⁸ Waterfall Height	The water surface drop height used to determine the barrier status. Record any additional, smaller drops in the comments. Record to the nearest 0.01 meter.
⁹ Waterfall Plunge Pool Depth	The maximum depth of the pool at the base of the waterfall. Record to the nearest 0.01 meter.
¹⁰ Cascade Horizontal Length	The horizontal distance between the launching point and landing point on a cascade. Record to the nearest 0.1 meter.
¹¹ Cascade Slope	The water surface slope of the cascade. Record to the nearest 0.5%.
¹² Cascade Vertical Height	The vertical distance between the launching point and landing point of the cascade. Record values to the nearest 0.1 meter.
¹³ Cascade Base Pool Depth	The maximum depth of the pool at the base of the cascade (if present). Record to the nearest 0.01 meter.
¹⁴ Fishway Present	Indicates whether a fishway associated with the barrier. Yes = fishway is present, No = fishway is not present.

Field Form Name	Description
¹⁵ Blockage	Degree of fish passage barrier. Values are; Total, Partial, Unknown. Partial barrier status should only be applied to waterfalls. Enter “Unknown” when conditions at the site do not allow you to make a full assessment of the barrier.
¹⁶ Comments	Concise description of the barrier feature. Include additional measurements or observations that may be relevant to making a barrier status determination.

7.6 References

Cannings, S.G., and Ptolemy, J. 1998. Rare freshwater fish of British Columbia. BC Environment (Ministry of Environment, Lands, and Parks), Fisheries Branch. Victoria, BC, Canada. 214 pp.

Jauquet, J.M. 2002. Coastal cutthroat trout (*Oncorhynchus clarki clarki*) diet in South Puget Sound, Washington, 1999-2002. M.Sc. Thesis, Evergreen State College. Olympia, WA. 79 pp.

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Reiser, D.W., Huang, C.M., Beck, S., Gagner, M., and Jeanes, E. 2006. Defining flow windows for upstream passage of adult anadromous salmonids at cascades and falls. Transactions of the American Fisheries Society. 135:668-679.

Ruggerone, G.T. 2006. Evaluation of Salmon and Steelhead Migration Through the Upper Sultan River Canyon Prior to Dam Construction. Natural Resources Consultants, Inc. Seattle, WA. 23 pp.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 8

FISHWAYS

Fishways are human-made fish passage improvement structures, constructed to facilitate the passage of fish through or around a barrier. Complete fishway evaluations are complex, requiring sophisticated hydraulic analysis and expertise to determine barrier status and passability. The evaluation guidance provided in this manual is intended to assist inventory crews in identifying common fishway designs, and recognize obvious structural issues that may create fish passage barrier conditions.

Fishways are constructed to improve passage for a target species or target age class during specific flows. Even when built according to design they can still be a partial barrier to fish passage. Thorough evaluations of barrier status require background knowledge of the design and purpose of the fishway. Inventory crews typically do not have access to, and are not expected to have access to, construction plans or other design documents. Without knowledge of the designed function of a fishway, the barrier assessment guidance in this manual is primarily based on the leaping ability of a 6" trout during fish passage flows (see Chapter 3). End users of inventory data should proceed with caution when prioritizing projects on systems with a fishway. The user should consider any and all other relevant information about the site, such as: species present, as-built drawings, inspection reports, purposes of the fishway, and hydraulics at different flows.

For new or previously undocumented fishways, follow the data collection and barrier assessment guidelines described in this chapter. For additional assistance with fishway evaluation and inspection, contact the WDFW Fish Passage Program: FishPassageInventory@dfw.wa.gov

8.1 Fishways - Inventory Overview

Fishway Definitions

Fishways are considered fish passage augmentations to existing structures. For the purpose of this manual they are not treated as a separate inventory feature. Instead they are defined as an attachment to a culvert, dam, miscellaneous obstruction, etc. Fishway data will be collected along with the primary feature data. Assessments will account for the condition of the primary fish passage feature, the influence of the fishway on the primary feature, and the condition of the fishway itself. The barrier status of the site will be determined as a whole.

FISHWAY EVALUATION FORM (04/11/2017)

¹Site ID _____

⁴Construction Year _____

⁵Attached To _____

Culvert Non-Culvert Crossing

Dam Other Natural

⁶Type BC BF WP PC VS SP
 SBC RCC BL TH Unk

BAFFLED CULVERTS AND FLUMES

⁷Number of Baffles _____

⁸Baffle Type WD CC MTL RC PVC Other

WEIR POOL, VERTICAL SLOT, POOL CHUTE, STEEPPASS

⁹Number of Pools _____ ¹⁰Entrance Pool Depth _____

¹¹Number of Weirs _____

¹²Weir Type WD CC MTL RC PVC Other

STREAMBED CONTROLS

¹³Control Type CC SCC RC GC LC PLC

¹⁴Number of Controls _____

¹⁵Control Location Upstream Downstream Both Ends

BARRIER STATUS

¹⁶Maximum Water Surface Drop _____

¹⁷Barrier Yes No Unk

¹⁸Barrier Criteria WS Drop Debris Other

¹⁹% Passability 0 33 67 100 Unk

²⁰Description _____

²¹Comments _____

Figure 8.1. Fishway Evaluation Form. Superscript numbers correspond with superscript numbers in Table 8.2.

Inventory Activities Overview

Conduct the following for each fishway encountered:

- Complete the Site Description Field Form found in Appendix E (instructions for this form are provided in Chapter 2).
- Complete the Fishway Evaluation Form (Figure 8.1; data attributes are explained in Table 8.2). Inventory and assess the fish passage feature that the fishway is associated with. Complete field forms (Appendix E) for the associated feature:
 - Culvert (Chapter 3)
 - Non-Culvert Crossing (Chapter 4)
 - Dam (Chapter 5)
 - Miscellaneous Obstruction (Chapter 6)
 - Natural Barrier (Chapter 7)
- Evaluate the feature for barrier status and passability.
- Photograph the fishway in the context of the associated feature and the surrounding landscape. Include photos of any fishway conditions that may require maintenance.
- If dam is a fish passage barrier, and prioritization for barrier correction is desired, then conduct a habitat assessment (see Chapter 10).

Detailed explanations of selected data fields in the Fishway Evaluation Form (Figure 8.1) are provided in the following subsections and summarized in the Quick Reference Table (Table 8.2) in Section 8.5.

8.2 Fishway Assessment

Fish passage conditions at sites with fishways are dynamic and may change overnight depending on water flow, sediment and debris transport, and the structural integrity of the fishway itself. Pool volume and depth, water surface drop, turbulence and energy dissipation, velocity, and physical blockages are all factors that affect passage within fishways.

Inventory crews are not expected to perform sophisticated modelling of turbulence, pool depth, etc. For the purpose of this manual, inventory crews are only expected to identify obvious fishway barrier conditions or maintenance issues. Consider the fishway a barrier if either of the following conditions exists:

- A water surface drop ≥ 0.24 m at any of the controls. When a weir, streambed control, baffle, etc. is set at an angle, measure the drops at the lowest point, where there is the smallest vertical leap. Indicate which drops exceeded the limit of 0.24 m. Assign passability based on the severity of the largest drop (Table 8.1).
- A total physical blockage created by large wood, debris, sediment, etc.

Table 8.1. Guidance for estimating percent passability based on water surface drop.

Water Surface Difference	≥ 0.24 m	0.24 m - 0.49 m	Yes	0.67
		0.5 m – 0.99 m		0.33
		≥ 1.00 m		0

If obvious maintenance issues are encountered at the site, such as broken baffles or weirs, plunge pools filled with bed material, etc., the site should be assigned a barrier status of “Unknown.” Provide detailed comments about any maintenance issues encountered. Absent either of the above barrier conditions, or obvious maintenance issues, the inventory crew may presume that the fishway is functioning as it was designed, and classify it as 100% passable.

Note: Unless an advanced hydraulic analysis is conducted, or there is an inspection record from WDFW staff, a fishway site with a passability of 100% should be viewed with uncertainty by end users. It only indicates that no barrier water surface drops or physical blockages are present. Because fishways are typically designed for a specific fish species, size, or flow, it is questionable whether the fishway will allow free movement of fish at all flows when fish are expected to move.

8.3 Fishway Designs

For the purpose of this manual, inventory crews are only expected to assign barrier status based on water surface drops, physical blockages, or maintenance issues. Depending upon the design of the fishway additional barrier conditions may be identified though. If it is determined that additional barrier conditions exist, the site should be considered a barrier, but passability will be unknown (except in the case of culverts with streambed controls). Fishway designs, and their potential barrier conditions are described in the following sections.

Baffled Culverts and Flumes

Baffles installed in culverts or flumes are designed to increase roughness and reduce the average cross-sectional velocity through the structure (Figure 8.2). They create a streaming flow regime during high-water conditions, or increase water depth during low-flow conditions. If the baffles create a plunging flow regime, consider whether they should be classified as a weir pool fishway (see below).



Figure 8.2. Photographic examples of baffled structure fishway designs.

When performing an inventory of baffled structures record the following:

- Number of baffles present and the baffle construction material.
- Note whether the baffles are installed at an angle, and describe any broken or missing baffles in the comments section.

When assessing barrier conditions in the structure, consider the following:

- When baffles are installed at an angle, measure the drop at the lowest point of the angle.
- Baffled culverts and flumes are particularly predisposed to collect debris, creating a barrier blockage.

Weir Pool, Pool Chute, Vertical Slot, and Steeppass Fishways

The following fish ladder designs consist of a series of velocity control structures. They are typically installed external to the associated fish passage feature. Note that weir pool and pool chute fishways can be totally contained within a culvert though. There are distinct differences between a structure containing baffles and one that contains weirs. Baffles are roughness features, designed to address velocity issues, and they are typically installed to create a streaming flow regime. Weirs are installed to create a plunging flow regime, with horizontal controls and energy dissipation pools.

Weir Pool - Weir pool fishways are the most common design found in the Pacific Northwest. Weir pool fishways are constructed with horizontal weir controls, and pools between the weirs which are sufficiently large to dissipate the energy of water plunging over the weirs (Figure 8.3). The weir pool fishway creates a plunging flow regime. The size, shape and material composition of weir pool type fishways can vary greatly.



Figure 8.3. Photographic examples of weir pool fishway designs.

Pool Chute - Pool chute fishways are hybrid structures, constructed with V-shaped baffles at the edges and a horizontal low-flow weir at the apex (Figure 8.4). At high flows, water flows down the center of the fishway, creating a streaming flow regime, while plunging flow and good fish passage conditions are maintained on the edges of the pools. During low-flow conditions the notches create a weir pool, plunging flow regime.

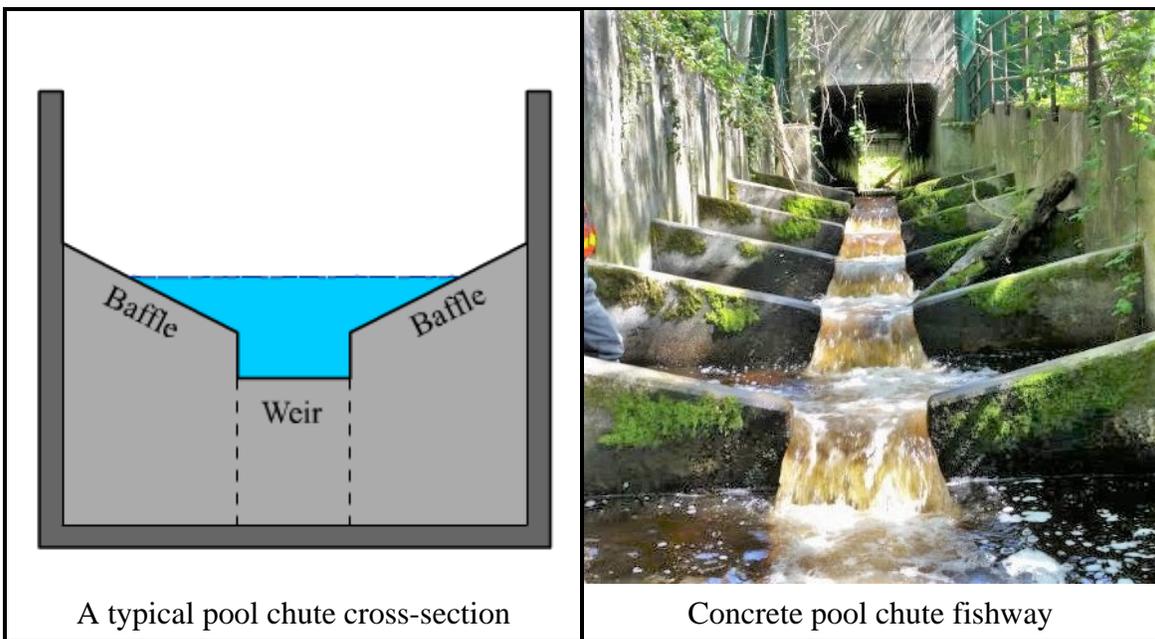


Figure 8.4. Illustrated and photographic examples of pool chute fishway designs.

Vertical Slot – A vertical slot fishway has distinct steps with hydraulic controls provided by a narrow vertical slot opening, often to the full depth of the fishway (Figure 8.5a). Vertical slot fishways have complex flow patterns that dissipate energy, and provide holding areas.

Steeppass – Steeppass fishways are steep, rectangular canals with baffles installed along the walls or floor (typically at a 45° angle) to reduce velocity (Figure 8.5b). Steeppass fishways are usually constructed in one or more pre-fabricated, modular sections, allowing them to be transported and installed at remote locations. For the purposes of this manual, denil fishways are classified as steeppass fishways.



Figure 8.5. Photographic examples of vertical slot (A), and steeppass (B) fishway designs.

Record the following data for weir pool, pool chute, vertical slot, and steeppass fishways only:

- The total number of plunge pools or steps within the fishway structure, including the entrance pool at the outlet of the structure. The entrance pool is the lowest, downstream plunge pool within the fishway, providing access to the fishway.
- The depth at the center of the entrance pool.
- The number of weirs, and the material from which the weirs are constructed.

When assessing barrier conditions in the structure, consider the following:

- When weirs or baffles are installed at an angle, or a low-flow notch is present, measure the water surface drop at the lowest point.

Roughened Channel

Roughened channel fishway designs are a graded mix of substrate installed upstream, downstream, or within a structure, to create roughness and diverse flow patterns, creating migration routes for a variety of fish sizes and species (Figure 8.6a). Roughened channels may

also be installed upstream or downstream of a structure to improve approach or exit conditions, or backwater the culvert.

Blasted Falls

Blasted falls fishways are excavated from the bedrock of a waterfall or cascades to create steps and pools (Figure 8.6b). When assessing the passability of blasted falls fishways, make a note of launching and landing conditions between pools.

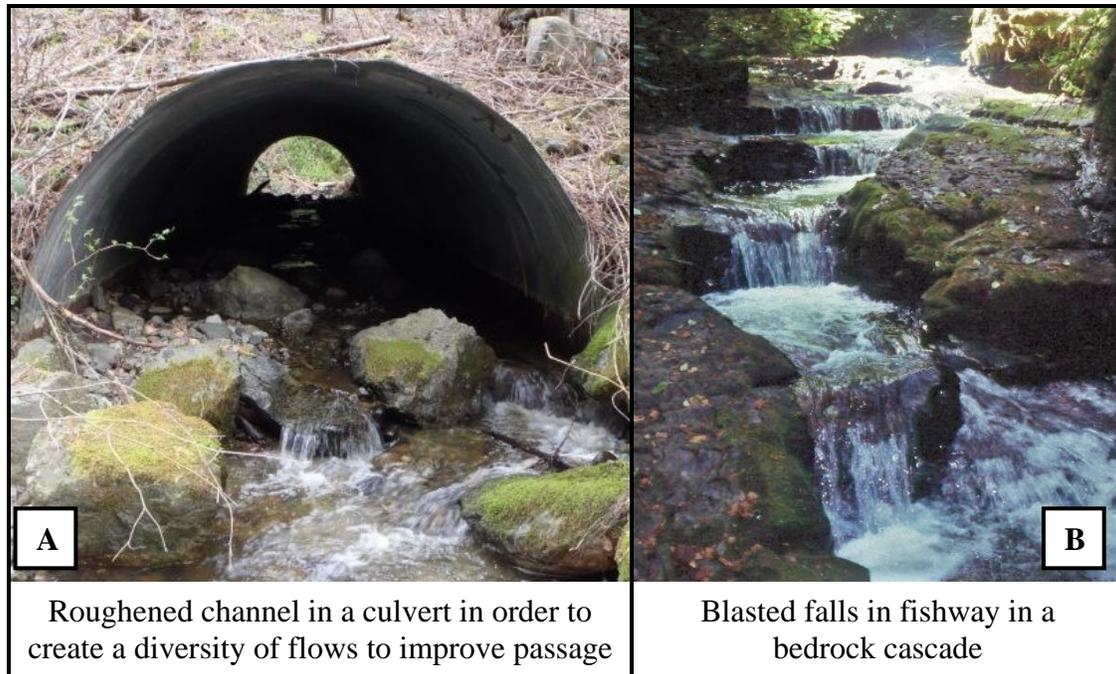


Figure 8.6. Photographic examples of roughened channel (A) and blasted falls (B) fishway designs.

Trap-and-Haul

When other fishway designs are impractical, a trap-and-haul operation may be used to move fish upstream. In a trap-and-haul operation, fish are drawn to holding pools and then transferred upstream using specialized vehicles. The fish are then released back into the waterbody at the upstream end of the fish passage barrier. Trap-and-haul facilities are generally used on large rivers with large-scale fish runs.

8.4 Streambed Controls

Streambed controls are gradient control structures installed directly into the channel substrate (Figure 8.7). They may be constructed of wood, rock, or other materials. Streambed controls are placed in channels to reduce water surface drops, control sediment movement, reduce velocities, and increase water depth. They may function like stair steps to backwater culverts, or they may promote aggradation of streambed material in order to reduce water surface drops.

Throughout the state many streams have undergone habitat enhancement work, including the placement of streambed controls in order to develop spawning areas and/or plunge pools for rearing habitat. Streambed controls should only be reported as a fishway if they were installed with the intention of improving fish passage. It is often difficult to ascertain what the intention of a streambed control is, therefore, if a streambed control is encountered which is not associated with another fish passage feature, evaluate it as a miscellaneous obstruction (Chapter 6).

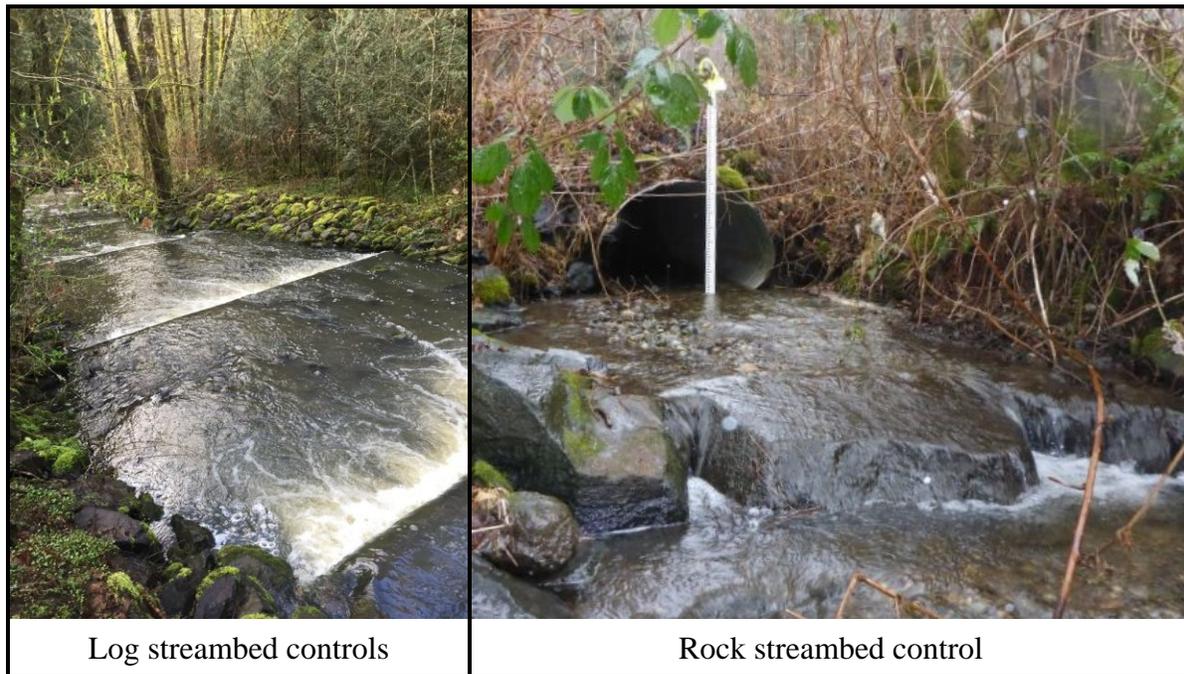


Figure 8.7. Photographic examples of streambed control materials.

Assessing Culverts with Streambed Controls

Because streambed controls are anchored into dynamic stream channels they are very prone to failure. Additionally, the intention of streambed controls is often ambiguous. Measuring water surface drops at streambed controls is a poor determinant of fish passage improvement at a barrier structure, therefore it is necessary to employ an alternate assessment methods when controls are present.

Unlike the other fishway structures, culverts with streambed controls should be assessed according to a Level A or Level B. When assessing a site with streambed controls upstream or downstream of a culvert, perform the following (see Figure 8.8):

- Conduct a Level A and measure all water surface drops associated with the streambed controls.
- Determine whether the streambed controls have the potential to backwater flow into *any length* of the culvert at any range of flows. *Note: the streambed controls do not have to backwater flow throughout the culvert. If they slow the flow through any length of the culvert, then the streambed controls are backwatering the culvert for the purposes of this*

assessment method. When in doubt, assume that the streambed controls backwater the culvert.

- If the streambed controls do have the potential to backwater the culvert, proceed to a Level B.
- If the streambed controls do not have the potential to backwater the culvert, assess passability based on a Level A (or Level B, if necessary). For example, if the streambed controls do not backwater a culvert, and the culvert has a slope greater than 1%, the site should be identified as a barrier.
- The streambed control will likely be the downstream hydraulic control, in which case you will use the top of the control as your downstream cross-section if a Level B is required.
- Assign a barrier status and percent passability. When multiple barrier conditions exist, use the most restrictive passability value.

Note that this protocol only applies to culverts with streambed controls, and *no* additional fishway components. It would not be applicable with baffled culverts, dams with weirs, flumes with streambed controls, etc.

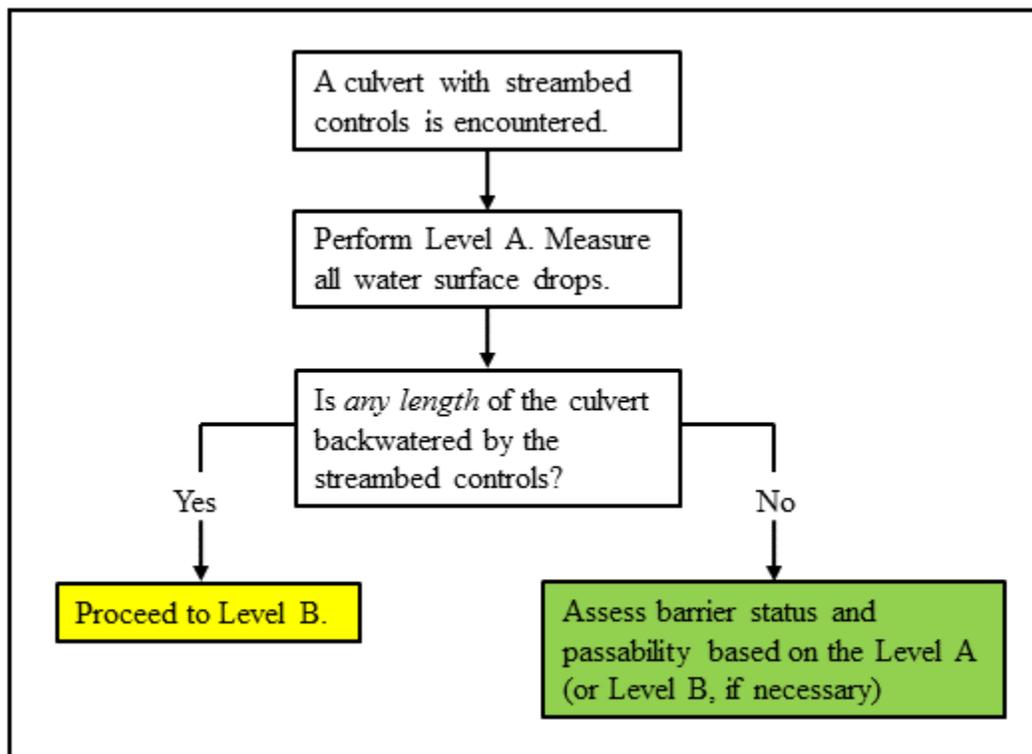


Figure 8.8. Streambed control assessment flow chart. Use this flow chart to determine barrier status and passability of culvert sites when streambed controls are present.

8.5 Quick Reference Table

Table 8.2. Data collection attribute descriptions for the Fishway Evaluation Form (Figure 8.1). Predefined field values are indicated in **bold** text.

Form Field Name	Description
¹ Site ID	Database unique identifier. Should be identical to the SiteID for associated fish passage features.
² Field Crew	Last name(s) of the field review team responsible for the data. E.g., “Givan; Penk”
³ Date	Field review date. MM/DD/YYYY format.
⁴ Construction Year	Year fishway was built. YYYY format. If unknown, then leave blank.
⁵ Attached To	The type of feature that the fishway is attached to in order to modify fish passage: Culvert, Non-Culvert Crossing Dam, Other, Natural.
⁶ Type	Fishway design type. Select all that apply from the list: BC – Baffled Culvert, BF – Baffled Flume, WP – Weir Pool, PC – Pool chute, VS – Vertical Slot, SP – Steeppass, SBC – Streambed Control, RCC – Roughened Channel, BL – Blasted Falls, TH – Trap-and-Haul, Unk – Unknown.
⁷ Number of Baffles	<i>For baffled structures only.</i> Record the number of baffles in the structure. WD – Wood, CC – Concrete, MTL – Metal, RC – Rock, PVC – Plastic, Other
⁸ Baffle Type	<i>For baffled structures only.</i> The material from which the baffles are constructed:
⁹ Number of Pools	<i>For weir pool, pool chute, vertical slot, and steeppass fishways only.</i> The total number of pools in the fishway structure. Include the most downstream pool below the last downstream control, i.e., the fishway entrance pool.
¹⁰ Entrance Pool Depth	<i>For weir pool, pool chute, vertical slot, and steeppass fishways only.</i> Depth of the fishway entrance pool. Record to the nearest 0.01 m.
¹¹ Number of Weirs	<i>For weir pool, pool chute, vertical slot, and steeppass fishways only.</i> The number of weirs present in the fishway.

Form Field Name	Description
¹² Weir Type	<i>For weir pool, pool chute, vertical slot, and steep pass fishways only.</i> Material of which the weirs are constructed. Select from list: WD – Wood, CC – Concrete, MTL – Metal, RC – Rock, PVC – Plastic, Other
¹³ Control Type	<i>For streambed control fishways only.</i> Streambed control type. Select all that apply from the list: CC – Concrete, SCC – Saccrete, RC – Rock, GC – Gabion, LC – Log, PLC – Plank.
¹⁴ Number of Controls	<i>For streambed control fishways only.</i> Total number of streambed controls upstream and downstream of the fish passage structure.
¹⁵ Control Location	Location of the streambed controls relative to the associated feature. Select from the list: Select from the list: US = Upstream, DS = Downstream, BE = Both Ends.
¹⁶ Maximum Water Surface Drop	Maximum fishway water surface drop, including all fishway components present at the site. Record to the nearest 0.01 m.
¹⁷ Barrier	Barrier status of the feature.
¹⁸ Barrier Criteria	Assessment method used to determine barrier status. Select from the list: WSDrop , Debris , Other
¹⁹ % Passability	Estimated percent passability. Select from the list: 0 , 33 , 67 , 100 , Unknown
²⁰ Description	Concise description of the fishway. Include any additional measurements.
²¹ Comments	Provide additional comments regarding the fishway conditions, including relevant contextual observations. If the fishway needs maintenance, describe here. If the barrier criteria is “Other”, provide detailed comments about any alternative assessment methods used.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 9

SURFACE WATER DIVERSIONS

A surface water diversion is any human-caused transfer of surface water from a waterway to another location. Surface water diversions are common instream features in agricultural areas where water is used for irrigation. Water may also be diverted for hydropower, industrial, recreational, residential, municipal, and hatchery purposes. Washington State law requires that all surface water diversions be screened to prevent fish from being drawn into diversions, where they are at risk of injury or mortality (RCW 77.57). The fish screen design criteria described in the Anadromous Salmonid Passage Facility Design (NMFS, 2011) outlines the screening criteria for surface water diversions, and has been adopted by the Washington Department of Fish and Wildlife.

There are three primary goals when inventorying surface water diversions:

- Locate and describe the type of diversion.
- Determine the presence and condition of screening.
- Collect information necessary to prioritize unscreened or inadequately screened diversions for correction.

Dams (Chapter 5), water crossing structures (Chapters 3 and 4), and miscellaneous obstructions (Chapter 6) are often associated with surface water diversions. These associated features influence diversion operations, and should be assessed for fish passage as described in this manual. Additionally, many diversions are unscreened, or only screened to exclude debris, and do not provide adequate fish protection.

For additional assistance evaluating surface water diversions and associated fish screens, collect the measurements described in this chapter and any additional relevant information, then contact the WDFW Fish Passage Program for technical assistance: FishPassageInventory@dfw.wa.gov

If screening facilities are fenced, locked, or otherwise inaccessible, WDFW may have existing records of the facility. Before attempting to enter the site, contact the WDFW Fish Passage Division.

9.1 Diversions - Inventory Overview

Activities

The following is a summary of general activities conducted at each surface water diversion site with the potential for salmonid fish use:

- Complete the Site Description Field Form in Appendix E (instructions for this form are provided in Chapter 2).

- Record descriptive information and physical measurements using the Surface Water Diversion Data Form (Figure 9.2; data attributes described in Table 9.1). If additional associated features are present (e.g., dam, culvert, roughened channel), complete applicable field forms in Appendix E.
- Photograph the diversion, capturing the structure in context to the landscape, and any additional associated features (Figure 9.1). Also photograph any notable conditions, such as screen damage, maintenance needs, and any structural or operational conditions that pose a risk to fish life.
- If a diversion is not adequately screened and correction prioritization is desired, then conduct a habitat assessment (see Chapter 10).



Figure 9.1. Photographs of a surface water diversion and associated fish passage feature. The image depicts the screened diversion channel, the associated fish passage feature (dam), attached fishway, and bypass channel.

SURFACE WATER DIVERSION EVALUATION FORM (5/10/2017)

¹Site ID _____

²Crew _____

⁴Diversion Type Gravity Pump

³Date _____

⁵Point of Diversion LB RB

⁶Headgate Yes No

⁷Diversion Dam Yes No

⁸Intake Location BA OS OC

⁹Fish Bypass Yes No

¹⁰Bypass Condition _____

¹¹Diversion Amount _____ (gpm or cfs – circle one)

¹²Water Right Number _____ ¹³Power Meter Number _____

¹⁴Fish Screen Yes No Unknown

¹⁵Screen Type TBS RDS VPS IPS HPS IG PMP OT

¹⁶Active Cleaning Yes No Unknown

¹⁷Screen Material PP PB WM PM OT

¹⁸Screen Height _____ ¹⁹Screen Width _____

²⁰Screen Diameter _____

²¹Screen Condition OK MN Unknown

²²Screen Under Operation Yes No Unknown

²³Problems/Comments _____

Figure 9.2. Surface Water Diversion Evaluation Form. Superscript numbers correspond with superscript numbers in Table 9.1.

9.2 Surface Water Diversion Assessment

The purpose of the surface water diversion assessment is to collect preliminary data that can be used by diversion specialists to identify and correct potential causes of fish injury and mortality.

Detailed explanations of selected data fields in the Surface Water Diversion Evaluation Form (Figure 9.2) are provided in the following subsections and summarized in the Quick Reference Table (Table 9.1) in Section 9.4.

Diversion Type - Surface water diversions are categorized into two general types: gravity and pump.

- Gravity diversions are typically characterized by open channels or canals where flow is diverted from a waterway, via differences in elevation, i.e., gravity.
- Pump diversions employ mechanical pumps to remove water directly from a body of water. Pumps are typically located on land, with the intake submerged in a nearby waterbody. However, submersible pumps are located directly in the stream.

Point of Diversion - The point at which water is diverted from a watercourse. Note whether the diversion is on the right bank or left bank, looking downstream.

Headgate - A headgate is a structure used to control the amount of water flowing into a diversion. They are typically associated with gravity diversions and located upstream of screens, if present. There are various types of headgates (Figure 9.3).



Figure 9.3. Examples of diversion headgate designs. The pictures above show two examples of headgates that may be associated with surface water diversions.

Diversion Dam - Many diversions use a dam to control the water surface elevation and deflect it to the Point of Diversion. When performing an assessment, record the presence or absence of a diversion dam. If a dam is present, it should also be inventoried and assessed for fish passage (see Chapter 5).

Intake Location - The intake location may be at the riverbank, offshore, or off-channel (Figure 9.4), and may or may not be screened. Select the appropriate intake location:

- Riverbank intakes are immediately adjacent to the streambank or shoreline of the main waterbody. When screens are present, they are installed at the point of diversion.
- Offshore intakes are away from the shoreline within the waterbody or channel, i.e., in the middle of a river, lake, pond, etc.
- Off-channel intakes are separate from the main flow, and often isolated from the river by a side channel or pipe. Intake screens located in human-made or modified side channels, ditches, or ponds should be recorded as an off-channel intake.

Fish Bypass - A fish bypass may be present, allowing fish to be transported from the area in front of a screen back to the main waterbody. Not all diversions require a fish bypass. For example, point of diversion screens do not require a fish bypass. Fish bypass systems associated with gravity diversions are typically installed behind a headgate and consist of a fish conveyance channel or pipeline and a bypass outfall that is intended to safely return fish to the main waterbody.

Although less common, pump diversions may also have a bypass; these are usually associated with diversions from ponds. Ponds should be configured with an outlet channel (or pipe) having sufficient flow away from the pump intake to carry fish back to the main waterway. An intake channel or pipe that diverts flow into a pond does not constitute a bypass channel, since it requires fish to swim back upstream to get back to the parent waterbody.

Bypass Condition - Describe the condition of the bypass at the time of the site visit. Evaluate and comment on the following:

- Does the bypass safely return fish to the waterbody of origin?
- Is the bypass entrance or return pipe blocked with debris?
- Is there sufficient flow and depth to allow fish to find and enter the bypass and return safely to the waterbody of origin?
- Do the flows in front of screens allow fish to bypass without delay or impingement?
- Does the bypass outfall have a water surface drop? What is the height of the drop? What is the depth of the receiving water? What are the landing conditions, e.g., are the fish landing on rocks?
- Is the bypass outfall location free of eddies, reverse flow, or known predator habitat?

Note: there are cases during low river flow when a bypass may be shut off to augment flows through the bypass channel. This should be recorded in the comments.

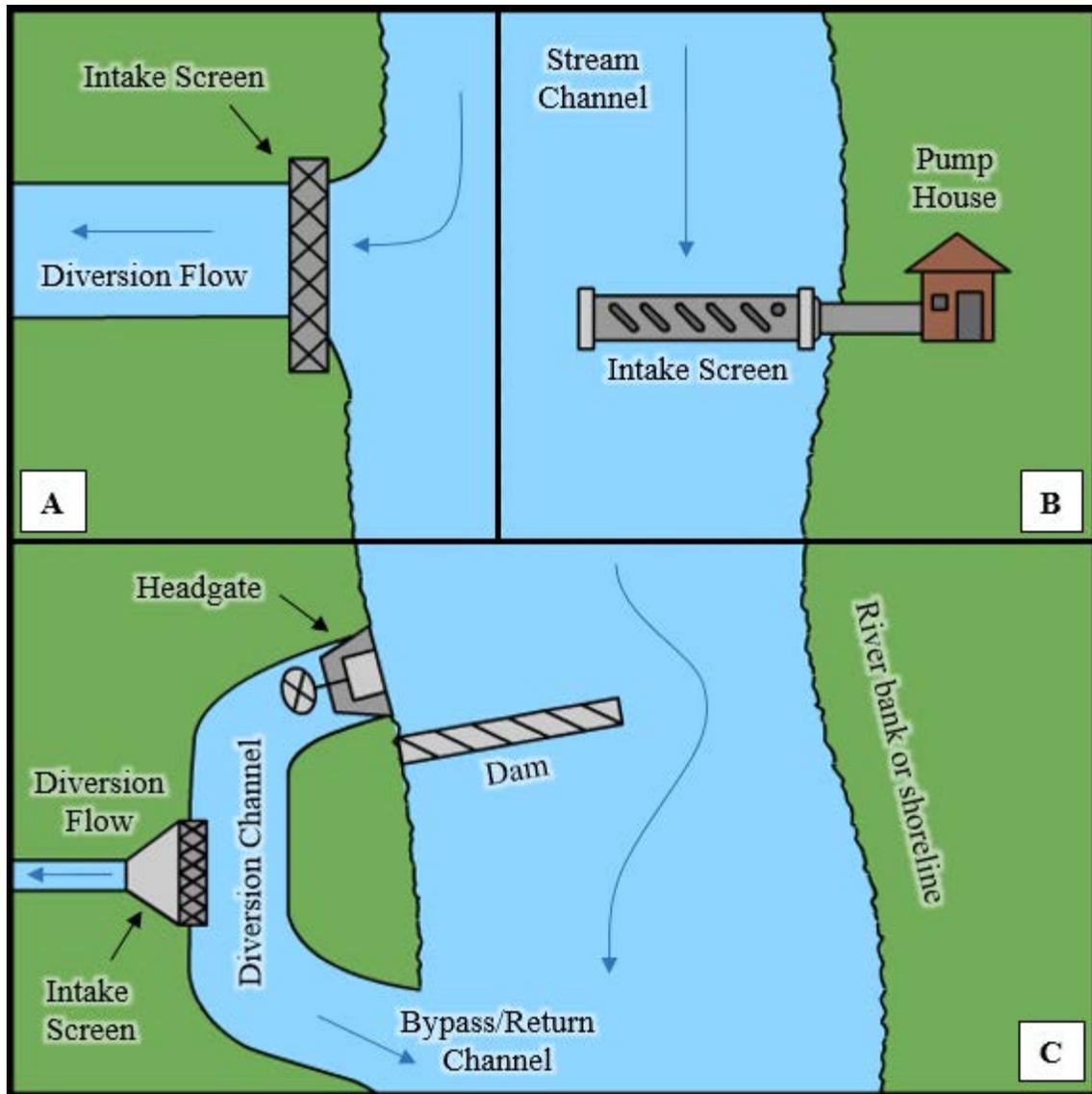


Figure 9.4. Diagram of intake and/or intake screen locations. A) Riverbank (BA) intake screens are located adjacent to the riverbank or shoreline. B) Offshore (OS) intakes are located within the waterbody or channel. C) Off-channel (OC) intakes are isolated from the main flow by a ditch, pond, etc.

Diversion Amount – The maximum allowable diversion amount is a critical piece of information used by WDFW to determine the compliant size and type of screen, and to prioritize the correction of unscreened or inadequately screened diversions. Record the maximum diverted flow volume that is allowed by the water right permit(s) or certificate(s).

Note that multiple water rights may be associated with a single diversion. Water right permits or certificates define the legal, maximum instantaneous flow allowed for the diversion. Water right information can be requested from the Washington Department of Ecology’s (WDOE) Water Resources Hotline at 1-800-468-0261, or obtained from the WDOE’s Water Resources Explorer,

Note: many diversion pumps have attached plaques which display maximum flow rates. The maximum flow rate is not the same as the diversion amount.

Water Right Number - Record the water right 'record number' listed by WDOE.

Power Meter Number - Power meter numbers are a unique identifier code, typically containing a combination of numbers and letters. If present, they can be found on the front of the meter, engraved on the meter box, or printed on a sticker attached to the meter box. Power meter numbers can help determine ownership of a surface water diversion.

9.3 Surface Water Diversion Assessment - Screens

Screen Presence - Indicate the presence or absence of a screen at the diversion. This field provides documentation that a screen is present even when access to the screen is restricted and assessment data cannot be collected. If it is not possible to determine if a screen is present or absent, select "Unknown".

Fish screens that are associated with gravity diversions are typically located near the point of diversion. However, they may be located a significant distance downstream, along a diversion channel. At a minimum, a field crew should walk 200 meters of the diversion channel to search for a screening facility. If the entire diversion channel cannot be walked, and/or a screening facility is not found within 200 meters, then select "Unknown" and report the distance walked by the field crew in the comments.

Pump diversions are usually screened near the intake pump. When evaluating pump diversions, do not pull pumps or pump intake lines out of the water or remove the pump housing; this may result in damage or personal injury. If you are unable to collect the data without disturbing the pump equipment, then leave the data entry fields blank and explain the situation in the comments.

Some innovative water users may attempt to construct homemade fish screens (Figure 9.4). While they may be well-intentioned, these 'informal' fish screens are not approved by WDFW, and are unlikely to offer adequate fish protection. When informal fish screens are encountered do not indicate that the diversion is screened; select "No" in the Screen Presence field, and comment on the condition.



Figure 9.4. Informal or homemade screens. Informal diversion screens are not considered adequate for the protection of fish life, and inventory crews should not indicate that a screen is present.

Screen Type - Surface water diversion screens are classified into a small number of general types; however, each screen type may have numerous variations due to size, location, site-specific constraints, and cleaning strategies. When screens are present, refer to the descriptors below to select the screen type. Screens configurations that do not fit one of these descriptions are classified as “Other”.

Common gravity diversion screen types include:

- **Traveling Belt Screen (TBS)** – A moving conveyor belt screen that excludes fish and debris while allowing surface water to be diverted (Figure 9.5).



Figure 9.5. A photograph of a traveling belt screen.

- Rotary Drum Screen (RDS) – A screen, rotating cylindrical drum (Figure 9.6).

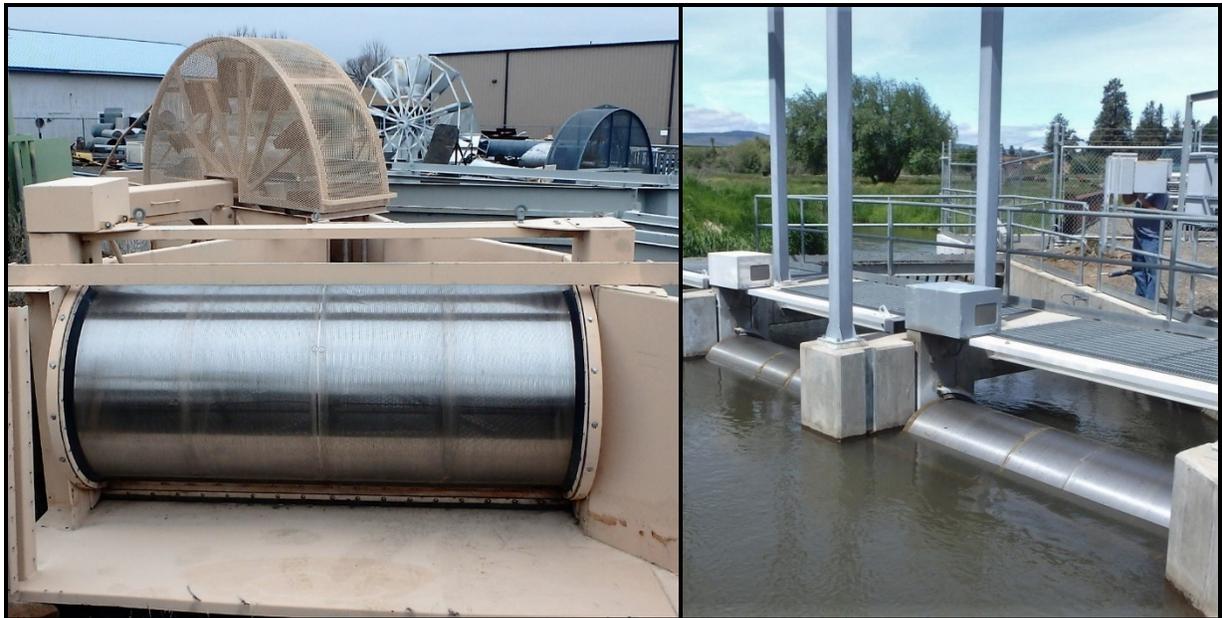


Figure 9.6. Photographs of rotary drum screens.

- Vertical Plate Screen (VPS) - Vertical plate screens are vertical and flat, usually oriented along the stream banks (Figure 9.7). Vertical plate screens are typically placed parallel to the flow of water, and are installed at 90° from the streambed.



Figure 9.7. Photographs of vertical plate screens.

- Inclined Plate Screen (IPS) – Inclined plate screens are flat, inclined, and oriented along the stream banks (Figure 9.8). Inclined plate screens are typically placed parallel to streamflow, and set at an angle of less than 45° from the vertical, unless the inclined screen is placed flush with the riverbank, and reasonably matches the bank slope.

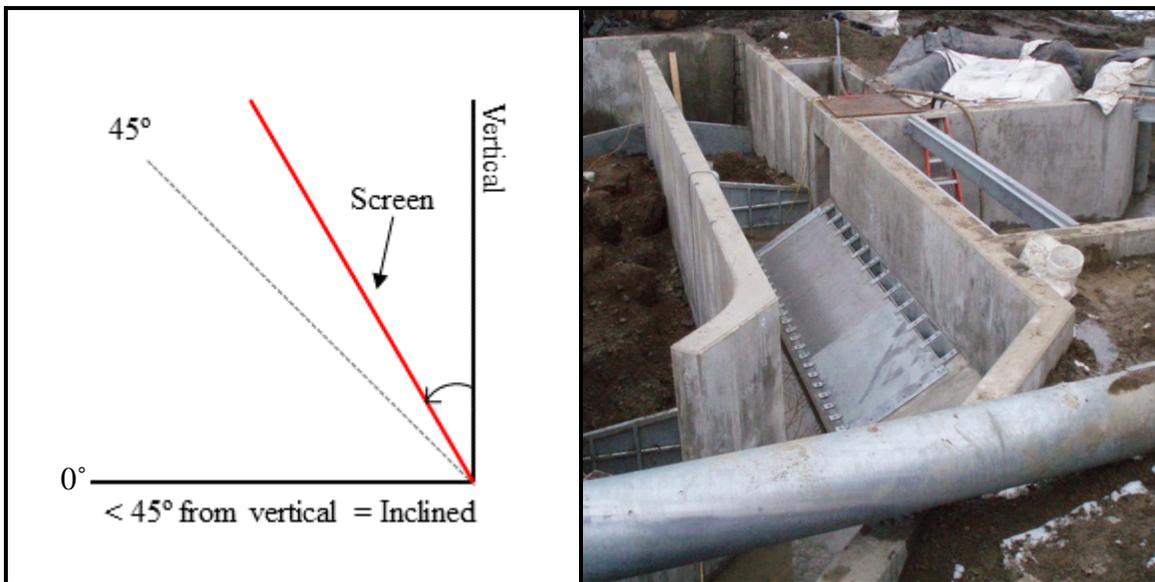


Figure 9.8. A diagram depicting the angle from the vertical, and a photograph of an inclined plate screen.

- Horizontal Plate Screen (HPS) – Horizontal plate screens are inclined or horizontal flat screens (Figure 9.9). They are typically placed *perpendicular* to streamflow, and slope upstream or downstream at an angle of 45° or greater from the vertical. Because water flows over the screen, sheet flow and inadequate water depth is a common problem with horizontally oriented screens, presenting a risk for fish and debris getting trapped on the screen surface.

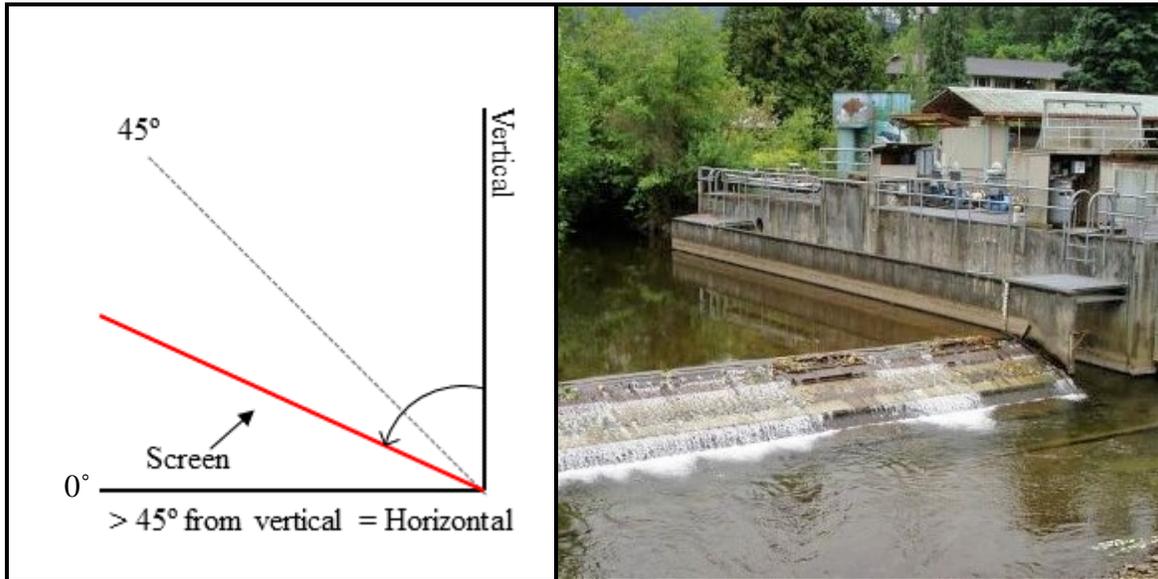


Figure 9.9. A diagram depicting the angle from the vertical, and a photograph of a horizontal plate screen.

- Infiltration Gallery (IG) – Infiltration galleries are placed within a saturated sub-surface aquifer to convey water to either a pumped or gravity-fed distribution network (Figure 9.10). Infiltration galleries may include one or more horizontal screens, perforated pipe manifolds, or unperforated pipes, buried in a streambed or bank. A significant portion of these systems are located under the ground with a pump house or a small building being the only visible clue to their presence. This makes infiltration galleries difficult to identify and evaluate.

Radial wells (including Ranney Wells) are a type of infiltration gallery consisting of a relatively shallow, vertical well with screens placed laterally in the alluvial aquifer zone. The lateral screens intercept and collect water, which is then pumped for use. These wells are located near a surface water source such as a river, or lake.

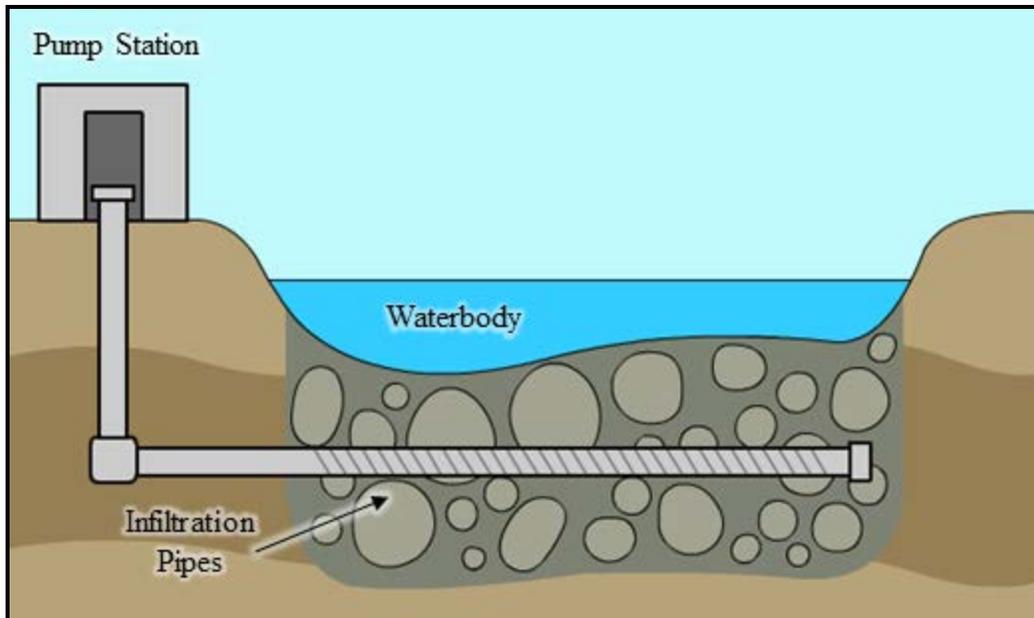


Figure 9.10. An illustrated cross-sectional diagram of an infiltration gallery screen.

Pump screens (PMP) - Also referred to as end-of-pipe screens, pump screens are used for a variety of applications. Pump screen designs range from small, relatively simple structures used for small irrigation withdrawals, to permanent structures associated with large water intake systems. Some larger pump screens may have an active cleaning feature such as spray bars or an airburst system. Many different pump screen configurations are commercially available and widely used throughout Washington State (Figure 9.11). For the purpose of this manual, any screen type associated with a pump diversion is classified as a PMP.



Figure 9.11. Photographs of pump screens.

A 'Riverscreen™' is one type of pump screen that floats on pontoons, and draws from the water surface (Figure 9.12). River screens provide active cleaning through hydraulically driven rotation and water spray bars.



Figure 9.12. A Riverscreen™ pump screen.

Note: Components such as foot valves, strainers, and skimmers are often associated with pump diversions, but should not be confused with the screen.

Active Cleaning - Active screen cleaning systems (e.g., brushes, wipers, and airburst systems) are an automated method of debris removal. Drum screens and belt screens are, by design, active cleaning systems. Passive screens have no cleaning system and must be cleaned manually. When it is not clear whether an active screen cleaning system is present, record that it is “Unknown”.

Screen Material - Screen material refers to the porous surface of the diversion screen, which can be constructed from many materials. Common screen materials include perforated plate (PP), profile bar (PB), woven wire mesh (WM) or plastic mesh (PM) (Figure 9.13). Materials that do not meet the descriptions above are designated as “Other”.

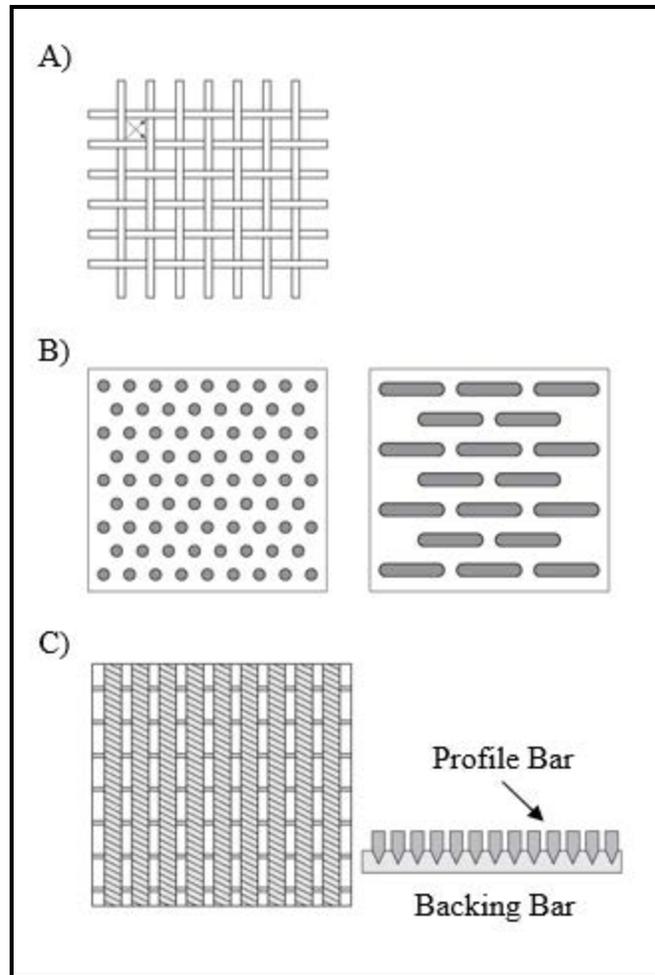


Figure 9.13. Common screen materials. A) Mesh screens can be manufactured using woven metal wire (WM) or plastic (PM). B) Perforated plate screens (PP) are manufactured by mechanically puncturing metal plates. C) Profile bar screens (PB), which include wedge wire screens, are manufactured by attaching the screen profile bars to a structural backing bar.

Screen Dimensions - The following measurements help to characterize the screen:

- Screen height – the vertical dimension of the screen
- Screen width – the horizontal dimension of the screen, i.e., the length of the screen
- Screen diameter - for drum screens and pump screens

Not all dimensions apply to all screen types, and it may not be possible to obtain these measurements while the screens are in operation.

Screen Condition - Screen condition reflects whether a screen is clean and intact, or if maintenance or replacement is required. *It is not an evaluation of compliance with federal and*

state screening requirements. Damaged and/or inadequately maintained screens can result in fish entrainment or impingement.

The following items should be considered when evaluating screen condition (Figure 9.14). If any of these conditions exist, record that maintenance is needed (MN):

- Holes or damage to the screen surface or frame that would allow small fish to pass through or be injured by contact with the screen surface.
- Gaps and spaces greater than the maximum screen openings. This includes spaces between the screens, seals, structural frames, and/or civil works – the wood, metal or concrete structures in the channel that the screen are mounted into.
- Screens or trash racks plugged with debris.

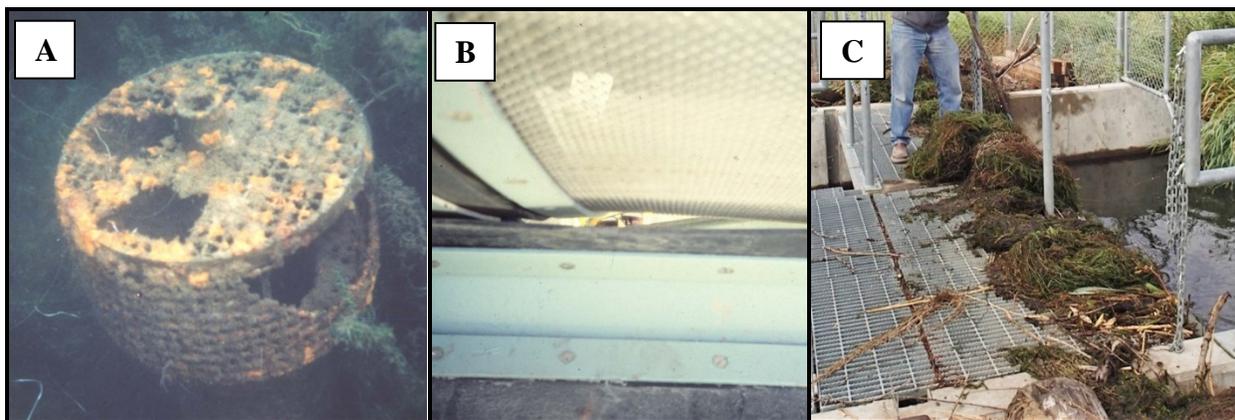


Figure 9.14. Photographic examples of adverse screen conditions. A) Damage to the screen surface would allow small fish to enter and potentially result in injury. B) A gap between the screen surface and the structural seal would allow small fish to enter. C) Screen is plugged with debris.

Problems/Comments - Briefly describe any noteworthy conditions not captured by the standard data elements. If “Other” or “Unknown” were selected for any of the above fields, provide further explanation in the comments. Note whether the screen was in operation at the time of assessment.

9.4 Quick Reference Table

Table 9.1. Field descriptions for the Surface Water Diversion Data Collection Form.

Predefined field values are indicated in **bold** text.

Field Form Name	Description
¹ Site ID	Database unique identifier. Should be identical to the SiteID for associated fish passage features.
² Field Crew	Last name(s) of the field review team responsible for the data. E.g., “Didricksen; Novak; Rogala; Simmons; Taylor”
³ Date	Field review date. MM/DD/YYYY format.
⁴ Diversion Type	The type of surface water diversion: Gravity or Pump diversion.
⁵ Point of Diversion	Point of diversion (POD): LB = left bank, RB = right bank. Referenced looking downstream.
⁶ Headgate	Indicate whether a headgate is present: Yes = present or No = not present.
⁷ Diversion Dam	Presence of an instream diversion dam structure: Yes = present or No = not present. If ‘Yes’, also complete a Dam form.
⁸ Intake or Screen Location	Intake or intake screen location, More detailed description of where the diversion intake is located: BA = Riverbank (or streambank), OS = Offshore, OC = Off-Channel.
⁹ Fish Bypass	Presence of a fish bypass. Yes = present, No = not present, or Unknown = unable to determine presence or absence.
¹⁰ Fish Bypass Condition	Indicate whether the fish bypass is in operation and comment on the condition of the bypass.
¹¹ Diversion Amount	Volume of water diverted in gallons per minute (gpm) or cubic feet per second (cfs).
¹² Water Right Number	The water right permit(s) or certificate(s) numbers associated with the diversion. Obtained from the Washington Department of Ecology.
¹³ Power Meter Number	Number issued to the Power Meter servicing the diversion, if present.
¹⁴ Fish Screen	Reports the presence of some type of screening device: Yes = present, No = not present, or Unknown = unable to determine presence or absence.
¹⁵ Screen Type	Screen Types: TBS = Traveling Belt Screen, RDS = Rotary Drum Screen, VPS = Vertical Plate Screen, IPS = Inclined Plate Screen, HPS = Horizontal Plate Screen, IG = Infiltration Galleries, PMP = Pump Screen, OT = Other

Field Form Name	Description
16 Active Cleaning	Presence of an automated system for debris removal: Yes = present, No = not present, or Unknown = unable to determine presence or absence.
17 Screen Material	The material screen that the screen is constructed from: PP = perforated plate, PB = profile bar, WM = woven wire mesh, PM = plastic mesh, OT = other.
18 Screen Height	Height of screen. Record to the nearest 0.01 m.
19 Screen Width	Width of screen. Record to the nearest 0.01 m.
20 Screen Diameter	For cylindrical screens. Record to the nearest 0.01 m.
21 Screen Condition	Indicate the screen condition: OK = screen clean and intact, MN = maintenance needed.
22 Screen Under Operation	Indicate if the screen is actively taking or diverting water at the time of the site visit. Yes , No or Unknown .
23 Problems/Comments	Include any comments or problems encountered at a diversion. Explain any “Other” or “Unknown” determinations.

9.5 Additional Reading

Bates, K., 1988. Screen Criteria for Juvenile Salmon. Washington Department of Fisheries Habitat Division, Olympia, Washington.

Bates, K., and Fuller, R. 1992. Salmon Fry Screen Mesh Study. Washington Department of Fish and Wildlife. Olympia, Washington.

NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.
http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_passage_design_criteria.pdf

Nordlund, B. 2008. Designing Fish Screens for Fish Protection at Water Diversions. National Marine Fisheries Service, Lacey, Washington.

Nordlund, B., and Bates, K. 2000. Fish Protection Screen Guidelines (WDFW) – DRAFT 4/25/00. Co-published by the NOAA Fisheries and Washington Department of Fish and Wildlife. Olympia, Washington. <http://wdfw.wa.gov/hab/ahg/screen51.pdf>

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 10

HABITAT ASSESSMENT

Fish passage inventories provide a summary of barrier locations and severity, but do not adequately capture the quantity, condition, and historic accessibility of the obstructed habitat. This chapter describes a consistent, science-based method for assessing species-specific habitat suitability and accessibility upstream and downstream of a fish passage barrier. The physical habitat survey protocol includes a survey of the downstream channel and a habitat assessment of all upstream, potentially fish-bearing channels. The resulting data can be used to help prioritize barrier corrections based on the potential benefits to the salmonid species that are affected by the barrier.

Chapter 11 provides instruction for habitat survey data entry. Chapter 12 describes the Prioritization Index (PI) model that incorporates the habitat assessment results into the calculation of a single numeric value that may be used to help prioritize barrier corrections.

Contact the WDFW Fish Passage Program for technical assistance with habitat data collection, data entry, prioritization calculations, or to request training: FishPassageInventory@dfw.wa.gov

10.1 Habitat Assessment Methods

The following sections describe habitat assessment methods that have been developed by WDFW and implemented since the late 1990s. The ‘Threshold Determination’ and ‘Physical Habitat Survey’ serve different purposes; the description of each should be reviewed to determine which survey is appropriate for your project needs.

Threshold Determination

The purpose of a Threshold Determination (TD) is to collect coarse level habitat data in the vicinity of a human-made barrier, and verify that a significant reach of potential salmonid habitat exists upstream and downstream of that barrier. A significant reach is defined as a section of stream having at least 200 linear meters of usable habitat without a gradient or natural barrier, both upstream and downstream of a fish passage feature. Refer to Chapter 2 to determine if stream habitat has the potential for salmonid fish use, and Chapter 7 for assessing natural barriers.

TDs are often conducted soon after a human-made feature is assessed as a fish passage barrier. If a significant reach exists upstream and downstream of the barrier, a physical habitat survey may be conducted to help determine upstream habitat gain, and prioritize the barrier correction; the TD survey cannot be used to calculate a PI value (Chapter 10). Barriers without a significant reach are not usually prioritized for correction, as correcting the barrier would not result in a significant habitat gain.

To perform a TD, survey 200 meters of potential fish habitat upstream of the barrier inlet. The 200 meters of habitat includes the mainstem and any upstream tributaries. For example, if a tributary is encountered 100 meters upstream of the barrier, it is only necessary to survey an additional 100 meters of the tributary *or* an additional 100 meters of the mainstem. If a natural barrier is encountered on either branch of the stream, survey the other branch until the 200-meter threshold is reached. Also survey 200 meters downstream of the barrier outlet. However, do not survey downstream tributaries, as these tributaries are not obstructed by the human-made barrier. Inventory and assess all fish passage features that are encountered during the upstream and downstream TD. Stream sections within culverts are not considered usable habitat, and do not count toward the 200-meter survey length. Measure and record representative bankfull widths, scour widths, and gradient. Describe the channel substrate, instream cover, land use, and any fish observations.

A TD is terminated when any of the following conditions are encountered (whichever comes first):

- Total natural barriers are encountered on all upstream watercourses (mainstem and tributaries), or on the downstream mainstem (see Chapter 7).
- The scour width is < 0.61 meters for a distance of ≥ 160 meters in Western Washington or < 0.91 meters for a distance of ≥ 160 meters in Eastern Washington. To determine if the channel has a scour width less than 0.61 meters, take several channel measurements in the 160-meter segment and average the values.
- There is subsurface stream flow with no defined channel, and no evidence of overland flow any time of the year.
- The 200-meter threshold has been reached, and a significant reach has been verified.

Physical Habitat Survey

If an objective of your fish passage inventory is to prioritize barriers for correction, a physical habitat survey is recommended. WDFW specifically recommends the Reduced Sample Full Survey (RSFS). The RSFS allows for the identification of upstream and downstream natural and human-made barriers, and an evaluation of the habitat that would be realized should the barrier be corrected. RSFS data is ultimately used to calculate the barrier correction PI value described in Chapter 12. The RSFS is discussed further in Section 10.2 below.

The previous version of this manual described an alternate habitat assessment method called a Full Survey (FS). The only difference between an FS and RSFS is the sampling frequency. Because the FS is rarely conducted, it was not included in this manual. For a description of the FS please see the 2009 Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual.

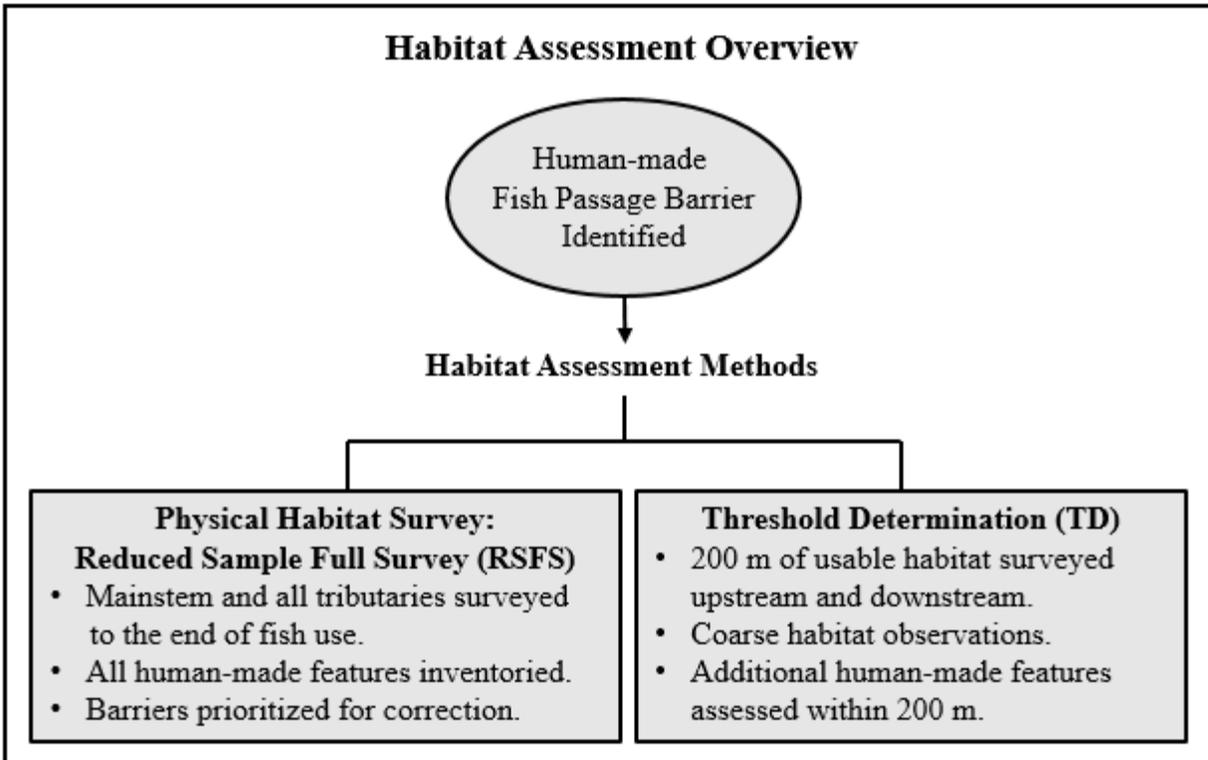


Figure 10.1. Overview of habitat assessment options.

10.2 Reduced Sample Full Survey Overview

The following sections describe a typical RSFS conducted to prioritize a barrier correction using the PI model. Throughout this chapter, the term ‘target barrier’ is used to refer to the most downstream human-made barrier for which you are calculating a PI value.

Data Collection for Reduced Sample Full Surveys

- Conduct a downstream survey to determine which salmonid species may potentially access the target barrier, and to record habitat observations.
- Collect habitat sample data upstream of the target barrier along the mainstem and any potentially fish bearing tributaries, and record habitat observations.
- Complete the Physical Habitat Survey Field Form (Figure 10.3).

A downstream survey will vary based on the type of inventory that is being conducted, and a review of any available information regarding the extent of potential anadromous salmonid fish use. The upstream survey requires walking all channels that contribute to the flow through the target barrier, including the mainstem and all potentially fish-bearing tributaries flowing into the mainstem. Each upstream watercourse (mainstem *and* tributaries) is surveyed until a total natural barrier is reached, or until the stream is no longer potentially fish bearing.

Fieldwork Considerations

To facilitate data collection and promote safety, a two-person crew should conduct habitat assessments. Typically, one crew member scouts ahead, cuts brush, and takes measurements, while the other carries a hip chain and records data. WDFW recommends using a 3-strand biodegradable thread in the hip chain, and collecting the thread at the end of the survey to prevent wildlife from becoming entangled and as a courtesy to landowners. A list of recommended survey equipment is presented in Appendix D.

Crews should follow safety precautions, such as carrying a first aid kit, having a communication plan, and using a mobile phone. Field crews should also receive first aid and CPR training.

Respect private property. Always obtain landowner permission to access private property before conducting a habitat assessment. Contact all landowners, explain the project, and ask for permission to survey the stream. Outreach is essential in creating a rapport with landowners. Landowners can often describe firsthand observations of fish in the stream, are aware of problem barriers, and can provide historical information about the site.

County assessor websites are an excellent resource for obtaining landowner information. Most counties offer parcel search engines and mapping applications that display landowners' names and addresses. Phone contact information for landowners can often be found using online telephone directories (white pages, yellow pages, etc.). Mailers and door-to-door outreach are also often necessary to secure permission.

Where to Begin the Assessment

The starting point of a habitat assessment typically depends upon which inventory method was employed (See Chapter 1). For a jurisdictional or road-based inventory, the survey begins at the most downstream barrier that you wish to prioritize using the PI model, i.e., the target barrier. For a watershed-based inventory, wherein all fish passage features in an entire watershed are identified and assessed, the survey begins at the mouth of the watershed of interest.

Fish Access Check

Before performing the upstream habitat assessment, a fish access check (FAC) may be necessary to determine which salmonid species may potentially access the target barrier. In this context, 'potential' refers to the accessibility of habitat if all human-made barriers were removed. The species that could potentially access the target barrier is primarily based on the presence of downstream natural barriers (total and partial), stream size, and historic use.

The FAC requires walking downstream of the target barrier to a point where there is known species-specific potential use. Stream length is measured to the nearest decimeter (0.1 meters) using a hip chain. If a total natural barrier is encountered during the FAC, then it is assumed that only resident species can access the target barrier.

A FAC is not necessary for watershed-based inventories if the mouth of the watershed of interest is at the confluence with a larger system that has well-documented potential species use. Instead, begin surveying upstream from the confluence and record the relevant FAC data in the bulleted list below until you encounter a human-made barrier.

While performing a FAC, record the following data and link any habitat measurements or observations to the corresponding hip-chain measurement:

- Fish use observations.
- Periodic gradient and bankfull measurements.
- Observations of salmonid spawning and rearing habitat quality, and riparian condition (instream cover, canopy cover, etc.).
- Partial natural barriers, which may limit the potential for certain species to utilize the habitat upstream.
- Land use observations, including potential sources of pollution, stormwater input, etc.
- Noteworthy stream morphology.
- The coordinates of any tributary confluences, an estimated percentage of contributing flow, and the potential fish use of those tributaries. *Do not survey downstream tributaries.*
- Inventory and assessments of all downstream fish passage features.
- Landowner denials.
- Representative habitat photos, and any noteworthy conditions.
- Distance to the end of the FAC, from the outlet of the target barrier, as measured on the hip chain.

Reaches

In the RSFS, the upstream observations and data are evaluated at a reach scale. A “reach” is generally defined as a section of a stream with similar characteristics, including but not limited to gradient, bed form, channel size, stream flow, and land use. Where one reach ends, and another begins, is defined as a “reach break”.

Create a reach break for any of the following conditions:

Tributary Confluence - Break reach at the confluence with any tributary contributing $\geq 20\%$ of the annual parent stream flow. If the survey is conducted during a low-flow period, when tributaries are dry or flow is significantly diminished, consider the relative scour widths and bankfull widths of the main channel and tributaries when determining whether to break reach. Do not rely exclusively on the existent water flow. *Note: The first reach of the tributary survey starts at the confluence with the parent stream.*

Human-Made Barriers - Break reach at the upstream end of any human-made barriers. It is *not* necessary to break reach at human-made features that are not barriers. If the barrier status of a feature is unknown, it is recommended to break reach if the barrier determination is in progress, e.g., when Level B data is still being analyzed. If you encounter a series of barrier culverts

without a 60-meter sample between, collect habitat samples outside of culvert influence (whatever length is possible), and contact WDFW for further instruction.

Changes in Habitat Quality - Break reach at significant changes in spawning and/or rearing habitat conditions. This may include changes in canopy cover, land use, riparian condition, etc. Each reach is assigned a spawning or rearing habitat quality modifier value (described later in this chapter). The reach should be broken at points where changes in the habitat will result in a different quality modifier.

Ponds - Break reach at the beginning and end of ponded segments of the channel. Pond reaches include perennial wetlands, lakes, etc., and comprise their own reach.

Gradient Breaks - Break reach when the average channel gradient shifts between 3%, 5%, 7%, 12%, or 16%. This is due to the expected habitat utilization and passability of anadromous Washington salmonid species within reaches at different gradient strata (Table 10.1).

Only break reach for sustained gradients to avoid creating excessive reach breaks. Because it is usually not possible to know how long the stream continues at a particular gradient, it is often necessary to record the hip chain reading at the point of a tentative gradient shift, then continue upstream to confirm that the gradient condition persists. Proceed a short distance upstream until you are confident that a reach break was appropriate. At that point, collect the 60-meter sample, and make a note that the reach break occurred at the tentative gradient shift. It is not necessary to back-track to collect the 60-meter sample from the point of the reach break.

Note: Collect GPS coordinates at each reach break. This allows for more accurate record keeping, as well as calculations of upstream basin area.

Table 10.1 illustrates the expected species rearing and spawning utilization of anadromous species within reaches at different gradient ranges (solid green cells). It also illustrates the reach gradients that each species may pass through (crossed-out yellow cells), even though they are not expected to exploit that habitat. Reaches with gradients that are neither usable nor passable are indicated by a blank box. For example, sockeye utilize reaches having gradients of 7% or less, however, they may ascend intermediate reaches up to 16% gradient, then spawn and rear in lower gradient reaches encountered upstream (< 7%). Sockeye would not be eliminated as a potential species in the upstream channel until they encounter a reach with a gradient greater than 16% for 160 m. Likewise, steelhead would not be expected to utilize habitat between 12-20%, but they would not be eliminated as a potential species in the channel until they encounter a reach with a gradient greater than 20% for 160 m. For the purpose of assigning potential species use to a reach, only include the species that can spawn or rear in that reach (solid green), not the species that can only pass through the reach (crossed-out yellow).

Table 10.1. Gradient ranges of anadromous species utilization. Each cell of the table represents a reach at a specific gradient range. Solid green cells indicate that reaches with usable spawning and rearing gradients. Crossed-out yellow cells indicate that the species can pass through the reach with the gradient range, but do not utilize the habitat for spawning or rearing. Blank cells indicate that the reach is not usable and is impassable.

Species	Gradient (%)						
	0-3	3-5	5-7m	7-12	12-16	16-20	20+
Chum		X					
Pink				X			
Coho				X	X		
Sockeye				X	X		
Chinook				X	X		
Steelhead					X	X	
Sea Run Cutthroat					X	X	

Resident trout and bull trout/Dolly Varden are expected to utilize habitat up to 20% for both rearing and spawning. While it is recognized that they may pass through gradients as high as 33%, for the purposes of this manual a 20% gradient threshold is considered the upper limit of spawning and rearing habitat, as well as fish passage for salmonids (See Chapter 7).

Naming Conventions

To maintain clear and consistent recordkeeping, a naming convention that uses letter and number sequences for the mainstem and tributaries has been established (Figure 10.2). The following abbreviations are used when describing the watercourses on an upstream survey:

- MS = Mainstem
- T = Tributary
- R = Reach

The mainstem channel upstream of the target barrier is coded with abbreviations for “mainstem” and “reach”, followed by sequential reach numbers. For example, the eighth reach of the mainstem is coded “MS R8”.

Potentially fish bearing tributaries are coded alphabetically in the order that they are encountered moving upstream, followed by sequential reach numbers. Hence, the first tributary encountered on the mainstem during the upstream survey would be considered Tributary A, coded ‘TA’. The first reach of TA is coded ‘TA R1’.

Additional tributaries are coded with alternating letter and number sequences. For example, while surveying Tributary C (TC), a potentially fish-bearing channel enters TC; this tributary

would be considered Tributary C1 (TC1), and the first reach of TC1 would be coded 'TC1 R1'. If another potentially fish bearing channel enters TC1, it would be considered Tributary C1a, and coded 'TC1a'.

Note: Collect GPS coordinates at each confluence. This allows for more accurate record keeping.

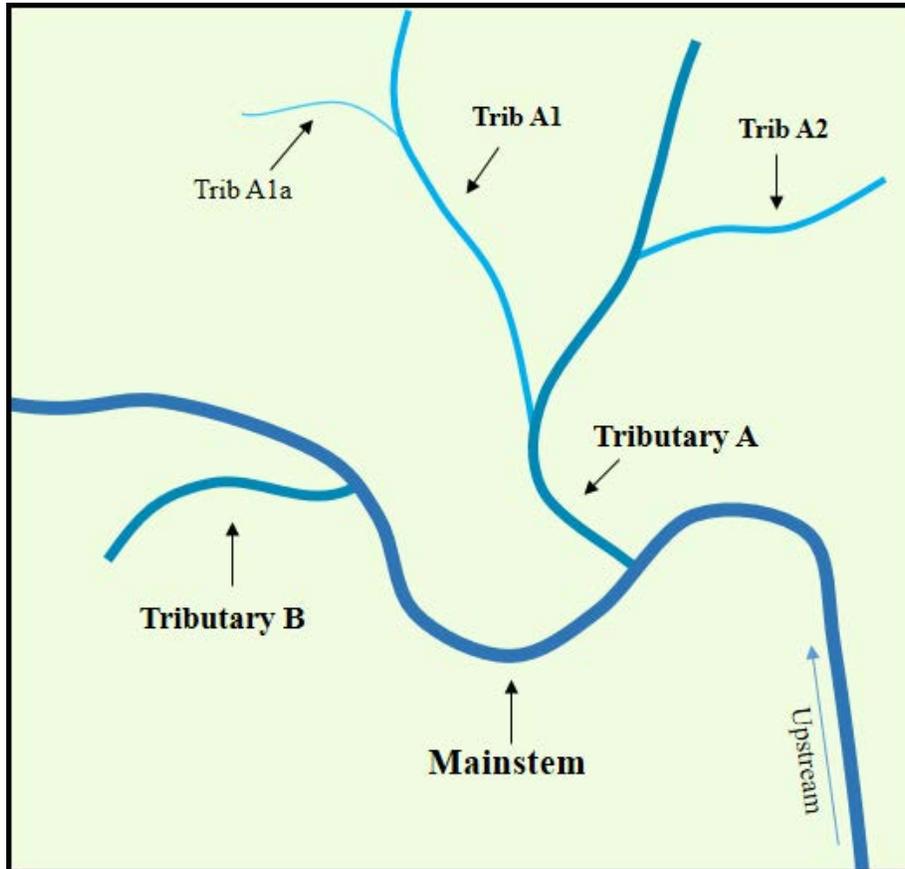


Figure 10.2. Mainstem and tributary naming conventions.

10.3 Upstream Habitat Survey

Starting from the target barrier inlet, and proceeding upstream, record reach-scale data and habitat samples on the Physical Habitat Survey Field Form. Provide detailed comments in separate field notes, and take photos. Document and assess all human-made and natural fish passage features that are encountered.

Detailed explanations of selected data fields in the Physical Habitat Survey Field Form (Figure 10.3) are provided in the following subsections and summarized in the Quick Reference Table (Table 10.6) in Section 10.5.

Position - Describe where the reach begins. Typically, the position is described in relation to the reason for the reach break, e.g., “Upstream of barrier Site ID 111222”.

Coordinates - Record the latitude/longitude coordinates at the beginning of the reach, or the name of the waypoint on a GPS unit.

Reach Code - See the “Naming Conventions” section above for how to code reaches.

Begin CR and End CR - Record the hip chain reading (CR) at the beginning and end of the reach.

Habitat Sample

When conducting a RSFS collect one 60-meter habitat sample per reach. Collect the habitat sample in a segment of stream that is representative of the reach as a whole. WDFW recommends taking the habitat sample early in the reach, once outside of the influence of any fish passage features, to help ensure that a full 60-meter sample can be collected before the next reach break.

An uninterrupted habitat sample is preferred. However, habitat samples can and should be interrupted for short non-representative stream segments or conditions that make data collection difficult or unsafe. Examples of these conditions include braided channels, log jams, and areas influenced by human-made features. If the habitat sample is interrupted, record the chain reading at the beginning and end of the segment that is not sampled, then continue the habitat sample until a total of 60 meters is sampled.

The stream is divided into four habitat types - pool, riffle, rapid, and pond.

- Pools are characterized by relatively deep, low velocity water with a smooth surface.
- Riffles are characterized by relatively shallow, high velocity water with a turbulent surface.
- Rapids are high gradient (>5%) riffles with large substrate. Rapids generally contain “white water”.
- Ponds have zero gradient, and an average width, length, and depth that is at least five times greater than that of the average pool in the preceding reach. If a pond is encountered, it is treated as its own reach. Large freshwater bodies, such as perennial wetlands and lakes, are classified as ‘ponds’ for purpose of data analysis.

There are no set dimensions for what constitutes a pool or riffle; they are relative to each stream. The classification of a habitat type should be based on the average dimensions (width, length, and depth) of the pools and riffles in that stream. For example, pools may have an average depth of 1 meter on one stream survey, but only 0.2 meters on another stream.

The classification of a habitat type can be challenging at times. Pools and riffles can look different at various flows. Observations of turbulence on the water surface can often help

delineate riffles from pools. A shift in the dominant substrate type may also be indicative of a change in the habitat type; fine sediments and organics tend to be deposited in lower velocity areas, such as pools.

If a cross-section of stream includes both pool and riffle habitat, assign the habitat type with the larger surface area. For example, if there is a one-meter wide pool against the left bank, and a three-meter wide riffle from the edge of that pool to the right bank, the habitat type should be classified as a riffle because the riffle has the larger surface area.

Data collection does not have to start at the beginning or end of a habitat type, e.g., the transition between the head of a riffle and the tailout of an adjacent pool; it is allowable to start the 60-meter sample in the middle of a riffle, pool, etc.

For each habitat type encountered in the habitat sample, collect the following data:

Chain Reading - Record the chain reading at the beginning of each habitat type. Chain readings are recorded to the nearest decimeter (0.1 meters).

Habitat Type - Record whether the habitat type is a pool, riffle, rapid, or pond. Each habitat type is denoted using the following abbreviations:

- Pool = PL
- Riffle = RF
- Rapid = RP
- Pond = PD

Length - Length is measured for every habitat type encountered in the sample segment. Length is measured using the hip chain, and recorded in decimeters (0.1 meters).

For a pond, measure length using a hip chain or laser range finder. If field measurements are not possible, the length of the pond can be map measured using GIS software and aerial imagery.

Wetted Width - Wetted width is the horizontal distance between the wetted margins of the stream (Figure 10.6). Measure the wetted width for the *first two* pools, riffles, and rapids encountered within the sample segment. The wetted width measurements should be taken at a representative location, typifying the average width within that habitat type. Use a stadia rod or meter tape to measure wetted width, perpendicular to flow, to the nearest decimeter (0.1 meters).

For a pond, measure the wetted width using the same methods described above for the length measurement (i.e., hip chain, range finder, or GIS software).

Scour Width - The scour width includes everything within the active channel where stream flow is expected during winter flows. Scour lines are produced as a result of water action that occurs with enough frequency to leave a distinct mark upon the soil or vegetation. Scour width is the horizontal distance between the scour lines on both banks, and should be measured perpendicular to flow. Look for indicators such as a line left by debris, pollen, or silt, and/or marks made by

erosion or destruction of terrestrial vegetation. Figure 2.2 in Chapter 2 illustrates the scour width measurement in a typical stream channel.

Measure the scour width for the *first two* pools, riffles, and rapids encountered within the sample segment. Scour width should be measured at the same location as the wetted width. Use a stadia rod or meter tape to measure scour width to the nearest decimeter (0.1 meters).

For a pond, measure the scour width using the same methods described above for the length measurement (i.e. hip chain, range finder, or GIS software).

Depth - Record the average water depth to the nearest 0.01 meters at the same cross-section where the wetted width and scour width measurements were taken. Take a minimum of three measurements within the wetted width that are representative of the range of depths across the wetted width (Figure 10.4). Average the depth measurements and record to the nearest centimeter (0.01 meters).

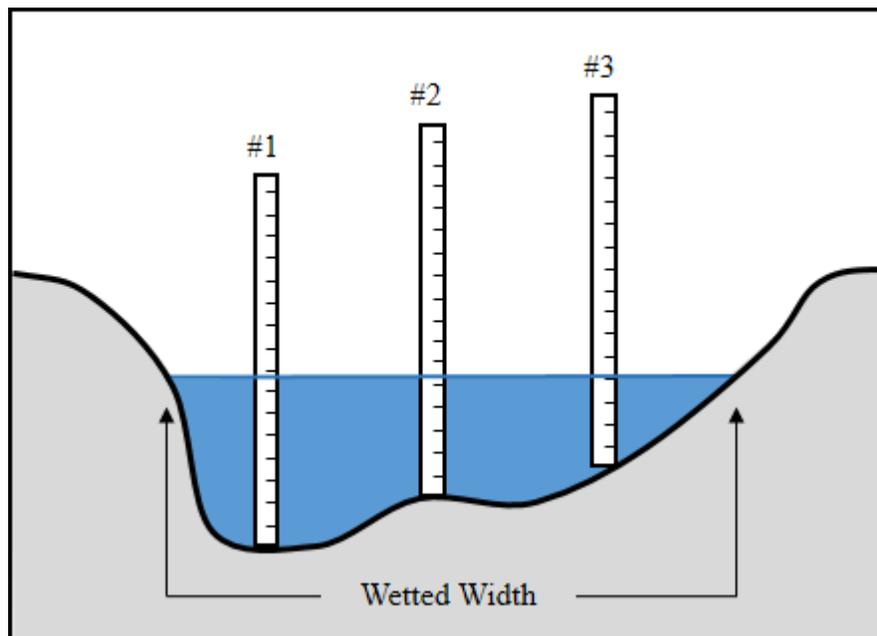


Figure 10.4. Cross-section depth measurements for each habitat type. Examples of where to measure depth within the channel's wetted width.

Gradient - Use a clinometer, rangefinder, or laser level to measure the water surface gradient at least once within the sample segment. Measure gradient over the longest stream segment that visibility allows, measuring between repeating channel features (i.e., pool crest to pool crest, or riffle to riffle), and taking care not to shoot across meanders. The gradient measurements may cross multiple habitat types (i.e., the measurement may cross multiple riffles and pools). To ensure greater accuracy, take backsight gradient measurements when possible. Record the gradient as a percentage anywhere in the gradient column of the Physical Habitat Survey Field Form (Figure 10.3). If multiple gradient measurements are collected, the order that they are

recorded in the gradient column is not important (they are calculated as an average across the entire 60-meter sample).

% Boulder/Cobble/Gravel/Fines - Substrate composition is visually estimated within the scour line width for the *first two* pools, riffles, and rapids encountered within the sample segment. Unlike wetted width, scour width, and depth (which are all measured at the same cross-section) substrate composition should be estimated throughout the entire habitat type, i.e., pool, riffle, etc. All substrates within the scour line width should be included in this estimate, even if some of the substrate is above the water surface, e.g., on a mid-channel bar.

Substrate composition is categorized according to the size class ranges in Table 10.5. Estimate the percent proportions of each substrate category, making sure that the values sum to 100%. Both observers should complete the process independently, then compare values to reach a consensus.

Substrate composition estimates are a very important variable in the estimation of potential spawning area. The production estimates for spawning-limited species such as chum, pink, and sockeye salmon are calculated using the estimated percent gravel per habitat type.

Table 10.5. Substrate size classes. Used to characterize substrate composition.

Substrate Composition Size Class Ranges		
Category	Size Class Range (mm)	Size Class Range (in)
Boulder	> 305 mm	> 12 in
Cobble	76 to 305 mm	3 to 12 in
Gravel	5 to 76 mm	0.20 to 3 in
Fines	< 5 mm	< 0.20 in

Length is calculated for each habitat type, throughout the entire 60-meter sample, as the difference in the chain reading measurements from one row to the next in the Habitat Sample section of the Physical Habitat Survey Field Form (Figure 10.3). Wetted width, scour width, depth, and % boulder/cobble/gravel/fines are recorded for the first two pools, two riffles, and two rapids in the 60-meter sample; these measurements are also recorded for a pond, but only once since a pond is considered its own reach. Once these measurements (wetted width, scour width, depth, and % boulder/cobble/gravel/fines) have been recorded twice for a habitat type (pool, riffle, or rapid), only the length is recorded for that habitat type until the 60-meter sample is complete.

Example: You collect all measurements for 2 pools and 2 riffles in the first 20 meters of a 60-meter sample. You would then only collect length measurements for any pools and riffles that

are encountered in the remaining 40 meters of that 60-meter sample. Forty-five meters into that habitat sample, you encounter the first rapid in that 60-meter sample; since you have not collected measurements for 2 rapids, you must collect all of the measurements for that habitat type (wetted width, scour width, depth, and % boulder/cobble/gravel/fines).

Dry Reaches

Habitat samples must be taken on stream segments with visible surface water. If a dry channel is encountered, continue the survey until a habitat sample must be collected. If the channel is still dry, postpone the survey until surface flow resumes. For example: while performing an RSFS, a field crew collects the 60-meter sample for a reach, then encounters a dry channel upstream. The gradient and scour line width indicate that there is still potential for fish use upstream, so the survey is not complete. The crew may continue the survey on the dry channel until the next reach break. If the next reach has surface flow, then the crew can collect the 60-meter sample for that reach and continue the upstream survey. If the stream is still dry, then the crew must postpone the survey.

Completing the Habitat Sample

Terminate the habitat sample at a length of 60 meters, even if the 60-meter mark falls in the middle of one of the habitat types, e.g., the middle of a pool. Calculate and record the length of the final habitat type as the difference in the chain reading observed on the hip chain, and the chain reading recorded on the last row of the Habitat Sample section of the Physical Habitat Survey Field Form (Figure 10.3).

Reach Data

Collect the following information for each reach of the mainstem and its tributaries. WDFW recommends postponing the reach data collection until the end of the reach, allowing for a complete assessment of its condition.

Note: Sometimes it is necessary to create tentative reach breaks for gradient, and then proceed upstream to confirm that the gradient is sustained. Don't forget to complete the data entry for the preceding reach, once the need for a reach break is confirmed.

Instream Cover - Instream cover provides refuge from predators, as well as places to rest and conserve energy. Instream cover includes features such as root wads, large woody material (LWM), close overhanging vegetation, deep pools, undercut banks, large boulders, etc. Visually estimate and categorize the density of instream cover as low, medium, or high.

Thermal Cover - Visually estimate the proportion of stream surface area covered by the riparian canopy and low overhanging vegetation, assuming full leaf out condition and a vertical projection from the water surface to the vegetated cover (Figure 10.5). Note the dominant tree and/or shrub species within the stream corridor. Estimates of thermal cover are reported as percent coverage.

Do not agonize over the precision of the thermal cover estimate – thermal cover values are used to characterize the habitat, but *not* for calculations of potential habitat gain. Typically, it is best to find a representative patch of vegetation, and estimate cover from that location.

Temp - Water temperature should be taken within each stream reach using a hand-held, mercury-free, Celsius scale thermometer. Mercury thermometers should never be used. Mercury is a toxic element, known neurotoxin, and suspected carcinogen, that accumulates in the environment over time.

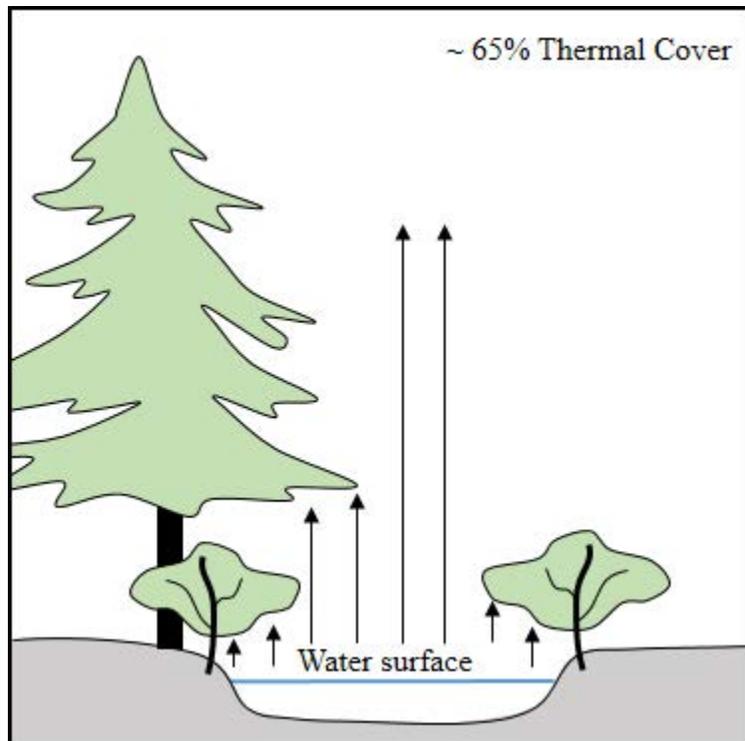


Figure 10.5. Thermal cover estimate. Illustrating the vertical projections from the water surface, to overhanging vegetation.

Habitat Quality Modifiers

Spawning and rearing habitat quality modifiers (HQM) are used to help estimate the production potential of a reach (Tables 10.2 and 10.3). The HQM is a multiplier value applied to the estimated rearing and spawning habitat areas. Multiplying the measured/calculated habitat area by the HQM provides the “H” value that is used in the PI model (Chapter 12).

$$H = \text{Habitat Area} \times \text{HQM}$$

HQMs are assigned independently for spawning and rearing. The spawning and rearing HQMs affect the production potential of salmonid species differently, depending upon whether they are spawning or rearing limited. Species that do not rear for an extended period of time in freshwater streams (chum, sockeye/kokanee, and pink) are considered ‘spawning limited’. Species that are

more dependent upon available freshwater stream rearing habitat (coho, chinook, sea-run cutthroat, steelhead, resident trout, and bull trout/Dolly Varden) are considered ‘rearing limited’.

Note: Spawning and rearing HQM values should not be reduced due to the presence of human-made barriers. Remember – we are evaluating the habitat that would become accessible should all human-made barriers be corrected.

The following information is intended to be general guidance for assigning spawning and rearing HQMs to a stream reach. Local knowledge and expertise *should* be taken into account when assigning HQM values, keeping in mind that HQMs are *not* species dependent, and every each reach should be evaluated using the same criteria.

Spawning HQM - The spawning HQM is primarily determined by a visual estimate of the percentage of embedded fines *within potential spawning gravel patches* (Table 10.2). Spawning HQM values should not be assigned for the reach as a whole, it should only be applied to those potential spawning gravel patches that exist in the reach. Estimate the percentage of fine particle composition (< 0.85 mm particles) within gravel patches (5 to 76 mm diameter particles). The estimate is a combination of subjective evaluations of gravel surface composition, silt plume characteristics as a boot heel is dug into a gravel patch, and the composition of several handfuls of the underlying substrate. *Do not disturb active redds*. The procedure should be repeated several times for each reach.

Table 10.2. Spawning habitat quality modifiers and criteria.

Spawning Habitat Quality Modifier		
Habitat Condition	HQM Value	Habitat Criteria
Good to Excellent	1	Spawning gravel patches have ≤ 16% fine particles.
Fair	0.67	Spawning gravel patches show moderate to widespread signs of instability (scour/filling), and/or > 16% to 21% fine particles.
Poor	0.33	Spawning gravel patches show widespread to major signs of instability (scour/filling), and/or 21% to 26% fine particles.
No Value	0	Spawning gravel patches have > 26% fine particles.

Rearing HQM -The rearing habitat quality modifier is an evaluation of physical characteristics that influence the ability of juvenile salmonids to survive and grow in a freshwater stream. The goal of juvenile salmonids is to optimize energy intake and minimize the risk of predation. For each reach, evaluate the features that positively and negatively influence rearing conditions, and assign a rearing HQM value (Table 10.3). Photographic examples of different rearing HQM conditions are provided in Figure 10.6.

The following features positively influence rearing conditions:

- Cool water temperature - temperature preferences vary by species, but, as a gross generalization, rearing juvenile salmonids prefer temperatures in the 8-16 degrees Celsius range. If a thermometer is not available, consider the presence or absence of thermal cover and the influence of cover on the water temperature throughout the reach.
- Water quality - lack of turbidity, agricultural/urban run-off, metal precipitates, etc.
- Riparian vegetation - thermal cover.
- Instream cover - low overhanging vegetation, macrophyte mats, large woody material (LWM), boulders, undercut banks, etc.

The following features negatively influence rearing conditions:

- Irregular flows - can cause stranding of juveniles.
- Warm water temperature - temperatures > 22 degrees Celsius can exclude salmonids from a location.
- Uniform channel morphology - lack of refuge habitat and general habitat structural complexity.

When features that negatively influence rearing conditions are present in a reach, evaluate the severity, and modify the rearing HQM value accordingly.

Table 10.3. Rearing habitat quality modifiers and criteria.

Rearing Habitat Quality Modifier		
Habitat Condition	HQM Value	Habitat Criteria
Good to Excellent	1	Rearing habitat is stable, and in a normal productive state, without features that negatively influence rearing conditions. Barring the presence of features that negatively influence rearing conditions, ponds and wetlands always have an HQM value of 1.
Fair	0.67	Rearing habitat shows signs of moderate to widespread instability and/or disturbances known to reduce productive capacity. A few of the features that positively influence rearing conditions are present, but only within $\leq 67\%$ of the reach.
Poor	0.33	Rearing habitat shows signs of widespread to major instability and/or disturbances known to reduce productive capacity. A few of the features that positively influence rearing conditions are present, but only within $\leq 33\%$ of the reach.
No Value	0	Habitat is severely disturbed and provides no rearing value to salmonids at this time.

Rearing HQM = 1



LWM jam on the right bank, left bank pool in the foreground, overhanging vegetation, and undercut banks provide great salmonid rearing habitat.



Pools created by large boulders, some LWM and overhanging vegetation, high thermal cover, and good water quality provide excellent rearing conditions.

Rearing HQM = 0.67



There is some overhanging LWM and vegetation, but most of the LWM is not in the channel so it does not create pooling. The channel is mostly uniform.



Remember to evaluate the site at assumed full leaf out condition for thermal cover; these alders will provide good thermal cover. Notice the pooling along the banks at the bends.

Figure 10.6. Photographic examples of different rearing HQM conditions.

Rearing HQM = 0.33



The channel is modified, and uniform. Adjacent road likely contributes to stormwater runoff. Overhanging vegetation over slow, pooled areas provide some rearing value.



Very little instream cover. Minimal thermal cover is mostly provided by invasive plants. A small pile of LWM is present on the left bank, but the channel is mostly uniform.

Rearing HQM = 0



No instream cover, and no thermal cover. The landscape is modified with erosion on both banks. Urban runoff is likely.



No instream cover and little thermal cover. High road runoff. Bank vegetation is predominantly invasive species. The channel is uniform.

Figure 10.6 (Continued). Photographic examples of different rearing HQM conditions.

Limiting Factors - If the spawning or rearing HQM is less than 1, describe the reason for the reduction in habitat quality. Each HQM reduction (e.g., from '1' to '0.67') should be accompanied by a short explanation (e.g., "Livestock runoff"). Two reductions in HQM should be accompanied by two explanations, three reductions accompanied by three explanations, etc.

Juvenile Abundance - Visually estimate the abundance of juvenile salmonids observed throughout the reach as 'high', 'medium', 'low', or 'none'. If you are able to identify the species, record species in notes.

Spring Factor - Estimate the contribution of springs to the total stream flow.

The spring factor is used in the calculation of the 60-day low flow. Spring influence affects the estimated wetted area during the 60-day low flow period, which is subsequently used in the rearing production area calculation. The spring factor is used to minimize the reduction of measured wetted area when springs contribute to the flow during the 60-day low flow period.

Spring factor values range from no influence (spring factor = 0), to total influence (spring factor = 3). A spring influence factor of '0' indicates that springs do not contribute flow during the 60-day low flow period. A spring influence factor of '3' indicates that the stream is nearly entirely spring-fed, and there is little to no reduction in wetted width during the 60-day low flow period. Few streams are unaffected by summer drought, so it is important to use good judgment when applying the spring factor. If springs are found in the upper reaches of a habitat survey, lower reaches should be adjusted to account for the additional spring influence. Use the guidelines found in Table 10.4, and photographic examples (Figure 10.7) to assign a spring factor to each reach surveyed.

Increased spring influence generally results in a reduction in the variability of flows, and is often characterized by rectangular-shaped stream cross-sections with little or no variation in depth; when depth variability does exist, it is usually caused by the presence of large objects rather than scouring. Oftentimes, streams with high spring influence do not have a thalweg or lateral bars that indicate scouring at high or low flow periods.

Ponded reaches do not exhibit many of the physical characteristics explained above, or in Table 10.4. Therefore, the spring factor value for pond reaches should be based on channel conditions upstream and downstream of the ponded waterbody.

Table 10.4. Criteria used for assigning spring factor. The ‘low flow wetted width’ is the wetted width during drier, baseflow conditions.

Spring Influence Factor		
Spring Influence	Spring Factor	Criteria
Absent	0	Normal channel morphology, with evidence of a full range of seasonal flows that create a scoured pool/riffle sequence. Negligible low flow wetted width.
Slight	1	Reduced variability of depth in pool/riffle sequences. Less evidence of lateral scouring and bed deposition due to seasonal flows. The low flow wetted width is approximately 1/3 of the scour line width.
Moderate	2	Little evidence of sediment transport or scour caused by seasonal high flow events. The low flow wetted width is approximately 2/3 of the scour line width.
Pronounced	3	Stream flow is nearly constant throughout the year. Uniform, heavy moss growth on exposed stream rocks, indicating that there is very little seasonal high flow scouring. The low flow wetted width is nearly equal to the scour line width. Bank vegetation is at, or nearly at, the water surface year-round. Streams that maintain a temperature of 7-8 degrees Celsius year-round are often spring-fed (Hayes et al., 2002).

Absent Spring Influence: Spring Factor = 0



Note the normal riffle/pool stream morphology that is created by scouring during high flow events. Large deposition bars are created by lateral scouring during higher flows. A low flow channel is obvious, and the low flow wetted width is much less than 1/3 of the scour line width.

Slight Spring Influence: Spring Factor = 1



This photo was taken during the summer low flow period. Notice that the low flow wetted width is approximately 1/3 of the scour line width. Also note the presence of scoured shelves that have resulted from seasonal high flows.

Figure 10.7. Photographic examples of spring influence factors.

Moderate Spring Influence: Spring Factor = 2



Notice the vegetation on the rocks in the stream channel – this indicates that there is some variation in flow, but without the scouring caused by seasonal high flow events. Pooling is primarily caused by large debris in the stream, rather than seasonal scouring. Notice that the low flow wetted width is approximately 2/3 of the scour line width.

Pronounced Spring Influence: Spring Factor = 3



Notice the rectangular-shaped stream cross-section, and uniform vegetation on the rocks and banks at nearly the same elevation as the water surface. This stream emerges at a spring approximately 300 meters upstream.

Figure 10.7 (Continued). Photographic examples of spring influence factors.

Culverted Length - Sum the lengths of all culverts, barriers and non-barriers, in the reach.

Culvert Site IDs - Record the Site IDs of all culverts that contribute to the culverted length of the reach.

Comments and Photos

Take detailed notes for each reach, and record the associated hip chain readings. Take at least one photo that is representative of the reach, and photos of any noteworthy features. Record the associated hip chain reading.

Comment on:

- Fish use observations. Note whether the fish are salmonids, and identify species if possible.
- Any human-made or natural fish passage features that are encountered. Record the associated hip chain reading and take GPS coordinates at the downstream end.
- Spawning and rearing habitat quality.
- Riparian condition.
- Land use observations.
- Natural features such as beaver dams, log jams, cascades, falls, etc.
- Noteworthy stream morphology, including incised channels, deeply undercut banks, erosion, etc.
- Tributary confluences, an estimate of flow contribution of the tributary, and the tributary's potential for fish use (remember to survey all upstream potentially salmonid bearing tributaries to the end of salmonid fish use).
- Seeps, or other indicators of spring influence.
- Changes in gradient. Include at least one gradient measurement per reach.
- Bankfull width. Measure bankfull width at least one per reach.
- Reasons for breaking reach.
- Landowner denials.

Landowner Denials

Periodically, when performing habitat assessments that transect private property, a landowner will deny access to survey the stream. Although it may be challenging to characterize the habitat of the stream segments that are not surveyed, these segments are still considered part of the upstream gain and should not be dropped from the survey.

When a landowner denies access to their property, perform the following actions:

- Collect waypoint coordinates at the downstream and upstream ends of the parcel that is not surveyed. Record the hip chain measurement at the downstream end of the parcel.
- Observing from outside of the property boundary, determine whether the habitat on the parcel that is not surveyed appears to be contiguous with the upstream and/or downstream habitat.

- Examine aerial imagery to determine if there are potential fish passage features on the property, or confluences with tributaries.
- Using GIS software, map-measure the segment of stream within the private property; this length will be used to adjust upstream hip chain measurements.
- Contact WDFW for assistance interpreting the data.

Terminating the Upstream Habitat Assessment

The potential habitat gain for a barrier correction is measured from the upstream end of the barrier, until the mainstem and each tributary become non fish-bearing according to physical criteria, or have a total natural barrier (See Chapter 7). Do not end the upstream survey at partial natural barriers.

The following physical criteria indicate that a channel has become non fish-bearing:

- A scour width < 0.61 meters for a distance greater than 160 meters in Western Washington.
- A scour width < 0.91 meters for a distance greater than 160 meters in Eastern Washington.
- There is subsurface stream flow with no defined channel, and no evidence of overland flow any time of the year.

The upstream survey for the mainstem and each tributary ends at the downstream extent of a total natural barrier, or at the downstream extent of the non fish-bearing condition. For example, when a scour width less than 0.61 meters is encountered in Western Washington, and the average scour width does not increase for 160 meters, the survey ends at the point where the < 0.61 meter scour width was first encountered.

Collect GPS coordinates at the points on the mainstem and each tributary where the upstream survey is terminated.

10.4 Watershed Surveys of all Potentially Fish Bearing Waters

For watershed surveys of all potentially fish-bearing waters, consult topographic maps or scout upstream whenever a total natural barrier is encountered. If potentially fish-bearing conditions exist above the total natural barrier, continue the upstream survey. For example, if a total gradient barrier is encountered, but the upstream channel gradient becomes less than 20% and potentially fish-bearing again, continue the survey to prioritize any other human-made barriers based on the benefit to resident species. Collect only hip-chain readings, habitat comments and photographs until another human-made barrier is reached. Begin collecting the upstream RSFS habitat data again above that human-made barrier. Repeat the aforementioned process until there is no potential for salmonid fish use in any upstream waters. Do not collect reach data or habitat samples in segments of stream that have gradients greater than 20%.

Resident-Only Fish Habitat

In streams without anadromous access, fish passage barriers can fragment and isolate resident fish populations, reducing genetic exchange, making isolated populations more susceptible to extinction. They can also isolate populations from beneficial habitat components, such as refuge habitat from floods or droughts, or resources necessary for survival. Removal of barriers in resident-only streams helps reconnect isolated fish populations and restore habitat connectivity.

If prioritizing resident-only barrier corrections is part of the scope of a project, perform an upstream RSFS above resident-only features. The RSFS is conducted under the assumption that human-made barriers present the greatest challenge to upstream movement, and therefore potential habitat gain will be upstream of the barrier. Additionally, PI values are based on the upstream passability of sites. The RSFS should be performed until the next total natural barrier, or non-fish-bearing condition is encountered.

10.5 Quick Reference Table

Table 10.6. Field descriptions for the Physical Habitat Survey Field Form.

Field Form Name	Description
Header Information	
¹ Survey ID	Unique identifier. Identical to the target barrier ID.
² Date	Date of the field review. MM/DD/YYYY format.
³ Observers	Last names of the individuals responsible for the data collection. Separate names with a semicolon, e.g., “Leigh; Tuttle”
⁴ Stream Name	Name of the stream where the feature is located. If the stream is unnamed, record as “unnamed”.
⁵ Tributary To	Name of the waterbody into which the stream flows. If the receiving waterbody is unnamed, record as “unnamed” followed by the name of the first named confluence, and then “trib”. E.g. “unnamed Grande Ronde R trib”.
⁶ WRIA	Enter the six digit stream identifier when available. The first two digits are the WRIA number (1-62), the remaining four digits are the stream catalogue number. If there is no four digit stream number, record the two digit WRIA number at the least.
⁷ Position	Location of the beginning of the reach (e.g., at barrier culvert Site 370054 on Jones Road)
⁸ Coordinates	GPS coordinates at the beginning of each reach. Record the latitude/longitude or waypoint name.
⁹ Reach Code	Label for the reach being sampled. See the naming conventions above. (e.g. “TC1 R1”)
¹⁰ Begin CR	Beginning hip chain reading (CR). Record the hip chain reading at the beginning of the reach in decimeters (0.1 meters).
¹¹ End CR	Ending CR. Record the hip chain reading at the end of the reach in tenths of a meter.

Field Form Name	Description
Habitat Sample Data	
Chain Reading	The measurement along the hip chain at the beginning of each habitat type. Recorded in tenths of a meter.
Habitat Type	The habitat type measured for each sample. PL = Pool; RF = Riffle; RP = Rapid; PD = Pond.
Length	The length of each habitat type sample. Recorded in tenths of a meter.
Wetted Width	The wetted width of each habitat type sample. Recorded in tenths of a meter.
Scour Line Width	The scour line width of each habitat type sample. Recorded in tenths of a meter.
Depth	The average depth at the wetted width cross section. Recorded in tenths of a meter.
Gradient	The percent stream gradient for each habitat sample. Expressed as a decimal. Record <i>at least one</i> gradient per 60 m sample.
% Boulder/Cobble/Gravel/Fines	The percent of each substrate classification per habitat type sample. Ensure that the sum of all substrate classifications is equal to “% 100”.
Reach Data	
¹² Instream Cover	Characterize the amount of instream cover as Low , Medium , or High . A low instream cover rating should be reflected in the rearing habitat quality modifier.
¹³ Thermal Cover	Visually estimate the percent of shaded stream assuming full leaf out condition. Record dominant tree and/or shrub species.
¹⁴ Temperature	Stream temperature. Measured in degrees Celsius.
¹⁵ Spawning HQM	Habitat Quality Modifier (HQM) assigned to spawning habitat for the reach. Appropriate values: Good = 1; Fair = 0.67; Poor = 0.33; Very Poor with No Habitat Value = 0.

Field Form Name	Description
16Rearing HQM	HQM assigned to rearing habitat for the reach. Appropriate values: Good = 1; Fair = 0.67; Poor = 0.33; Very Poor with No Habitat Value = 0.
17Limiting Factors	If an HQM less than 1 was assigned, explain why. Include an explanation for every increment of habitat reduction.
18Juvenile Abundance	A visual estimate of salmonid juvenile abundance. Characterize as None Observed, Low, Medium, or High. Identify to species if possible.
19Spring Influence	Estimate of the spring contribution to the flow of the stream. Absent = 0; Slight = 1; Moderate = 2; Pronounced = 3.
20Culverted Length	Total length of all culverts within the reach, in meters.
21Culvert Site IDs	List of culvert features in the reach that contribute to the total culverted length.

10.6 Additional Reading

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FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 11

HABITAT ASSESSMENT DATA ENTRY

11.1 Habitat Survey Data Entry

Use the customized “Physical Habitat Survey” Excel workbook to process and record field data collected using the RSFS habitat assessment methods. The workbook is titled “survey5.xls” and can be downloaded from the WDFW Fish Passage web site.

Separate workbook files are created for the mainstem upstream of the target site, as well as each upstream tributary. Typically there are a series of upstream tributaries, resulting in a number of workbook files.

Contact the WDFW Fish Passage Program for technical assistance with the data entry methods presented in this manual, or to obtain a copy of the habitat survey workbook:

FishPassageInventory@dfw.wa.gov

The workbook consists of four spreadsheets:

1. An **Input** sheet where all the reach data, and habitat sample data is entered.
2. An **Output** sheet containing the results of the habitat gain analysis.
3. The **Fish Access Check Comments** sheet where downstream field observations and pictures are recorded.
4. The **Upstream Comments** sheet where upstream observations and pictures are recorded.

Input Sheet

The input sheet header section contains the target site and contextual information (see Table 11.2). This information is automatically inserted into the following Output, Fish Access Check Comments, and Upstream Comments sheets. The header is followed by ten reach sections, each containing fields for reach data and habitat sample data. Data entry is restricted to the gray shaded cells on the spreadsheet. White cells contain either labels, or display the results of underlying formulas. An example of the input sheet, with the sample data, is presented in Appendix I.

Surveys with more than 10 reaches require a new file with Reach 11 data entered under Reach 1 of the second file, Reach 12 data under Reach 2, etc. Actual reach numbers should be explained in the comments section.

Each data field and its appropriate inputs are described below or summarized in Table 11.2. Most workbook data is collected in the field using the RSFS habitat survey methods described in Chapter 10, with the exception of the following fields:

Estimated Drainage Area - Calculate the basin area upstream of each reach break (Figure 11.1).

The basin area (also known as ‘watershed’ or ‘drainage area’) is the area of land from which all water converges at a single outlet. Each drainage basin is separated topographically from adjacent basins by a ridge, hill, or mountain - also known as a watershed boundary. In highly modified agricultural or urban areas, human development infrastructure and stormwater management systems may alter the watershed boundaries. Use your local knowledge of the area when delineating basin areas.

When delineating the boundaries of a basin area, include all upstream area that would contribute water to the point at the outlet of the reach. Use the GPS coordinates at the beginning of each reach as the lowest point in the reach basin. The basin area for each reach can be derived from topographic or digital elevation maps using readily available GIS-based software. Basin areas are recorded in square miles (mi²).

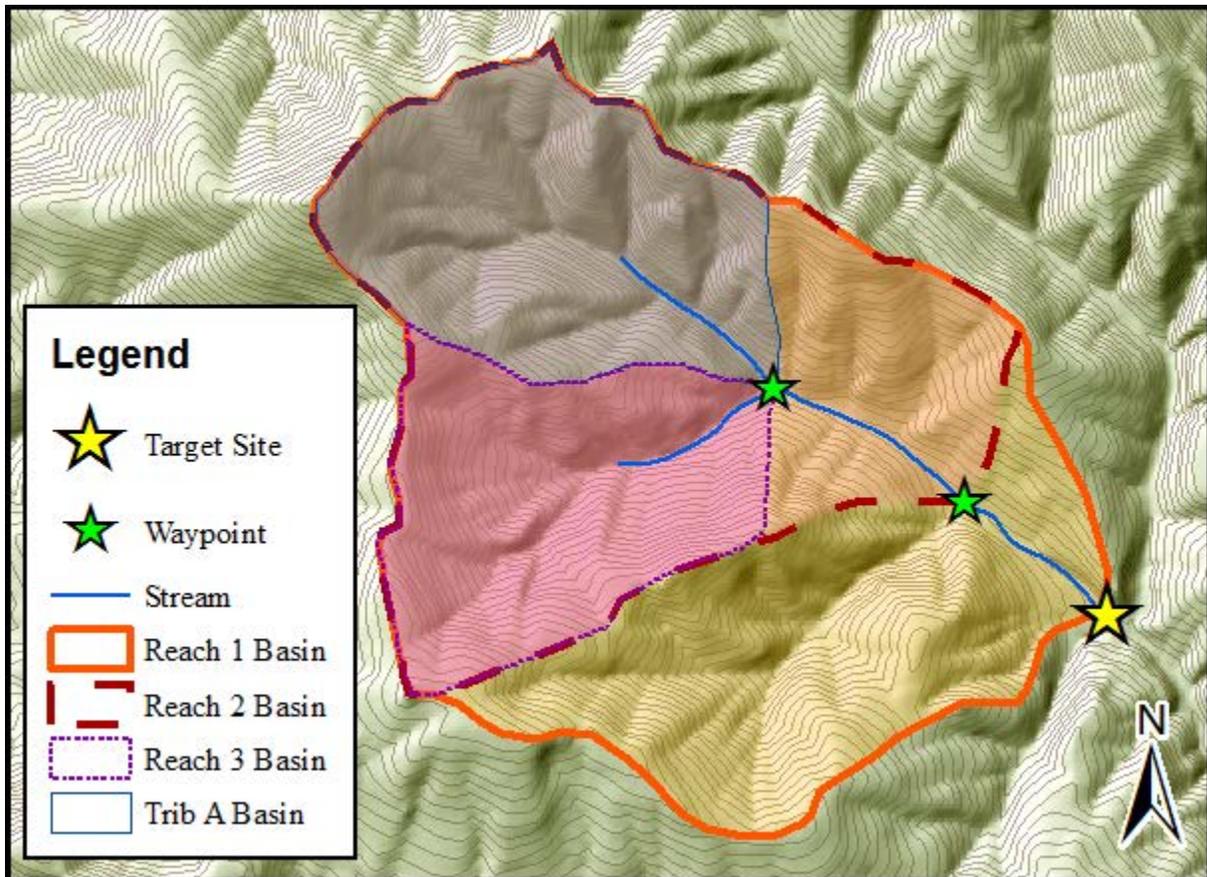


Figure 11.1. Delineated basin areas. Illustrates three reaches upstream of the target site, as well as one tributary. Notice the watershed boundaries along ridges. The first upstream reach break was at the confluence with a non-fish bearing tributary, and GPS waypoint coordinates were collected.

Species Expected to Benefit - Mark with an “X” any salmonid species that could potentially utilize the habitat within each reach, assuming a lack of downstream human-made barriers. If potential species utilization is unknown, contact local biologists or consult online resources.

Online resources include:

- SalmonScape - (<http://apps.wdfw.wa.gov/salmonscape/>) – An online, interactive, computer mapping system displaying the distribution of most Washington State salmonids, in addition to other species. Fish distribution is drawn from the Statewide Washington Integrated Fish Distribution database, and displayed according to species and run. The database includes a series of distribution types, such as documented, presumed, potential, and modeled use. Typically if a species has documented, presumed, or potential distribution it should be included in the list of species expected to benefit. If the distribution is modeled, take into account additional habitat observations, such as stream dimensions, downstream barriers, etc. SalmonScape also displays ESA Listing Units, which are used as a variable in PI calculations (Chapter 12).
- Washington Stream Catalog - (http://www.streamnetlibrary.org/?page_id=95) – The online home of a large, comprehensive report, originally released in 1975. Divided into WRIAs, the catalogue provided a comprehensive view of present (as of 1975) and future fish status in Washington State.
- Washington State Fish Passage Map Application - (<http://apps.wdfw.wa.gov/fishpassage/>) – A centralized database of fish passage features throughout Washington State. The application has a number of helpful operational layers in the context of fish passage, including the fish distribution and ESA listing unit data from SalmonScape.

Fish distribution data from online resources is often spotty or incomplete, especially for smaller streams. Species known to be present in the main stem, are assumed to be present in the tributaries, providing the tributaries are accessible (or can be made accessible if all human-made barriers are removed) and do not exceed the normal upper gradient limits for the species. For example, if there is documented chum salmon in a larger downstream tributary, but you encounter gradients greater than 5% in the fish access check, do not include chum in upstream reaches (see Table 11.1). Also account for any species blocked by any partial natural barriers encountered during the habitat survey (see Chapter 7).

Remember to consider rearing juvenile fish when assigning species. Benefit is not limited to spawning adults. Even off channel habitats where adults would not spawn can act as refuge or rearing habitat for salmon.

Table 11.1. Gradient ranges of anadromous species utilization. Each cell of the table represents a reach at a specific gradient range. Solid green cells indicate that reaches with usable spawning and rearing gradients. Crossed-out yellow cells indicate that the species can pass through the reach with the gradient range, but do not utilize the habitat for spawning or rearing. Blank cells indicate that the reach is not usable, and is impassable.

Species	Gradient (%)						
	0-3	3-5	5-7m	7-12	12-16	16-20	20+
Chum		X					
Pink				X			
Coho				X	X		
Sockeye				X	X		
Chinook				X	X		
Steelhead					X	X	
Sea Run Cutthroat					X	X	

Regional Constant - The regional constant value is used to calculate the 60-day low flow value. Consult Figure 11.2 below to determine the regional constant for the survey.

Regions in Western Washington are divided by WRIAs. Therefore, if your survey lies close to one of the regional lines, trace the stream downstream to determine which of the regions it flows into.

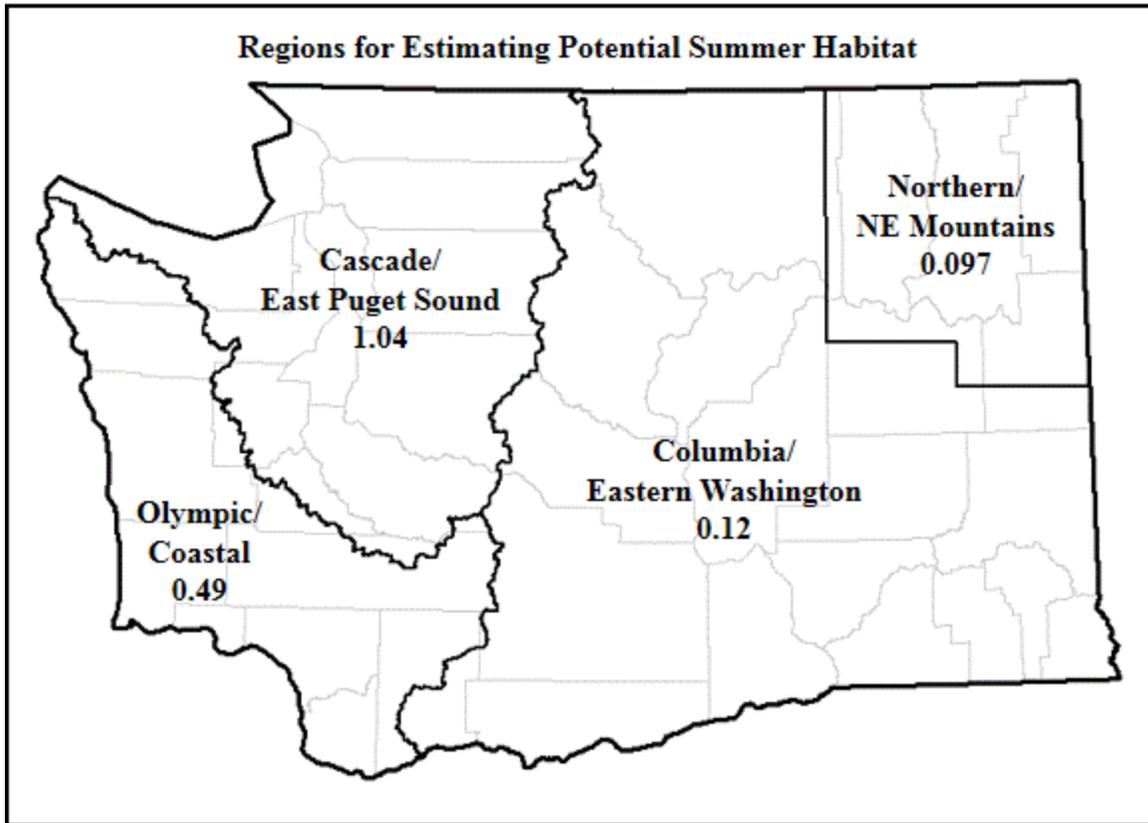


Figure 11.2. Regional constants. Washington State regions and their associated constants for estimating the 60-day low flow.

Table 11.2. Input Sheet fields.

Field Name	Field Type	Instructions for Data Entry
Header Information		
Survey ID	Character	Unique identifier. Typically identical to the target site ID.
Date	Date	Date of the field review. MM/DD/YYYY format. If the stream survey took more than one day to complete enter the date when the survey began.
Observer(s)	Character	Last names of individuals responsible for field data collection. Separate names with a semicolon, e.g., “Bouchillon; Tran”
Stream Name	Character	Name of the stream where the feature is located. If the stream is unnamed, record as “unnamed”.
Tributary To	Character	Name of the waterbody into which the stream flows. If the receiving waterbody is unnamed, record as “unnamed” followed by the name of the first named confluence, and then “trib”. E.g. “unnamed Grande Ronde R trib”.
WRIA	Character	Water Resource Inventory Area (WRIA) number for the stream. Enter the six digit stream identifier when available. The first two digits are the WRIA number (1-62), the remaining four digits are the stream number. If there is no four digit stream number, record the two digit WRIA number at the least.
Survey Extent	Character	Enter text describing the entire upstream section surveyed, from beginning to ending point. (e.g. “ <i>Target Site # to End of Fish Use</i> ”)
Filename	Character	The survey workbook filename. (e.g. 991745.xls, 991745TribA.xls, etc.)

Field Name	Field Type	Instructions for Data Entry
Field Data		
<i>Note: All of the following fields are repeated for each reach within the survey.</i>		
Begin (m)	Numeric	Beginning hip chain reading (CR). Record the hip chain reading at the beginning of the reach in tenths of a meter. Reach 1 should begin at zero, Reach 2 should begin where Reach 1 ends, Reach 3 begins where Reach 2 ends, etc.
End (m)	Numeric	Ending CR. Record the hip chain reading at the end of the reach in tenths of a meter.
Reach Length (m)	Numeric	Total length of the surveyed reach, in meters, based on beginning and ending positions. <i>Calculated field.</i>
Position	Character	Location of the beginning of the reach (<i>e.g.</i> , at barrier culvert Site 370054 on Jones Road; or; at left bank tributary entering at 1543 meters upstream Site 370054).
Habitat Quality Modifiers		
Spawning	Numeric	Habitat Quality Modifier (HQM) assigned to spawning habitat for the reach. Appropriate values: Good = 1; Fair = 0.67; Poor = 0.33; Very Poor with No Habitat Value = 0.
Rearing	Numeric	HQM assigned to rearing habitat for the reach. Appropriate values: Good = 1; Fair = 0.67; Poor = 0.33; Very Poor with No Habitat Value = 0.
Reach Habitat Data		
T (C)	Numeric	Stream temperature. Measured in degrees Celsius.
Instream Cover	Character	Characterize the amount of instream cover as Low, Medium, or High.
Thermal Cover	Character	Visually estimate the percent of shaded stream assuming full leaf out condition. Record dominant tree and/or shrub species.
Juvenile Abundance	Character	A visual estimate of salmonid juvenile abundance. Characterize as None Observed, Low, Medium, or High. Identify to species if possible.
Limiting Factors	Character	If an HQM less than 1 was assigned, explain why. Include an explanation for every increment of habitat reduction.

Field Name	Field Type	Instructions for Data Entry
Culvert Site IDs	Character	List of culverted feature IDs in the reach that contribute to the total culverted length. Include dams with culvert outlets. If there is no additional barrier within the reach, then leave blank.
Total Culverted Length	Numeric	Total length of all culverts (including 100% passable culverts) located within the reach, including culvert outlets from dams. If there are no additional barriers within the reach, enter "0".
Est. Drainage Area	Numeric	Estimated basin area for the reach. Units in square miles rounded to the nearest hundredth.
Reach Species Use		
Species Expected to Benefit	Character	Enter an 'X' under each species that has the potential use the habitat, if all downstream barriers are removed.
60-Day Low Flow		
Spring Influence	Numeric	Estimate of the spring contribution to the flow of the stream. Absent = 0; Slight = 1; Moderate = 2; Pronounced = 3.
Regional Constant	Numeric	Regional constant for 60- day low flow calculation. Olympic/Coastal region = 0.49; Cascade/Puget = 1.04; Columbia/Eastern WA = 0.12; Northern/NE mountains = 0.097.
Habitat Sample Data		
Type	Character	The habitat type measured for each sample. PL = Pool; RF = Riffle; RP = Rapid; PD = Pond.
L	Numeric	The length (in tenths of a meter) of the habitat type measured for each sample.
W	Numeric	The wetted width (in tenths of a meter) of the habitat type measured for each sample.
SLW	Numeric	The scour line width (in tenths of a meter) of the habitat type measured for each sample.
D	Numeric	The average depth (in hundredths of a meter) of the habitat type measured for each sample.

Field Name	Field Type	Instructions for Data Entry
Grad.	Numeric	The percent stream gradient for each sample section, expressed as a decimal. E.g. a 5% stream gradient would be entered as “0.05”. Enter <i>at least</i> one gradient per 60- or 30-meter sample.
B	Numeric	The percentage of boulder that is present within each habitat type measured, expressed as an integer.
C	Numeric	The percentage of cobble that is present within each habitat type measured, expressed as an integer.
G	Numeric	The percentage of gravel that is present within each habitat type measured, expressed as an integer.
F	Numeric	The percentage of sand/silt/fines that is present within each habitat type measured, expressed as an integer.
SUM BRGS	Numeric	The sum of gradient percentages. Ensure that the SUM BRGS cell is equal to “100” for every habitat type measured. <i>Calculated field.</i>

Data Analysis and Output Sheet

Physical habitat survey data entered in the input sheet are used to estimate habitat gains in terms of fish production potential. Habitat gain is expressed in square meters (m²) of either spawning or summer rearing habitat. Spawning area is used for those species whose production is limited by spawning habitat (chum, pink, and sockeye salmon). Rearing area is used for those species whose production is limited by rearing habitat (coho and Chinook salmon, steelhead, cutthroat, resident rainbow, and bull trout).

Spawning area is calculated as the sum of the areas of each habitat type, measured at scour line width, multiplied by the gravel percentage in each habitat type.

Rearing area is calculated using a projected 60-day low flow, or a measure of wetted width, depending on which is lower. 60-day low flow is calculated using basin area, spring influence, and a regional constant (Figure 11.2). Sixty-day low flow is defined as the lowest average flow occurring over any period of 60 consecutive days during the year. The 60-day low flow rearing area represents calculated low flow conditions. Wetted area represents rearing area at the time of the survey.

Pond and lake habitat are included in rearing habitat. When large ponds and lakes are present in a watershed, the calculated rearing areas are extremely large, yielding unreasonably high production values. To adjust this, a lake adjustment factor was developed that reduces the rearing area for lakes and ponds larger than 4,000 square meters through the formula:

$$(((\text{Area} - 2,000)/2,000)^{1/2} 2,000) + 2,000.$$

This reduces the rearing area to a number that approximates the littoral area, which more accurately describes the rearing potential for a large pond or lake.

The Habitat Quality Modifiers (HQMs) assigned during the physical habitat survey are then applied to adjust for reductions in spawning or rearing area.

Gains in spawning or rearing area are calculated for each potentially present species within a reach, and displayed as the “Production Area Calculations” in the output sheet. Production area values are then subjected to an analysis of species interaction to account for competition between species with similar freshwater life histories, which tends to reduce the production rate below single species production values. Competition is modeled using a species complex factor.

For example, if there are 3 species in the species complex then:

$$\text{Species Complex Factor (CF)} = \frac{\text{production value species 1} + 0.67 (\text{production value species 2}) + 0.33 (\text{production value species 3})}{\text{production value species 1} + \text{production value species 2} + \text{production value species 3}}$$

If there are 4 species in the species complex then:

$$\text{Species Complex Factor (CF)} = \frac{\text{production value species 1} + 0.75 (\text{production value species 2}) + 0.5 (\text{production value species 3}) + 0.25 (\text{production value species 4})}{\text{production value species 1} + \text{production value species 2} + \text{production value species 3} + \text{production value species 4}}$$

The results of the species interaction are displayed as the “Adjusted Production Areas” on the output sheet, and are used as “H” variable in the Priority Index equation (Chapter 12).

In addition to the production areas, the output sheet includes summary habitat statistics for the entire upstream channel, and individual reaches. Within each reach pool, riffle, rapid, and pond statistics are calculated for the wetted area, the area within the scour lines, and 60-day low flow area.

The output sheet is read-only sheet, so do not attempt to enter or edit data. Any corrections must be made on the input sheet. Altering or deleting any of the formulas will result in erroneous or missing data. The output sheet is formatted into 11 printable pages (see printing instructions below), one survey summary page and ten reach summary pages. An example is presented in Appendix I with the sample data.

Fish Access Check and Upstream Comments

Fish Access Check (FAC) Comments, and Upstream Comments are recorded in the corresponding workbook sheets. Most of the header information will be auto-populated from the input/output sheets. Auto-populated cells have a white background. Enter data in cells with a grey background in the FAC sheet - enter the fish access check extent, and total length of the downstream survey. The FAC survey extent should be from the outlet of the target site, to the

confluence with a downstream waterbody of known fish use, where the fish access check ended (e.g. “Target site 999999 to confluence with Humptulips R”). FAC “Total Length” is the hip chain measurement from the outlet of the target site, to the confluence with the fish bearing waterbody downstream. Record the total length in tenths of a meter. Do not change heading data in cells with a white background. Errors in fields with a white background should be corrected in the input sheet.

Below the heading there is a column (A) for the hip chain reading and a column (B) for the habitat comments associated with that chain reading. Hip chain readings should be continuous through the entire survey of each channel – do not restart the chain readings at reach breaks. Tributaries should start at chain reading “0”. Include at least one representative habitat photo per reach. Also include photos of noteworthy features. Site photos do not need to be included in the habitat notes.

Format the text and pictures so they do not exceed the boundaries of the comments pages. WDFW recommends emphasizing additional barriers, stream dimensions, and notable features with bold text. Things that should be written in **bold** print in the habitat notes are:

- Site ID #s and feature dimensions.
- Physical measurements: BFW, WW, SCL, Depth, Substrates, Gradients, etc.
- Fish observations.
- Tributaries.
- Reasons for breaking reach.
- Justification for determining the end of potential fish. Report the GPS coordinates.
- DS Check: Verified anadromous fish access and name confluence with known anadromous use.

Examples of the Fish Access Check Comments, and Upstream Comments are presented in Appendix I using the sample data.

File Management and Printing

The unique site identification number assigned to the target barrier is used in naming all associated survey files. For the mainstem survey file the name consists of the site ID and the file extension (e.g. 991754MS.xls). For tributaries to the mainstem, the name consists of the site ID plus the tributary naming conventions from Chapter 10 and the file extension (e.g. 991754TA.xls, 991754TA1.xls, 991754TA1a.xls, etc).

The Physical Habitat Survey workbook output and comments sheets are printable. The input sheet is solely for entering data.

11.2 Additional Barriers

Use the Additional Barriers Workbook to combine output data when a survey includes multiple upstream channels associated with a single fish passage barrier. I.e. if a survey had multiple tributaries, the upstream mainstem and its tributaries should have their own physical habitat survey workbook, and the outputs of those workbooks can be summed using the additional

barriers workbook. The workbook is titled “AddBarrsPI.xls” and can be obtained by contacting WDFW staff: FishPassageInventory@dfw.wa.gov

Enter data into cells with a gray background. Cells with a white background are instructional, or automatically calculated, and should not be altered.

Header Information - The header information in the Additional Barriers workbook is identical to the header information in the Physical Habitat Survey mainstem file, with the following exceptions:

- Basin Area – The entire drainage area upstream of the target barrier. Identical to the estimated drainage area of the first mainstem reach. Entered in square miles, rounded to the nearest hundredth.
- Number of DS Barriers – A count of all barriers encountered in the fish access check.
- DS Check Length – The total length of the fish access check. Recorded in tenths of a meter.
- River Mile – The downstream check length divided by the number of meters in a mile. *Calculated field.*
- Number of US Barriers – A count of all barriers encountered in the upstream physical habitat survey. *Calculated field.*

Totals - Below the header information are the calculated habitat totals for all reaches upstream of the target barrier. Then there are multiple channels upstream of a target barrier, the total adjusted production areas are used as the H value in the PI calculations (Chapter 12).

Data Entry - Enter the habitat data for every surveyed reach of the mainstem and upstream tributaries. Each reach has its own row for data entry. The spreadsheet is formatted to accept 22 reaches on the first page, and 30 reaches on the second page. Detailed instructions for entering the reach data are included on the second page of the “Addl Barrs” tab. Examples of how to use the spreadsheet are included in the “Examples” tab.

File Management and Printing

Additional Barrier workbook filename consists of the site ID number plus the characters “AddBarr” (e.g., 991754AddBarr.xls).

The Additional Barriers workbook should be printed in landscape orientation on 11 X 17 inch paper.

FISH PASSAGE INVENTORY, ASSESSMENT, AND PRIORITIZATION MANUAL

CHAPTER 12

PRIORITIZATION

This chapter presents methods for prioritizing the correction of fish passage barriers or unscreened/insufficiently screened diversions.

Why Prioritize?

- Prioritization helps ensure that the projects with the greatest benefits to fish are constructed first.
- It supports the ability to compare similar projects in different watersheds.
- It weighs the benefits to fish against considerations like project cost and stock status.
- Prioritization may be advantageous when competing for grant funding.

12.1 Fish Passage Barrier Correction Priority Index

The WDFW Fish Passage Program suggests using the Priority Index model to consolidate several variables that affect the feasibility of a fish passage project, including: expected passage improvement, habitat gain, fish stock status, etc. The variables are entered into a manageable equation for developing prioritized lists of projects. The result is a numeric indicator of each project's relative priority. The Priority Index (PI) for each barrier is calculated as follows:

$$PI_{\text{Total}} = \sum_{\text{All Species}} \sqrt[4]{[(\text{BPH}) \times \text{MDC}]}$$

Where:

PI_{Total} = Barrier Correction Priority Index

- PI values are calculated for each species that is potentially present in a stream. The PI_{Total} value is the sum ($\sum_{\text{All Species}}$) of individual species' PI values (e.g., PI_{Coho} is added to PI_{Chum} to obtain $PI_{\text{All Species}}$).
- The quadratic root provides more manageable values and represents a geometric mean of variables used.

B = Proportion of Passage Improvement

- Proportion of fish run expected to gain access due to the project. This variable gives greater weight to those projects which provide greater passage improvement.
- Derived from the barrier assessment passability estimate (Chapter 3):
 - 0% passable = 1.00 improvement
 - 33% passable = 0.67 improvement
 - 67% passable = 0.33 improvement

P = Annual Adult Equivalent Production Potential Per m²

- An estimate of annual adult salmonid production potential for every m² of habitat (adults/m²).
- The values are species specific: Chinook salmon = 0.016, chum salmon = 1.25, coho salmon = 0.05, pink salmon = 1.25, sockeye/kokanee salmon = 3.00, steelhead = 0.0021, bull trout/Dolly Varden = 0.0007, sea run cutthroat trout = 0.037, resident cutthroat/rainbow trout = 0.04.

H = Habitat Gain in m²

- The habitat gain value gives greater weight to barrier correction projects that emancipate larger amounts of upstream habitat.
- Habitat gain is derived from the physical habitat survey and subsequent data analysis (Chapters 10 and 11).
- For species whose productive potential is limited by access to spawning habitat, the “spawning area” from the Physical Habitat Survey workbook is used as an indicator of habitat gain. Spawning limited species include sockeye/kokanee, chum, and pink salmon.
- For species whose productive potential is limited by access to rearing habitat, the “rearing area” is used as an indicator of habitat gain. Rearing limited species include coho, chinook, cutthroat trout, steelhead, resident trout, and bull trout.
- The H value is adjusted to reflect sympatric interactions between species with similar life histories. The adjustment is made in the Physical Habitat Survey workbook.

M = Mobility Modifier

- The mobility modifier gives greater weight to projects that benefit fish stocks which are highly mobile, and therefore subject to geographically diverse recreational and commercial fisheries.

2 = Highly mobile stock. Anadromous species.

1 = Moderately mobile stock. Resident species.

D = Species Condition Modifier

- The species condition modifier gives greater weight to Endangered Species Act (ESA) listed species. The ESA status for most Washington State salmonids can be found at the WDFW SalmonScape web-site: <http://apps.wdfw.wa.gov/salmonscape/>. In the absence of an ESA status, stock condition should be estimated using the best available information.

3 = Endangered or Threatened ESA status.

2 = Species of Concern or Candidate.

1 = Not warranted or not listed.

C = Cost Modifier

- The cost modifier represents the projected cost of project, giving greater weight to less expensive projects.

3 = privately owned or single lane public road.

2 = city/county owned roadway or 2 lane state highway.

1 = state highway greater than 2 lanes

12.2 Screening Priority Index

The Screening Priority Index (SPI) model is adapted from the quadratic formula used to prioritize fish passage barrier corrections. The SPI was created to consolidate many variables relevant to water diversions, and create a manageable framework for developing project prioritization lists.

The SPI for each unscreened or ineffectively screened diversion is calculated as follows:

$$SPI_{Total} = \sum_{All\ Species} \sqrt[4]{[(QP) \times MDC]}$$

Where:

SPI = Screening Priority Index

- SPI values are calculated for each species that is potentially present in a stream. The SPI_{Total} value is the sum ($\Sigma_{\text{All Species}}$) of individual species' SPI values (e.g., SPI_{Coho} is added to SPI_{Chum} to obtain SPI_{All Species}).
- The quadratic root provides more manageable values and represents a geometric mean of variables used.

Q = Flow in Gallons Per Minute

- Flow through the diversion is used as a surrogate for the number of adult equivalent salmonids potentially killed by an unscreened diversion.
- For gravity diversions, flow is derived from the water right, is directly measured, or is calculated as a portion of the diversion ditch area (Flow = Diversion Ditch Area x 0.75).
- For pump diversions, flow is derived from the water right, flow meter, or gauge.
- Diversion amounts are typically provided in cubic feet per second (cfs), however, the Screen Priority Index equation requires the diversion amount to be in gallons per minute (gpm). Convert cubic feet per second to gallons per minute using the following equation:

$$\text{CFS} * 499 = \text{GPM}$$

P = Annual Adult Equivalent Production Potential Per m²

- An estimate of annual adult salmonid production potential for every m² of habitat (adults/m²).
- The values are species specific: Chinook salmon = 0.016, chum salmon = 1.25, coho salmon = 0.05, pink salmon = 1.25, sockeye/kokanee salmon = 3.00, steelhead = 0.0021, bull trout/Dolly Varden = 0.0007, sea run cutthroat trout = 0.037, resident cutthroat/rainbow trout = 0.04.

M = Mobility Modifier

- The mobility modifier gives greater weight to projects that benefit fish stocks which are highly mobile, and therefore subject to geographically diverse recreational and commercial fisheries. The potential for mobile, undesirable fish stocks to access a system is also considered in the SPI mobility modifier.

2 = Highly mobile stock. Anadromous species.

1 = Moderately mobile stock. Resident species.

0 = Increased survival of the fish stock would have negative or undesirable impacts on the productivity of native species, or would be contrary to fish management policy.

D = Species Condition Modifier

- The species condition modifier gives greater weight to Endangered Species Act (ESA) listed species. The ESA status for most Washington State salmonids can be found at the WDFW SalmonScape web-site: <http://apps.wdfw.wa.gov/salmonscape/>. In the absence of an ESA status, stock condition should be estimated using the best available information.

3 = Endangered or Threatened ESA status.

2 = Species of Concern or Candidate.

1 = Not warranted or not listed.

C = Cost Modifier

- The cost modifier represents the projected cost of project, giving greater weight to less expensive projects.

3 = incremental funds needed \leq \$1,000

2 = incremental funds needed between $>$ \$1,000 and \$5,000

1 = incremental funds needed $>$ \$5,000

12.3 Additional Considerations

In addition to using the PI and SPI models, some other considerations to make when prioritizing projects include:

- Coordination – Does the project compliment, or is it complimented, by other work in the watershed?
- Juveniles – The current PI and SPI models do not evaluate the benefits of passage improvements for juvenile salmonids. Does this project have the potential to improve landscape connectivity for rearing or out-migrating juveniles?
- Benefits – Does the project have other habitat restoration benefits, beyond fish passage or screening? Do other, non-target species stand to benefit (e.g. Pacific lamprey)?
- Community Support – Does the project have the potential to involve multiple stakeholders? Will the project have educational value?
- Funding Opportunities – Is grant, mitigation, or other funding readily available for this project?

APPENDIX A

Glossary of Terms

active screen: Screens equipped with an automatic mechanical cleaning system.

abandoned crossing: An abandoned crossing is a former road crossing that has been permanently decommissioned, the water crossing structure (such as a culvert, bridge or dam) has been removed, and the stream channel and adjacent banks are typically restored. The roads are blocked or recontoured, and vehicles are no longer able to cross.

anadromous fish: Fish which mature and spend much of their adult life in the ocean, returning to inland freshwater systems to spawn. Examples include salmon and steelhead.

apron: An erosion protection structure at the inlet or outlet of a fish passage feature. Usually a pad or slab of non-erosive material.

average stream width: See definition for “bankfull width”.

backwater: The increase in water surface elevation relative to the elevation occurring under normal open-channel conditions. Induced by a structure that obstructs the free flow of water.

backwatered culvert: The condition where the average velocity through the entire length of the culvert is visibly slower than the average velocity of the adjacent channel; or, a pool with little or no visible current exists throughout the entire length of the culvert.

baffle: Pieces of wood, concrete, or metal that are mounted in a series on the floor and/or wall of a culvert or flume to increase hydraulic roughness, reducing the cross-sectional mean velocity and increasing water depth.

bankfull width: The width of a stream channel at the point where water begins to overflow into the active floodplain. The bankfull width is created by the dominant channel forming flow. In streams without a floodplain, determine the bankfull width using indicators that do not depend on a floodplain, such as changes in vegetation, topographic breaks, change in substrate size, etc. See Appendix G for more guidance on measuring bankfull width.

bed: The land below the ordinary high water marks.

bedload: Stream sediment consisting of coarse material that is carried along the stream bed without being permanently suspended in the flowing water.

bed roughness: The unevenness of streambed material (i.e., gravel, cobbles) that contributes resistance to stream flow. The degree of roughness is commonly expressed using the Manning’s n roughness coefficient.

benchmark: A marked point of known elevation from which other elevations may be established.

bridge: A bottomless structure with a structural span greater than the bankfull width of the stream it crosses.

cascade: A steep, non-vertical channel, dominated by boulders and cobbles, sometimes with small steps and pools. Cascade features require a combination of burst swimming, and vertical and horizontal leaps to access upstream habitat.

channel bed slope: Vertical change with respect to horizontal distance measured at the stream bed material. See “gradient”.

channel bed width: For the purpose of culvert design, the channel-bed width is defined as the width of the bankfull channel.

check structure: A small seasonal dam constructed of rocks, gravel bags, sandbags, fiber rolls, or other materials placed within a waterway to temporarily impound or redirect flow to a water surface diversion. Check structures may partially or fully span the waterway.

chute: A steep, non-vertical channel, dominated by boulders and cobbles, sometimes with small steps and pools. Chute features require a combination of burst swimming, and vertical and horizontal leaps to access upstream habitat. See “cascades”.

countersunk: The downstream culvert invert is embedded below the channel bed by a minimum of 20% of the culvert rise, and streambed material is present throughout the length of the culvert invert.

culvert: A structure that allows water to flow under a road, trail, dike, or other obstruction.

culvert span to bankfull width ratio: The ratio of the culvert width to the bankfull width. Expressed as a whole number percentage.

culvert influence: A channel reach upstream and downstream of a culvert that is impacted by the water crossing. Impacts may include: channel constriction, channel instability, large scour or plunge pools, sediment deposition, etc.

dam: A structure designed for water detention, water impoundment, or to elevate the upstream water surface.

dike: A long wall or embankment built to regulate water levels and prevent flooding.

entrainment: The voluntary or involuntary movement of fish from the parent water body into a surface water diversion. Entrainment occurs when a fish is drawn into a water intake and cannot escape.

ephemeral stream: An ephemeral stream has flowing water only during, and for a short duration after precipitation events in a typical year. Ephemeral streams are located above the water table year-round, and groundwater is not a source of stream flow. Runoff from rainfall is the primary source of stream flow.

exceedance flow: The flow that is equaled or exceeded. n% exceedance flow is the flow that is equaled or exceeded n% of the time.

fish screen: A fish protection device installed at or near a surface water diversion intake to prevent entrainment, impingement, injury, or death. Fish screens physically preclude fish from entering the diversion, and do not rely on avoidance behavior like electrical or sonic fish barrier technology.

fishway: Fishways, commonly called *fish ladders* or *fish passes*, are fish passage improvement structures built to facilitate passage of fish through, over, or around an instream barrier.

fish bypass system: A system to collect fish from in front of a diversion intake screen and safely transport them back to the stream. The fish bypass consists of an entrance/flow control section, and a fish conveyance channel or pipeline to return them to the stream.

fish bypass water: A portion of the diverted flow used to transport fish through the fish bypass system.

fish passage flow (Q_{fp}): The flows between low fish passage flow (95% exceedance flow), and high fish passage flow (10% exceedance flow).

flap gate: A plate, usually made of wood or metal, which is hinged at the top of a culvert outlet. The plate falls into a near vertical position to cover the culvert. When the water pressure is greater at the downstream side, the gate is forced closed. The gate is forced open when the water pressure at the upstream end is greater than the water pressure at the downstream end. Flapgates at the outlet of a culvert prevent upstream flow, and are not classified as “dams”. When a flapgate is present on a culvert, the culvert is a 0% passable

flashboard riser: Commonly called a “stoplog”. A removable weir that can be used to impound and adjust the level of upstream water. Flashboard risers are typically constructed of wood, but may also be made of plastic or metal.

flood gate: A regulator consisting of a valve or gate that controls the rate of water flow, or prevents water flow from entering behind the gate.

ford: A shallow in-stream motorized crossing. Fords often have a reinforced foundation, such as concrete or compressed rock, but may also cross the natural streambed material.

FPDSI: The Fish Passage and Diversion Screening Inventory database developed and maintained by the Washington Department of Fish and Wildlife.

freshet: A rapid, temporary rise in stream flow caused by snow melt or rain.

Full Survey: Habitat survey method formerly used for assessing the habitat above or below a human-made fish passage barrier. The main difference between a Full Survey (FS) and a Reduced Sampling Full Survey (RSFS) is the sampling rate. The FS achieves a 20 percent

sampling rate by sampling for 30 meters every 160 linear meters or 60 meters every 320 meters within every reach, depending on the length of the stream. The Full Survey methods are no longer included in the Fish Passage Inventory, Assessment and Prioritization Manual.

GPS: Global Positioning System. A GPS Unit is an electronic receiver that uses GPS (a system of satellites) to calculate (by triangulation) positions on earth with great accuracy.

grade control: Stabilization of the streambed surface elevation to protect against degradation. Grade stabilization usually consists of a natural or man-made hard point in the channel, anchored to the banks, that holds a set elevation.

gradient: The slope of a stream-channel bed or water surface. The elevation rise divided by distance, expressed as a percentage.

Habitat Quality Modifier (HQM): A subjective estimate of habitat quality used to adjust both the spawning and rearing areas independently. The HQM has a value that ranges in one-third increments from zero to one.

half-round riser: A vertically placed, metal, round or squash shaped culvert attached to a horizontally placed culvert, used to impound water. May or may not have slots to accommodate wooden flashboards. This structure is sometimes placed in regulated wetlands to enhance wetland hydrology.

headgate: A gated structure used to control the amount of water flowing into a diversion. Typically associated with gravity diversions, and located upstream of intake screens.

impingement: Involuntary contact and entrapment. Impingement occurs when fish become trapped on the face of an intake screen by approaching flows, or suction. It may be temporary or permanent.

intermittent stream: An intermittent stream has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow.

invert: The lowest point of the internal cross section of culvert or pipe arch.

lead entity (LE): Lead entities are local, watershed-based organizations that function to guide salmon recovery efforts within their geographic and watershed boundaries.

levee: An embankment constructed to prevent a river from overflowing (flooding); a dike.

littoral: Shallow water habitats of waterbodies. In freshwater systems they occur at the shores of lakes, ponds, and rivers.

mainstem: The main channel of a river or stream.

Manning's Equation: An empirical equation used to calculate average flow velocities in open-channel systems.

Manning's n: A roughness coefficient used in Manning's Equation to describe resistance to flow due to surface roughness.

mean cross-sectional velocity: The average velocity perpendicular to flow through a cross-section of a structure or open channel.

passive screen: Screens that are designed to be self-cleaning without an automatic mechanical cleaning system. Passive screens should only be used when the debris load is expected to be low, where sufficient sweeping velocity exists to eliminate debris build-up on the screen surface, and where the maximum diverted flow is less than 0.01% of the total stream flow, or the intake is deep in a reservoir away from the shoreline.

perched culvert: A culvert where the outlet is elevated above the downstream water surface, creating a water surface drop. Perched culverts are often the result of high velocity flow eroding the channel downstream of a culvert.

perennial stream: A perennial stream has flowing water year-round during a typical year. The water table is located above the stream bed for most of the year. Groundwater is the primary source of water for stream flow. Runoff from rainfall is a supplemental source of water for stream flow.

pinch valve tide gate: A pinch valve is a flexible pipe extension that is an alternative to flap gates, but does not provide fish passage. Pinch valves have no moving or mechanical parts and are silent.

plunging flow: Plunging flow occurs when the downstream water surface is below the outlet of a culvert or the crest of a weir. Plunging flow results in the dissipation of kinetic energy – also known as “turbulence”.

pond: A body of water that is five times the width, length, and depth of representative pools located within the downstream reach.

pool: A segment of stream that is characterized by relatively deep, low velocity water and a smooth water surface.

priority index (PI): An objective value for prioritizing fish passage barrier correction projects. The PI consolidates several factors affecting a project's feasibility into a manageable framework for developing prioritized lists of projects.

pump intake screens: Screening devices attached directly to a pressurized diversion intake pipe.

puncheon: Low-lying, or partially submerged lumber or native logs placed in the channel to elevate a crossing above the wet areas. Typically used to cross wet, boggy ground or small creeks.

rack: A structure that prevents water-borne debris, animals, or humans from entering a fish passage feature. Typically composed of vertical slats separated by narrow gaps.

Ranney well: A well that has a center chamber with horizontal perforated pipes extending radially into an aquifer.

rapids: A reach of stream that is characterized by small falls and turbulent high velocity water.

reach: A section of a stream having similar physical and biological characteristics.

Reduced Sampling Full Survey: Contemporary habitat survey method used for assessing the habitat above or below a human-made barrier. One 60-meter habitat samples is collected per reach using the RSFS method.

resident fish: Fish that do not migrate to the ocean and complete their entire life cycle in fresh water.

riffle: A segment of stream characterized by relatively shallow, high velocity water with a turbulent water surface.

riparian: The area adjacent to flowing water (e.g., rivers, perennial or intermittent streams, seeps, or springs) that contains elements of both aquatic and terrestrial ecosystems, which mutually influence each other.

riprap: Large, durable materials (usually fractured rocks; sometimes broken concrete, etc.) used to protect sloped surfaces to prevent erosion. Commonly used to prevent erosion of streambanks or lake shores.

rise: The maximum, vertical, open dimension of a culvert; equal to the diameter in a round culvert and the height in a rectangular culvert.

roadfill: Soil material that is used to fill road embankments around and above a culvert feature.

salmonid: any fish of the taxonomic family Salmonidae, including salmon, trout, char, whitefish, and grayling. For the purposes of this manual, the term “salmonid” is used to indicate members of the Salmoninae sub-family, and more specifically species within the genus “*Oncorhynchus*” – containing Pacific salmon and trout.

scour: The process of removing material from the bed or banks of a channel through the erosive action of flowing water.

scour line: The point on the bank or shore, up to which the presence and action of water is so continuous or frequent as to leave a distinct mark and impede the growth of vegetation. Scour lines may be indicated by a line left by debris, pollen or silt; a mark made by erosion; destruction of terrestrial vegetation; or other easily recognized characteristics.

scour line width: The distance measured from the scour line of one bank to the scour line of the opposite bank, measured perpendicularly to flow.

screen mesh opening: The narrowest opening in screen mesh.

screening priority index (SPI): An objective value for prioritizing surface water diversion correction projects. The SPI consolidates several factors affecting a project's feasibility into a manageable framework for developing prioritized lists of projects.

significant reach: A section of stream having at least 200 linear meters of usable habitat without a gradient or natural barrier, both upstream and downstream of the fish passage feature.

site ID: Site identification number. A unique number assigned to features stored in a database.

slide gate: Slidegates and screw gates are manually or electronically lowered and risen to seal a culvert, depending on water control needs.

slope: Vertical change with respect to horizontal distance within a culvert or channel (*see gradient*).

soffit: The highest point on the interior surface of a water crossing structure. Opposite of the invert.

span: The horizontal dimension of the culvert, i.e., the width of the culvert spanning the channel.

stream catalog number: A four digit number identifying specific waterbodies within a water resource inventory area (WRIA) in the State of Washington.

streaming flow: When water flows overtop roughness elements such as baffles or weirs.

substrate: Mineral and organic material that forms the bed of a stream.

subsurface water flow: Water flowing below, but close to the ground surface.

surface water diversion: A man-made structure or installation for diverting water from a stream, river, or other surface water body for human use (municipal, industrial, agricultural, hydroelectric generation, etc.). Surface water diversions fall into two general categories: "**gravity**" and "**pump**".

sweeping velocity: The component of approaching water velocity which moves **parallel** to a screen surface. High sweeping velocity reduces the chance of screen impingement.

swing gate: A swing gate covers a culvert like a flap gate except the hinge is on the side and oriented vertically. Since the swing gate is mounted vertically like a door, its weight does not cause it to close by itself.

tailout: The downstream end of a pool where the bed surface gradually rises and the water depth decreases. It may vary in length, but usually occurs at the upstream end of a riffle

thalweg: A longitudinal line defining the lowest elevations along the course of a stream.

tide gate: An opening through which water may flow freely during an outgoing tide, but closes automatically during an incoming tide, or at certain tide levels.

toe: The point where the streambed and the bank intersect, usually indicated by a break in gradient.

water resource inventory area (WRIA): A two digit number denoting areas or boundaries created around major watersheds within the State of Washington for administration and planning purposes. These boundaries were jointly agreed upon in 1970 by Washington's natural resource agencies (departments of Ecology, Natural Resources, and Fisheries).

watershed: The specific land area that drains into a river system or other body of water.

washouts: Stream crossing where a previously existing instream structure (i.e. culvert or dam) has washed out, failed, and/or no longer exists. *Note: this differs from a formally abandoned road crossing (see definition).*

weir: A low dam across a stream that causes water to back up behind it, with flow plunging over it. Weirs are often notched to concentrate low-flow water conditions.

Source of Definitions:

Some of the definitions used in this glossary were derived from the following sources:

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APPENDIX B

Summary of Major Changes

from the 2009 Fish Passage Barrier and Surface Water
Diversion Screening Assessment and Prioritization Manual

This appendix provides a summary of significant updates to the 2009 version of this manual.

Cover:

- Shortened the manual title.
- Redesigned the cover.

Chapter 1: Introduction/Welcome to Fish Passage

- Provided a series of disclaimers and clarifications about the scope of this, and previous versions, of the fish passage manual.
- Outlined services provided by the WDFW Fish Passage program.
- Defined high and low fish passage flows.
- Abbreviated the section on inventory methods, removing the examples of each inventory type. Removed the attached maps.
- Updated links to current online resources.

Chapter 2: Site Information

- Provided detailed descriptions for each field on the Site field form.
- Clarified that the fish use classification “Biological” applies only to native Pacific trout and salmon.
- Established a hierarchy for entering fish use criteria.
- Provided a definition of Scour Line Width, and a map of the dividing line between Eastern and Western Washington.
- Updated links to current online resources for determining potential species use.
- Provided further guidance on how to inventory features without fish use potential.

Chapter 3: Culverts

- Included a section on tidal influence, and link to an “in development” tidal protocol.
- Removed the section on non-culvert crossings and made it a separate chapter. Provided instruction for differentiating between dams, bridges, and culverts.
- Specified where span and rise should be measured for different culvert conditions, including a definition of “soffit”.
- Culverts outside of bankfull width, when there are at multiple culverts at a single crossing, were defined as “overflow” regardless of invert elevations.
- Provided additional instructions for measuring span in unstraightforward circumstances (countersunk squash culverts, skewed, different dimensions at inlet/outlet, etc.).
- Specified where to take water surface drop measurements when the culvert does not outlet directly into a resting/launching pool.
- Provided direction for broken back culverts: measuring slope and elevations for Level B analysis.
- Specified where to measure road fill depth.
- Provided instruction for assessing culverts where embedment depth is too great/headroom is too small to allow fish passage.

- Provided additional instruction for assessing gates. Linked to the in-development tidal protocol when tide gates are present.
- Provided instructions for determining fish passage when racks are present at the inlet or outlet of a culvert.
- Created a decision sequence to determine barrier status on multiple-culvert crossings.
- Removed the ‘Reason’ determination from the Level A workflow.
- Rewrote the Level B section to better reflect current barrier assessment methods using commercially available software.
- Removed the Level B flow chart.
- Removed references to the Level B analysis spreadsheet, and backwater analysis.
- Provided a link to a new “Hydraulic Analysis Workbook”. Workbook includes a Qfp calculator and Level B data entry worksheet that can be submitted to WDFW.
- Corrected and elaborated upon circumstances where a Level B analysis is appropriate.
- Described in greater detail where to measure elevations at the downstream control and how to measure the downstream channel slope.
- Added instructions for measuring channel substrate at the downstream control.
- Removed ordinary high water measurements on the east side of the cascades, and removed the average channel substrate segment.
- Added instructions for measuring instantaneous flow rates when Level A or Level B analysis does not apply.
- Updated the Level A field form with fields for presence of rack and determination of tidal influence.
- Updated the Level B field form with fields for substrate at downstream control and distance between water surface elevations; removed field for substrate downstream of control.

Chapter 4: Non-Culvert Crossings

- Created a separate chapter for non-culvert crossings.
- Provided additional guidance on distinguishing non-culvert crossings from culvert crossings or miscellaneous obstructions, including highlighting the requisite that crossings must be motorized.
- Included a suggestion that the channel bankfull width and bridge span should be collected, when feasible.
- Updated the field form with fields for bankfull width and span.
- Indicated that flow meters may be used, under certain circumstances, to determine whether a non-culvert crossing creates a barrier condition.
- Provided more detailed definitions of fords and puncheon/fill crossings.
- Clarified which non-culvert crossing information is considered relevant, and when it should be collected.

Chapter 5: Dams

- Stated that the definition of dams, as used in this manual, is not a legal definition. It is not intended to supplement or supersede the Washington State Department of Ecology definition.

- Clarified the difference between a vertical standpipe functioning as a dam, and a vertical stormwater input functions as a culvert.
- Provided detailed descriptions for each field on the Dam field form.
- Provided clarification on how to define the “outlet type”.
- Provided instructions on measuring dam length.
- Provided guidance on how to assess dams that do not have an outflow.
- Provided guidance on assessing the barrier status of dams with attached trash racks.
- Adjusted the wording to allow measurements of water surface difference at standpipes.
- Referred to Chapter 3 for assessing gated culverts instead of simply classifying gates as barriers based on whether they are flap or self-regulating.

Chapter 6: Miscellaneous Obstructions

- Removed some Miscellaneous Obstruction types which are no long assessed from the field form.
- Provided written definitions of miscellaneous obstruction types and included pictures for each obstruction classification.
- Provided guidance on assessing the barrier status of obstructions with attached racks.

Chapter 7: Natural Barriers

- Clarified when a natural gradient should be considered a barrier.
- Provided additional guidance for determining the barrier status of waterfalls, incorporating launching and landing conditions, seasonal flow variation, and the potential for fish to circumnavigate the worst barrier conditions using step pools or alternate channels.
- Included directions for assessing chutes and cascades for barrier status, considering leap angle, horizontal and vertical leaping abilities of specific salmonid species, turbulence, and depth.
- Provided instruction for assessing ‘partial’ natural barriers.
- Added ‘cascade’ to the field form as a barrier type, and removed ‘subsurface flow’.

Chapter 8: Fishways

- Redefined fishways to better match the definition in the Washington Administrative Code.
- Clarified the purpose and intent of fishways, and how that influences barrier determinations.
- Clarified how to assess the barrier status of sites with attached fishways.
- Provided instructions on what to do when there are obvious maintenance issues with a fishway, and how to assign a barrier status.
- Included a disclaimer about fishway passability determinations, which continues to be based primarily on hydraulic drops and the leaping ability of a 6” trout during fish passage flows – a 100% passability value should be viewed with uncertainty as it does not necessarily indicate full passage for all species and life stages.

- Provided definitions of each fishway type, described the typical flow regimes, and described how they should be assessed for passability.
- Provided guidance on assessing the barrier status of streambed control fishways, allowing for Level A and Level B barrier determinations when appropriate.
- Removed the Fishway Inspection section from the chapter. Inventory and assessment crews are not expected to perform fishway inspections. A separate fishway inspection protocol is in development.

Chapter 9: Surface Water Diversions

- This chapter was significantly rewritten to better describe the data collection expected of inventory crews.
- Removed the instructions for reading staff gages and calculating diversion flow amounts. Diversion flow amounts require a greater level of analysis than is expected of inventory crews, and crews should not disturb diversion equipment in order to measure flows.
- Because the mesh size measurements require special instruments, and may necessitate moving the diversion equipment, mesh sizes are no longer measured by the inventory crew.
- Re-categorized the screen types and eliminated the need to record the pump screen shape.
- Clarified how to treat informal or home-made screens.
- Removed instructions for determining screen compliance. Determining screen compliance requires far greater analysis than is expected of inventory crews.
- Updated the field form to include determination of presence of active cleaning system.

Chapter 10: Habitat Assessment

- Removed the instructions for how to perform the Full Survey (FS). If Full Survey guidance is needed, refer to the 2009 Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual.
- Updated the instructions for contacting landowners given newer technologies.
- Provided instructions for performing the downstream fish access check, detailing which data should be collected.
- Provided additional instruction on where to break reach, and how to name tributaries and reaches.
- Changed substrate composition “rubble” to “cobble”.
- Changed “canopy cover” to “thermal cover”.
- Provided more quantitative methods for assigning a rearing habitat HQM, as well as representative photographs.
- Provided additional instruction for recording limiting factors.
- Provided more quantitative methods for determining the spring factor, and included representative photographs.
- Updated the section on upstream comments and photographs. Described specific information that is expected in the upstream comments.
- Provided guidance on documenting landowner denials.
- Changed the habitat gain criteria for resident-only fish.

Chapter 11: Habitat Assessment Data Entry

- Created a separate chapter for habitat data entry, and updated the “Physical Habitat Survey” Excel workbook.
- Provided more detailed step-by-step instruction for entering and interpreting habitat data.
- Provided formatting suggestions for the upstream and downstream comments.
- Removed the “Habitat Survey Summary” section, and replaced it with the “Additional Barriers” section, providing guidance on how to fill out the Additional Barriers spreadsheet in order to calculate PI numbers.
- Provided a link to the updated Additional Barriers spreadsheet.

Chapter 12: Prioritization

- Updated the Species Condition Modifier and Cost Modifier instructions for the PI, and the Species Condition Modifier for the SPI.

Appendices

- Moved ‘Summary of Significant Updates’ to Appendix B; this was provided in Chapter 1 of the 2009 version of this manual.
- Created new guidance for measuring bankfull width (Appendix G). New guidance derived from WDFW bankfull width estimation procedures: Atha and Wilhere (2015) and Barnard et al. (2013).
- Created new guidance for estimating fish passage flows (Appendix C).
- Created new guidance for photographing fish passage features (Appendix F).
- Created new guidance for instantaneous flow rate measurements (Appendix J). For suspected velocity barriers that cannot be assessed using the Level B hydraulic analysis, this appendix describes how to measure cross-sectional mean velocity, the applicability, and how to interpret the results.
- Removed WAC that was provided in appendix of 2009 version.
- Removed Level B spreadsheet instructions and precipitation map that were provided in appendices of 2009 version. These are now provided within the Hydraulic Analysis Workbook, with link in Chapter 3.
- Removed screening requirements that were provided in appendix of 2009 version. These requirements are outside of the scope of this manual.

APPENDIX C

Estimating Fish Passage Flows

Barrier determination is based on the ability of salmonids to migrate through, around, or over an instream feature. For an instream feature to be considered a non-barrier, it should not obstruct upstream migration at any time between the low and high fish passage flows (Q_{fp}) at the location:

- Low fish passage flow is the 95% exceedance flow.
- High fish passage flow is the 10% exceedance flow.

Calculating High Fish Passage Flow (Q_{fp} High)

Stream gauge recordings at a water crossing are the preferred method for estimating high fish passage flows. When stream gauge data is missing, calculate high fish passage flow using regional regression equations. The regional regression analysis includes a series of variables, which effect the high fish passage flows. The variables are described below, and can be entered into the Q_{fp} Calculator tab in the Hydraulic Analysis Spreadsheet, which is available on the Fish Passage web site.

Region

The Fish-Passage Design Flows for Ungauged Catchments in Washington (Powers and Saunders 2002) includes regression equations for calculating 10-percent exceedance flows in three regions of Western Washington (Figure 1): Coastal Lowland region (Region 1), Puget Sound region (Region 2), and Lower Columbia region (Region 3). Each region has a regional constant and regional coefficient values that are included in the regional regression equation. The regional constants and coefficients are also partially dependent on the *month* when high fish passage flows occur. When entering data into the Q_{fp} calculator the regional constant and coefficients are automatically entered when you select the region.

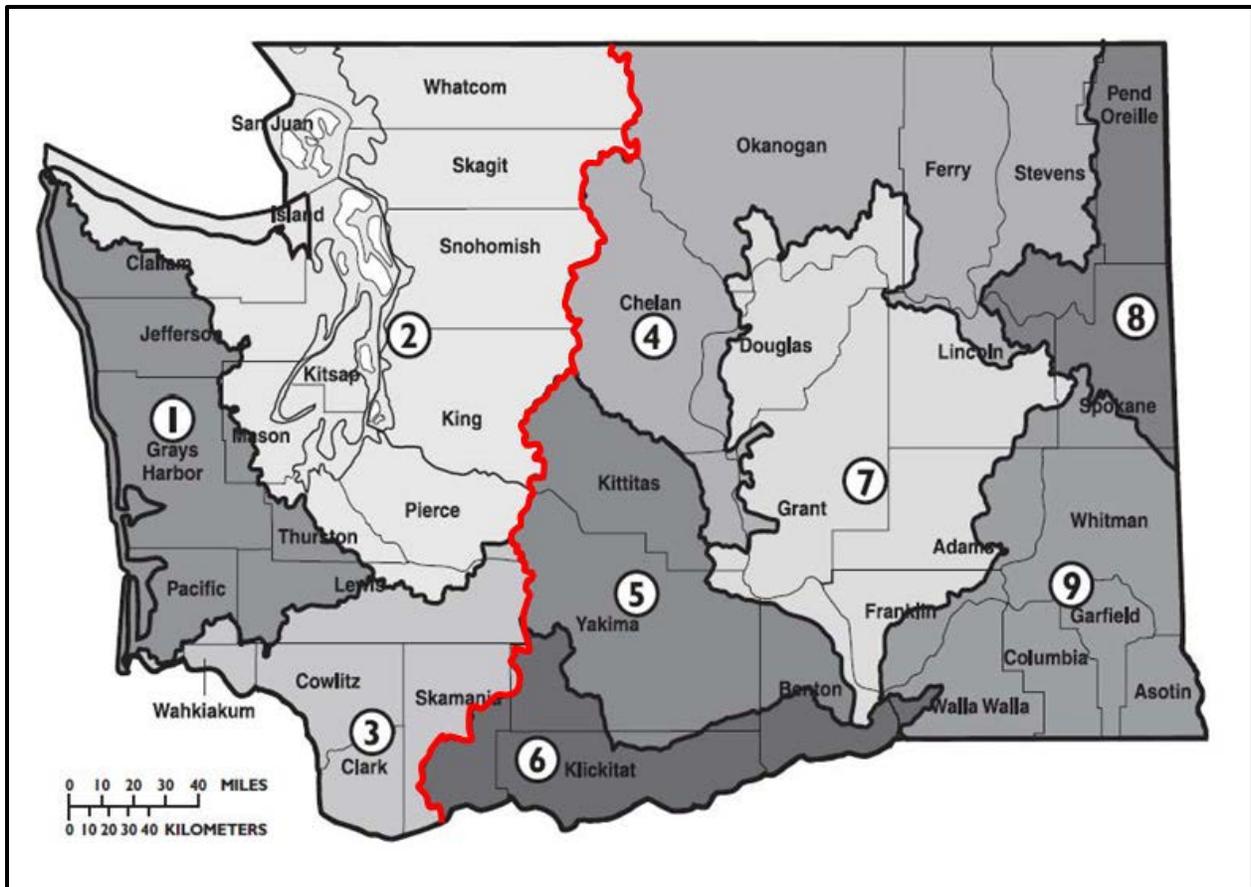


Figure 1. Regions in Washington State used in regional regression equations (USGS 1996). Regression equations used by the WDFW fish passage division to calculate high fish passage flows in regions 1-3.

Elevation

The original regression equations developed by Powers and Saunders (2002) included an elevation variable. Subsequently they advised that the elevation values should not be used. If you are using a high fish passage calculator that includes the elevation measurement, we recommend entering a value less than 1000 ft.

Drainage Area

The area of the upstream drainage basin influences high fish passage flows. Drainage basins can be measured using a combination of USGS topographical maps, digital elevation maps, aerial imagery, web-applications, etc. Measure and record the drainage basin area in square miles.

Precipitation

Precipitation measurements are dependent upon the drainage basin region. In Regions 2 and 3 record the mean annual precipitation, in inches. In Region 1 precipitation “intensity” is measured

as the two-year, 24-hour precipitation, in inches. Using mapping resources, web-applications, etc., record the precipitation for the drainage basin in question.

Impervious Surface

Impervious surface variables were also included in the original high fish passage flow regression equations to gauge urbanization. Subsequent guidance has also recommended that impervious surface estimates should not be used when calculating high fish passage flows. If you are using a high fish passage calculator that includes the impervious surface measurements, we recommend entering a value less than 20%.

References

Powers, P.D., and Saunders, C.S. 2002. Fish-Passage Design Flows for Ungauged Catchments in Washington. Lands and Restoration Services Program. Environmental Engineering Services.

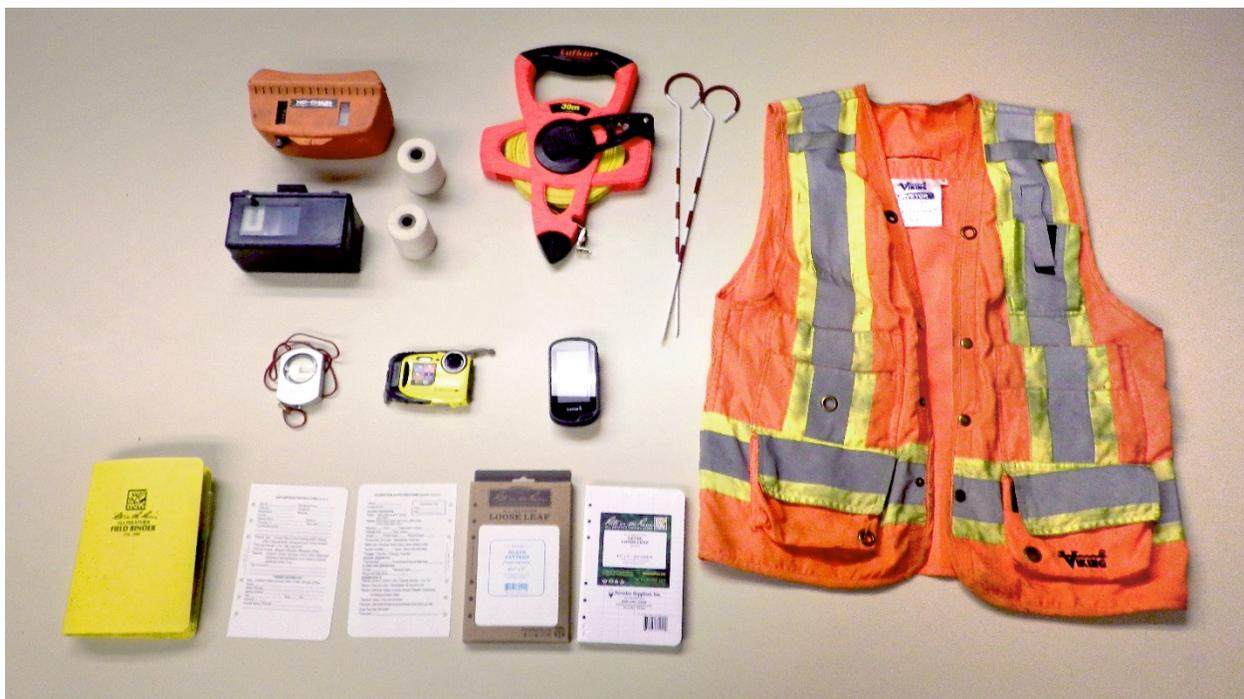
APPENDIX D

Recommended Survey Equipment

Washington Department of Fish and Wildlife recommends using the following standard equipment when performing fish passage barrier assessments, and physical habitat surveys.

Fish Passage Feature and Habitat Survey Equipment

- Site and Feature forms printed on *Rite in the Rain* paper
- *Rite in the Rain* notebook paper for taking field notes, especially for habitat surveys
- Field binder to hold forms
- Camera
- GPS Unit
- Clinometer – Used to measure gradient in habitat surveys.
- Hip chain box and string – Used to measure distances in habitat surveys.
- Surveyors tape (we use 30 m or 50 m) – Used to measure cross-section stations, and channel slope in a Level B barrier assessment, but can be used to measure the length of a culvert when a range finder is not available.
- Chaining pins – Used to anchor the ends of a cross-section in a Level B barrier assessment.
- Reflective safety vest – Barrier assessments are most often conducted where roads cross streams and natural drainages. Safety first!
- Waders & Hip boots – To stay dry, insulate from cold water, and allow access to pools and deeper streams.



Laser Surveying Equipment

- Stadia Rods – Stadia rods should be in metric units. They are used to measure the dimensions of a culvert, and for measuring lengths and slopes using laser rangefinders or laser levels.
- Tile, or “Gravel” Probe – Used to assess whether a culvert is countersunk or if there is a bottom to an in-stream feature. A probe may also be necessary to measure the elevation of an embedded culvert invert.
- Laser Rangefinder – Laser rangefinders are used to measure vertical and horizontal distances to calculate the relative elevations of a culvert inlet, outlet and streambed controls. A laser rangefinder is also used to measure the culvert length. When selecting a laser rangefinder choose an instrument that can measure horizontal and vertical distances. Horizontal distance should be measured to a minimum precision of 0.01 m. Vertical distance should be measured to a minimum precision of 0.01 m. Mount the laser rangefinder on a monopod with a bubble level to ensure that the instrument does not move during a culvert assessment.
- Rotary Laser Levels – Rotary laser levels measure vertical distances in order to calculate the relative elevations of a culvert inlet, outlet, and streambed control. A rotary laser level should be mounted on a tripod to ensure that the instrument does not move during a culvert assessment. A laser receiver is mounted at the end of stadia rod to measure the vertical distance from rotary laser.
- Reflective target – for use with laser rangefinders. Reflective targets may not be available to purchase, but they are easy to make. Mount a piece of adhesive-backed reflective tape (preferably yellow or red), onto a flat piece of solid material. We recommend plexi-glass cut into 2 inch by 8 inch rectangles. Mount the reflective tape on the plexi-glass and trim the excess. Then drill two holes in the middle of the reflector, approximately 1.5 inches apart horizontally. Thread an elastic cord through the holes, and attach a cord lock. We recommend making several reflectors, as they tend to escape.



Equipment for Conducting Culvert Evaluations (Level A and Level B assessments)		
Equipment	Used For	Approximate Cost
Stadia Rod (Metric; 7.1 m length)	Physical culvert measurements	\$200.00
Laser Rangefinder*	Determining culvert length and slope	\$1700.00
Rotary Laser Level	Measuring relative culvert and streambed elevations.	\$600.00
Monopod	Stabilizes laser rangefinder	\$55.00
Mounting Brackets	Connecting laser unit to monopod	\$180 - \$440
GPS Receiver	Determining features geographic location	Prices vary
Surveyors Tape (50 m)	Level B hydraulic analysis.	\$30.00
Chaining Pins (set of 11)	Level B hydraulic analysis	\$22.95 (set of 11)

Equipment for Conducting Culvert Evaluations (Level A and Level B assessments)		
Equipment	Used For	Approximate Cost
Retro-reflective safety vest	Improved safety	\$55.50
Water resistant camera (standard or digital)	Taking photos of barrier features (culverts, dams, fishways, other)	Varies
Two-way radios	Communication	\$50-\$100
Flashlight	Looking inside culverts	Varies
Tile Probe (gravel probe) 3/8" x 48"	Locating culvert bottom through bed material	\$42.00
Aluminum tree caliper or other caliper measuring tool	Measuring screen mesh diameter	\$32.00

*An optical auto-level or total station mounted to a tripod may also be used to conduct Level A and Level B culvert assessments. However, the auto-level and total station are more suitable for road-based inventories, as they are not as practical for conducting watershed based surveys where you carry equipment with you while walking the stream.

Equipment for Conducting Physical Habitat Surveys		
Equipment	Used For	Approximate Cost
Hip Chain box (metric)	Measuring Distance	\$140.00
Biodegradable string for hip chain	Used with hip chain box	\$10.00 per roll
Clinometer	Measuring stream gradients	\$140.00
Mercury-free Thermometer (Celsius)	Recording water temperature	\$10.00
Stadia Rod (Metric; 7.1 m length)	Measuring stream widths, depths, culvert dimensions, etc.	\$200.00
Write-In-The-Rain ring notebook	Note taking, field forms, etc.	\$12.45

Equipment for Conducting Physical Habitat Surveys		
Equipment	Used For	Approximate Cost
Rite in the Rain Loose Leaf Paper, No. 395 (blank)	Print Field Forms	\$13.95/100 sheets
Rite in the Rain Loose Leaf Paper, No. 312 (lined)	Note taking	\$13.95/100 sheets
Polarized sunglasses and/or safety glasses	Eye protection and to aid in stream observations	Varies
Hip boots or waders	Stream walking	\$50 and up
Orange surveyor's vest	For safety, visibility and carrying equipment	\$40-\$90
Leather gloves	Personal protection	Varies
Cell phone	Emergency communication	Varies

Recommended Software		
Mapping Software	Capabilities	Approximate Cost
ESRI ArcExplorer Software www.esri.com/software/arcexplorer/	Creating field and report maps, displaying feature data and other corporate data, and measuring lengths and areas.	Free
DeLorme Topo USA Mapping Software	Creating field maps, displaying feature data, measuring basin areas.	\$99.00
Terrain Navigator Pro 8.0/8.1 MapTech	Creating field and report maps, displaying feature data and other corporate data, and measuring lengths and areas.	\$300.00

Recommended Software		
Mapping Software	Capabilities	Approximate Cost
ArcView 9.2, ESRI	Creating field and report maps, displaying feature data and other corporate data, and measuring lengths and areas.	\$1500.00

Recommended Reading		
Books	Contents	Approximate Cost
<u>Field Identification of Coastal Juvenile Salmonids</u> , by W.R. Pollard et al, 1997, Harbour Publishing.	Field guide to identifying juvenile salmonids observed during field surveys.	\$13.00
<u>Inland Fishes of Washington</u> , 2 nd edition, by R.S. Wydoski and R.R. Whitney, 2003, University of Washington Press.	Field guide to inland fishes of Washington, including salmonids.	\$50.00 (hardcover)
<u>Aquatic Habitat Assessment: Common Methods</u> , Mark B. Bain and Nathalie J. Stevenson, editors, 1999, American Fisheries Society.	Assessing and describing regional setting, basin attributes, water body identification, stream reaches, macrohabitat, substrate, cover and refuge, bank condition, riparian vegetation, barriers, stream discharge and volume, water velocity, temperature, lake morphometry, and optical and chemical properties.	\$33.00
<u>Better Trout Habitat</u> , by Christopher J. Hunter, 1991.	Guide to stream restoration and management. Also, book has habitat requirements for salmonids.	\$30.00

APPENDIX E

Field Forms

SITE DESCRIPTION FIELD FORM (1/2/2018)

¹Site ID _____ ²Identifying Group _____

³Latitude _____ ⁴Longitude _____

⁵Road Name _____ ⁶Milepost _____

⁷County _____ ⁸WRIA # _____

⁹Stream Name _____ ¹⁰Tributary To _____

¹¹Location/Directions _____

¹²Feature Type Culvert Non-Culvert Crossing Dam
 Misc. Obstruction Natural Barrier Fishway Diversion

¹³Fish Use Potential Yes No Unknown

¹⁴Fish Use Criteria Biological Mapped Physical Other

¹⁵Species Chinook Chum Sockeye/Kokanee Coho Pink
 Steelhead Sea Run Cutthroat Bull/Dolly Varden Trout
 Resident Cutthroat/Rainbow Trout

¹⁶Site Comments _____

¹⁷OWNER INFORMATION

Type Federal State County City Tribal Private Other

Name _____

Street Address _____

Mailing Address _____

City _____ State _____

Zip Code _____ Phone (_____) _____ - _____

Contact Name _____

Contact Phone _____

SITE FORM INSTRUCTIONS

- 1) Database unique identifier
- 2) Organization responsible for data collection
- 3) Northerly geographic position of the feature expressed in decimal degrees (WGS 84)
- 4) Westerly geographic position of the feature expressed in decimal degrees (WGS 84)
- 5) Name of roadway (if any) associated with feature
- 6) Milepost (to nearest .01 mile) where feature is located, if applicable
- 7) County in which feature is located
- 8) Water Resource Inventory Area (WRIA) number
- 9) Name of stream where feature is located
- 10) Name of downstream waterbody to which stream is connected
- 11) Location of feature relative to landmarks or driving directions
- 12) Type of instream feature(s) encountered (may select more than one)
- 13) Indicate whether or not stream has potential to support fish life
- 14) Basis for potential fish use determination
- 15) Salmon and trout species that are either known or assumed to be present or historically present
- 16) Concise comments pertinent to operation or characteristics of site being evaluated
- 17) Information about owner of feature(s)

LEVEL A CULVERT ASSESSMENT FIELD FORM (5/22/2018)

¹Site ID _____

²Culvert Number _____

³Crew _____

⁴Date _____

CULVERT DESCRIPTION

⁵Material PCC CPC CST SST CAL SPS

SPA PVC TMB MRY OTH

⁶Span _____ ⁷Rise _____ ⁸Water Depth in Culvert _____

⁹Shape RND BOX ARCH SQSH ELL OTH

¹⁰WS Drop _____ ¹¹Drop Location Outlet Inlet Interior

¹²Apron None US DS Both ¹³Total Length _____

¹⁴Culvert Slope _____ ¹⁵Road Fill Depth _____

¹⁶Countersunk Yes No ¹⁷Backwatered Yes No Unk

¹⁸Gate Yes No ¹⁹Rack Yes No ²⁰Fishway Yes No

CHANNEL DESCRIPTION

²¹Bankfull Width _____ ²²Span/Bankfull Width _____

²³Tidal Influence Yes No Unk

PLUNGE POOL DESCRIPTION

²⁴Pool Length _____ ²⁵Pool Maximum Depth _____

²⁶Pool Scour Line Width _____

BARRIER STATUS

²⁷Barrier Yes No Unk

²⁸Method LA LB Fishway Other

²⁹% Passability 0 33 67 100 Unk

³⁰Significant Reach Yes No Unk

³¹Comments _____

LEVEL A FORM INSTRUCTIONS

- 1) Database unique identifier
- 2) Culvert Number: if 1 culvert at site then 1.1, if 2 then 1.2 or 2.2, etc.
- 3) Last name(s) of field review team responsible for data
- 4) Field review date: MM/DD/YYYY format
- 5) Construction material of culvert: PCC = pre-cast concrete, CPC = cast-in-place concrete, CST = corrugated steel, SST = smooth steel, CAL = corrugated aluminum, SPS = structural plate steel, SPA = structural plate aluminum, PVC = plastic, TMB = timber, MRY = masonry, OTH = other
- 6) Width of culvert to nearest 0.01 meter
- 7) Height of culvert to nearest 0.01 meter
- 8) Water depth in culvert to nearest 0.01 meter
- 9) Cross-sectional shape of culvert: RND = round, BOX = square or rectangular, ARCH = bottomless, SQSH = squash (pipe arch), ELL = elliptical, OTH = other
- 10) The difference between any abrupt change in water surface elevation at the inlet, outlet or anywhere within culvert
- 11) Location of hydraulic drop
- 12) Presence and location of apron(s), if any
- 13) Length of culvert to nearest 0.1 meter
- 14) Slope of culvert reported as a percentage. May be positive or negative
- 15) Estimated height of road fill to nearest 1 meter
- 16) Indicates whether culvert outlet invert is embedded at least 20% of culvert rise and streambed material is present throughout entire length of culvert
- 17) Indicates whether there is little to no visible flow throughout entire length of culvert, or the average velocity through culvert is visibly slower than the average velocity in the adjacent channel
- 18) Indicates whether there is a gate associated with culvert
- 19) Indicates whether there is a rack associated with culvert
- 20) Indicates whether there is a fishway associated with culvert
- 21) Width of bank measured where water begins to overflow into floodplain
- 22) Width of culvert divided by bankfull width
- 23) Indicates whether tidal conditions affect culvert hydraulics at any time during fish passage flows
- 24) Length of plunge pool measured from culvert outlet to downstream control
- 25) Maximum depth of plunge pool
- 26) Maximum width of plunge pool measured at scour line
- 27) Barrier status
- 28) Assessment method used to determine barrier status
- 29) Estimated percent passability
- 30) Indicates whether there is 200 linear meters of potential fish habitat upstream and downstream of culvert
- 31) Concise comments pertinent to culvert and an explanation for any attribute where 'Other' is selected

LEVEL B HYDRAULIC ANALYSIS FIELD FORM (3/18/2019)

¹Site ID _____

²Culvert Number _____

⁵Datum Elevation _____

⁶Datum Location _____

³ Crew _____
⁴ Date _____

⁷CULVERT MEASUREMENTS

	IH	RH	VD +/-	ELEV
Upstream Invert				
Upstream Culvert Bed				
Downstream Invert				
Downstream Culvert Bed				

IH = Instrument Height; RH = Rod Height; VD = Vertical Distance (for equipment that measures incline); ELEV = Elevation (relative to Datum Elevation). Formulas on reverse side.

⁸Culvert Roughness concrete smooth paved invert
 corrugation: 0.5" x 2.67" 1" x 3" 2" x 6" other _____

⁹Sediment Through Length of Pipe? yes no unknown

¹⁰DOWNSTREAM CONTROL CROSS-SECTION

	STA	IH	RH	VD +/-	ELEV	DEP	WSE	SUB
Top LB	0.00							
Toe LB								
Bed 1								
Bed 2								
Bed 3								
Toe RB								
Top RB								

¹⁰Avg. WSE _____

STA = Station; DEP = Water Depth; WSE = Water Surface Elevation; SUB = Dominant Substrate (F = Fines, C = Gravels/Cobbles/Bedrock, B = Boulders, W = Wood)

	IH	RH	VD +/-	WSE
¹² Water Surface Downstream of X-Section;				

¹³Distance from X-section _____

LEVEL B FORMULAS

Formulas for Determining Instrument Height (IH)

For survey equipment that measures incline:

if VD is positive: $IH = \text{Datum Elevation} + RH - VD$

if VD is negative: $IH = \text{Datum Elevation} + RH + |VD|$

*** | | Denotes absolute value

For Auto Level: $IH = \text{Datum Elevation} + RH$

Formulas for Calculating Elevations

For survey equipment that measures incline:

if VD is positive: $ELEV = IH - (RH - VD)$

*** Do math in parentheses first

if VD is negative: $ELEV = IH - RH - |VD|$

*** | | Denotes absolute value

For Auto Level: $ELEV = IH - RH$

LEVEL B FORM INSTRUCTIONS

- 1) Database unique identifier
- 2) Culvert Number: if 1 culvert at: 1.1; if 2 then 1.2 or 2.2, etc.
- 3) Last name(s) of field review team responsible for data
- 4) Field review date: MM/DD/YYYY format
- 5) Elevation assigned to datum
- 6) Location of datum
- 7) Data used to calculate relative elevations at culvert inlet and outlet
- 8) Corrugation dimensions in inches, measured valley to peak x peak to peak. If the corrugations at the culvert invert are completely covered with asphalt or concrete, select 'paved invert'.
- 9) Does bed material cover the low-flow channel throughout the entire length of the culvert (i.e., no missing substrate or exposed corrugation)?
- 10) The downstream control is usually the head of the first riffle downstream of the culvert. Start at the top of the left bank (facing downstream) and measure 7 elevations to the top of the right bank (measure to the nearest 0.01 meters) to describe the cross sectional profile of the stream. The station is the distance read from measuring tape from the top of left bank to top of right bank.
- 11) Average of the Water Surface Elevations calculated at only those points in the downstream control that have a water depth recorded in the DEP column.
- 12) Water surface elevation downstream of the control to the nearest 0.01 meter
- 13) Distance downstream of the control that the water surface elevation was measured.

NON-CULVERT CROSSING EVALUATION FORM (07/6/2017)

¹Site ID _____

⁴Crossing Type

- Bridge Ford
- Fill / Puncheon Abandoned
- Washout Undefined

² Crew _____
³ Date _____

⁵Bankfull Width _____ ⁶Span _____

⁷Fishway Attached Yes No

⁸Barrier Yes No Unk

⁹Barrier Criteria WS Drop Slope Depth Debris
 Failed Other Unspecified Tidegate

¹⁰%Passability 0 33 67 100 Unk

¹¹Significant Reach Yes No Unk

¹²Description _____

¹³Comments _____

NON-CULVERT CROSSING FORM INSTRUCTIONS

- 1) Database unique identifier.
- 2) Last name(s) of the field review team responsible for the data.
- 3) Field review date: MM/DD/YYYY format.
- 4) Type of non-culvert crossing feature being assessed.
- 5) Width of bank measured where water begins to overflow into floodplain
- 6) Width of bridge interior to nearest 0.01 meter
- 7) Indicates where there is a fishway associated with the barrier.
- 8) Barrier status of the feature.
- 9) Assessment method used to determine barrier status.
- 10) Estimated percent passability.
- 11) Indicates whether there is 200 linear meters of potential fish habitat upstream and downstream of the obstruction.
- 12) Concise description of the feature. Include any additional relevant measurements, such as span, length, water depth, etc.
- 13) Additional comments regarding the feature, including observations that may be relevant to making a barrier status determination.

DAM EVALUATION FORM (07/10/2017)

¹Site ID _____

⁴Dam Name _____

⁵Reservoir Name _____

²Crew _____

³Date _____

⁶Material Type CN EF MS

MT RF TB OT

⁷Primary Purpose FldCtrl Debris Elec Irr Nav Oth

StockPd WQual Rec WSup Tail FshProp WildHab

⁸Outlet Type Spillway Standpipe Flashboard Riser Culvert

⁹Span Full Partial

¹⁰Operation Timing Year-round Seasonal

¹¹Length _____ ¹²Height _____

¹³Water Surface Difference _____ ¹⁴Plunge Pool Depth _____

¹⁵Fishway Yes No ¹⁶Gate Yes No

¹⁷Barrier Yes No Unk

¹⁸Barrier Criteria WS Drop Depth Other

¹⁹%Passability 0 33 67 100 Unk

²⁰Significant Reach Yes No Unk

²¹Description _____

²²Comments _____

DAM EVALUATION FORM INSTRUCTIONS

- 1) Database unique identifier.
- 2) Last name(s) of the field review team responsible for the data.
- 3) Field review date: MM/DD/YYYY format.
- 4) Legal or local name of the dam.
- 5) Legal or local name of the reservoir.
- 6) Type of dam, referring to the material from which the dam is constructed:
CN – Concrete, **EF** – Earth Fill, **MS** - Masonry, **MT** - Metal, **RF** - Rock Fill, **TB** - Timber, **OT** - Other.
- 7) The purpose of the dam: **FldCtrl** – Flood Control, **Debris**-Debris Control, **Elec** - Hydroelectric, **Irr** - Irrigation, **Nav**- Navigation, **Oth** - Other, **StockPd**- Stock or Farm Pond, **WQual**- Water Quality, **Rec**- Recreation, **WSup** - Water Supply, **Tail**- Tailings, **FshProp**- Fish Propagation, **WildHab**- Wildlife Habitat.
- 8) Describes the outlet control structure|at the dam. Is there a **Spillway**, **Standpipe**, **Flashboard Riser**, or **Culvert** attached at the outlet?
- 9) Does the dam completely or partially span the stream channel?
- 10) Is the dam in operation year-round or just seasonally?
- 11) Length of the dam. Record to the nearest 0.1 meters.
- 12) The height of the dam from the front base to the crest. Record to the nearest 0.01 meters.
- 13) If water is flowing over the crest of the dam, give the difference between the water surface elevations above and below the dam. Record to the nearest 0.01 meters.
- 14) Maximum depth of the plunge pool. Record to the nearest 0.01 meters.
- 15) Is there a fishway present?
- 16) Is a floodgate present?
- 17) Barrier status of the feature.
- 18) Assessment method used to determine barrier status.
- 19) Estimated percent passability.
- 20) Indicate whether there is 200 linear meters of potential fish habitat upstream and downstream of the dam.
- 21) Concise description of the feature.
- 22) Additional comments regarding the dam, including observation that may be relevant to making a barrier status determination.

MISCELLANEOUS OBSTRUCTION EVALUATION FORM (05/24/2018)

¹Site ID _____

⁴Type

- Artificial Waterfall
- Dike/Levee
- Erosion Control
- Fill/Debris
- Flume
- Hatchery Rack
- Lake Screen
- Pipeline
- Roughened Channel
- Streambed Control
- Other Miscellaneous Obstruction

²Crew _____

³Date _____

⁵Fishway Yes No

⁶Barrier Yes No Unk

⁷Barrier Criteria WS Drop Slope Velocity Depth

Debris Rack Failed Other N/A

⁸% Passability 0 33 67 100 Unk

⁹Significant Reach Yes No Unk

¹⁰Description _____

¹¹Comments _____

MISCELLANEOUS OBSTRUCTION FORM INSTRUCTIONS

- 1) Database unique identifier.
- 2) Last name(s) of the field review team responsible for the data.
- 3) Field review date: MM/DD/YYYY format.
- 4) Type of feature being assessed.
- 5) Indicates whether there is a fishway associated with the barrier.
- 6) Barrier status of the feature.
- 7) Assessment method used to determine barrier status.
- 8) Estimated percent passability.
- 9) Indicates whether there is 200 linear meters of potential fish habitat upstream and downstream of the obstruction.
- 10) Concise description of the barrier feature. Include any additional measurements
- 11) Additional comments regarding the feature, including observations that may be relevant to making a barrier status determination.

NATURAL BARRIER EVALUATION FORM (7/20/2017)

¹Site ID _____

²Site Name _____

³Crew _____

⁴Date _____

⁵Barrier Type Gradient

Waterfall

Cascade

GRADIENT

⁶Length _____ ⁷Slope (%) _____

WATERFALL

⁸Water Surface Drop _____ ⁹Plunge Pool Depth _____

CASCADE

¹⁰Horizontal Length _____ ¹¹Slope (%) _____

¹²Vertical Height _____ ¹³Base Pool Depth _____

BARRIER STATUS

¹⁴Fishway Present Yes No

¹⁵Blockage Total Partial Unknown

¹⁶Description _____

NATURAL BARRIER FORM INSTRUCTIONS

- 1) Database unique identifier.
- 2) If one exists, record the common or popular name of the site.
- 3) Last name(s) of the field review team responsible for the data.
- 4) Field review date: MM/DD/YYYY format.
- 5) Type of natural barrier present.
- 6) **For Gradient Barriers:** Length of stream segment exceeding a 20% gradient. Record to the nearest meter.
- 7) **For Gradient Barriers:** The water surface slope of the barrier stream segment. Report as a percentage.
- 8) **For Waterfall Barriers:** The water surface drop height used to determine the barrier status. Record any additional, smaller drops in the comments. Record to the nearest 0.01 meter.
- 9) **For Waterfall Barriers:** The maximum depth of the pool at the base of the waterfall. Record to the nearest 0.01 meter.
- 10) **For Cascade Barriers:** The horizontal distance between the launching point and landing point. Record to the nearest 0.1 meter.
- 11) **For Cascade Barriers:** The water surface slope of the cascade. Record to the nearest 0.5%.
- 12) **For Cascade Barriers:** The vertical distance between the launching point and landing point. Record values to the nearest 0.1 meter.
- 13) **For Cascade Barriers:** The maximum depth of the pool at the base of the cascade (if present). Record to the nearest 0.01 meter.
- 14) Indicates whether there is a fishway associated with the barrier.
- 15) Specifies whether the barrier is a total barrier, partial barrier, or unknown.
- 16) Concise description of the barrier feature. Include additional measurements of observations that may be relevant to making a barrier status determination.

FISHWAY EVALUATION FORM (04/11/2017)

¹Site ID _____

⁴Construction Year _____

²Crew _____

⁵Attached To _____

³Date _____

Culvert Non-Culvert Crossing

Dam Other Natural

⁶Type BC BF WP PC VS SP

SBC RCC BL TH Unk

BAFFLED CULVERTS AND FLUMES

⁷Number of Baffles _____

⁸Baffle Type WD CC MTL RC PVC Other

WEIR POOL, VERTICAL SLOT, POOL CHUTE, STEEPPASS

⁹Number of Pools _____ ¹⁰Entrance Pool Depth _____

¹¹Number of Weirs _____

¹²Weir Type WD CC MTL RC PVC Other

STREAMBED CONTROLS

¹³Control Type CC SCC RC GC LC PLC

¹⁴Number of Controls _____

¹⁵Control Location Upstream Downstream Both Ends

BARRIER STATUS

¹⁶Maximum Water Surface Drop _____

¹⁷Barrier Yes No Unk

¹⁸Barrier Criteria WS Drop Debris Other

¹⁹% Passability 0 33 67 100 Unk

²⁰Description _____

_____ *Cont. on reverse*

²¹Comments _____

FISHWAY FORM INSTRUCTIONS

- 1) Database unique identifier.
- 2) Last name(s) of the field review team responsible for the data.
- 3) Field review date: MM/DD/YYYY format.
- 4) Construction year.
- 5) The type of feature that the fishway is attached to in order to modify fish passage.
- 6) Fishway Type: **BC** – Baffled Culvert, **BF** – Baffled Flume, **WP** – Weir Pool, **PC** – Pool Chute, **VS** – Vertical Slot, **SP** – Steeppass, **SBC** – Streambed Control, **RCC** – Roughened Channel, **BL** – Blasted Falls, **TH** – Trap-and-Haul, **Unk** – Unknown. **Select all that apply.**
- 7) Number of baffles.
- 8) Material from which the baffles are constructed: **WD** – Wood, **CC** – Concrete, **MTL** – Metal, **RC** – Rock, **PVC** – Plastic, **Other**
- 9) Number of pools. Include the most downstream pool below the last downstream control. i.e., the fishway entrance pool.
- 10) Depth of the fishway entrance pool. Record to the nearest 0.01 m.
- 11) Number of weirs present in the fishway.
- 12) Material from which the weirs are constructed: **WD** – Wood, **CC** – Concrete, **MTL** – Metal, **RC** – Rock, **PVC** – Plastic, **Other**
- 13) Control Type: **CC** – Concrete, **SCC** – Saccrete, **RC** – Rock, **GC** – Gabion, **LC** – Log, **PLC** – Plank. **Select all that apply.**
- 14) Number of streambed controls.
- 15) Location of the streambed controls relative to the associated feature.
- 16) Maximum fishway water surface drop, including all fishway components present at the site. Record to the nearest 0.01 m.
- 17) Barrier status of the feature.
- 18) Assessment method used to determine barrier status.
- 19) Estimated percent passability.
- 20) Concise description of the fishway. Include any additional measurements.
- 21) Additional comments regarding the fishway conditions, including relevant contextual observations.

SURFACE WATER DIVERSION EVALUATION FORM (5/10/2017)

¹Site ID _____

²Crew _____

⁴Diversion Type Gravity Pump

³Date _____

⁵Point of Diversion LB RB

⁶Headgate Yes No

⁷Diversion Dam Yes No

⁸Intake Location BA OS OC

⁹Fish Bypass Yes No

¹⁰Bypass Condition _____

¹¹Diversion Amount _____ (gpm or cfs – circle one)

¹²Water Right Number _____ ¹³Power Meter Number _____

¹⁴Fish Screen Yes No Unknown

¹⁵Screen Type TBS RDS VPS IPS HPS IG PMP OT

¹⁶Active Cleaning Yes No Unknown

¹⁷Screen Material PP PB WM PM OT

¹⁸Screen Height _____ ¹⁹Screen Width _____

²⁰Screen Diameter _____

²¹Screen Condition OK MN Unknown

²²Screen Under Operation Yes No Unknown

²³Problems/Comments _____

SURFACE WATER DIVERSION DATA FORM INSTRUCTIONS

- 1) Database unique identifier.
- 2) Last name(s) of the field review team responsible for the data.
- 3) Field review date: MM/DD/YYYY format.
- 4) Indicate the type of water surface diversion: **Gravity or Pump**
- 5) Indicate whether a headgate is present: **Yes or No**
- 6) The location of the point of diversion: **LB = Left Bank, RB = Right Bank**
- 7) Indicate whether an instream diversion dam is present: **Yes or No**. If "Yes", complete a dam feature form.
- 8) Location of the diversion intake: **BA = Riverbank (or streambank), OS = Offshore (inward of the banks), OC = Off-Channel**.
- 9) Indicates whether a fish bypass is present: **Yes, No, or Unknown**
- 10) Indicate whether the fish bypass is operational. Comment on the condition.
- 11) Volume of water diverted in gallons per minute or cubic feet per second.
- 12) Numbers associated with the water right permit(s) or certificate(s). Obtained from the Washington Department of Ecology.
- 13) Number issued to the power meter servicing the diversion.
- 14) Indicates the presence of a fish screening device: **Yes, No, or Unknown**.
- 15) Screen types: **TBS = Traveling Belt Screen, RDS = Rotary Drum Screen, VPS = Vertical Plate Screen, IPS = Inclined Plate Screen, HPS = Horizontal Plate Screen, IG = Infiltration Galleries, PMP = Pump Screen, OT = Other**
- 16) Presence of an automated debris removal system: **Yes, No, or Unknown**
- 17) Material the screen is constructed of: **PP = Perforated Plate, PB = Profile Bar, WM = Woven Wire Mesh, PM = Plastic Mesh, OT = Other**
- 18) Height of screen. Record to the nearest 0.01 m.
- 19) Width of screen. Record to the nearest 0.01 m.
- 20) Diameter of cylindrical screens. Record to the nearest 0.01 m.
- 21) Condition: **OK = Screen is Clean and Intact, MN = Maintenance Needed**
- 22) Indicate if the intake is actively diverting water at the time of assessment.
- 23) Concise description. Include observations of problems encountered at the diversion.

HABITAT FORM INSTRUCTIONS

- 1) Should be the same as the target barrier ID.
- 2) Date of survey.
- 3) Last names of field crew conducting the survey.
- 4) Name of stream being surveyed.
- 5) Name of stream at first named confluence.
- 6) Watershed Resource Inventory Area (WRIA) number.
- 7) Location of the beginning of the reach.
- 8) Lat/Long coordinates, or waypoint name at the beginning of the reach.
- 9) Label for reach being sampled. See naming conventions in manual. (e.g. 'TC1 R1')
- 10) Hip chain reading at the beginning of the reach in meters.
- 11) Hip chain reading at the end of the reach in meters.
- 14) Characterize the amount of instream cover as: **Low, Medium, or High.**
- 15) Visually estimate percent of shaded stream. Note dominant species.
- 16) Temperature in degrees Celsius.
- 17) Habitat Quality Modifier assigned to spawning habitat for the reach:
Good = 1, Fair = 0.67, Poor = 0.33, Very poor with no habitat value = 0.
- 18) Habitat Quality Modifier assigned to rearing habitat for the reach:
Good = 1, Fair = 0.67, Poor = 0.33, Very poor with no habitat value = 0.
- 19) If a habitat quality modifier of less than 1 was assigned, provide a short explanation.
- 20) A visual estimate of juvenile abundance: **Low, Medium, or High.**
- 21) Estimate of the spring contribution to the flow of the stream:
Absent - 0, Slight - 1, Moderate - 2, Pronounced - 3.
- 22) Sum the total length of all culverts in the reach in meters.
- 23) List all features in the reach that contribute to the total culverted length.

Chain Reading: Distance on hip chain at beginning of a habitat type in meters.

Habitat Type: Pool = Pl, Riffle = Rf, Rapid = Rp, Pond = Pd.

Length: Length of the habitat type in meters.

Wetted Width: The wetted width of the habitat type in meters.

Scour Width: The width at the scour line in meters.

Depth: Average depth of the habitat type in meters.

Gradient: Percent gradient measurements within the 60 m sample. Collect at least one measurement. Record anywhere within the gradient column.

% Boulder/Cobble/Gravel/Fines: Visual estimate of the percent composition of each substrate category in each habitat type. Must sum up to 100%. (e.g., 15/35/40/10).

APPENDIX F

Photography Tips

Feature and Site Photographs

A picture is worth a thousand words. In many cases, the inventory crew are the only eyes on a site until plans for correction are initiated. Various entities rely on the data collected and entered into the Fish Passage Diversion, Screening, & Inventory (FPDSI) database and the pictures provided with that data are vital to our interpretation and understanding of feature data.

When conducting a barrier assessment of a feature, the two most useful photos are of the outlet and inlet perspective. The following are some formatting guidelines for photographs:

- Photograph the outlet facing upstream
- Photograph the inlet facing downstream
- Stand back from the feature to capture road fill and road surface (if possible)
- Capture the immediate land-use context
- Include the stadia rod for scale
- The aspect ratio of the photographs should be 4:3

Additional site and feature photos are encouraged to capture noteworthy and unique conditions. Examples of these include:

- Physical characteristics of the feature beyond outlet and inlet, such as internal baffles
- Streambed control and fishway features such as baffles.
- Maintenance issues with the feature (e.g., rusted out invert, failing culvert, internal conditions, grade breaks, separating segments, exposed rebar, etc.).
- Site conditions that threaten the function of the feature such as undercutting of feature or roadway, failing road grade, debris accumulation or blockage, etc.
- Land-use that may affect the structure or function of feature.

The following are things to avoid or correct when photographing a feature:

- Close ups of the feature (inlet or outlet), unless the purpose of the picture is to document the condition of the feature (rusted out invert, failing culvert, internal conditions, grade breaks, separating segments, exposed rebar, etc.)
- Clear vegetation that is blocking the view of the feature.
- Rotate images to the correct landscape aspect.
- Keep your fingers out of the frame.
- Avoid sunspots, reflective surfaces, and lens flares. Use a flash to illuminate the structure when necessary.
- Keep landowners and non-staff out of the photos, as these are posted on the internet.

Note: storage space is cheap. Take many pictures of the structure or notable conditions. Images can be sorted in the office.

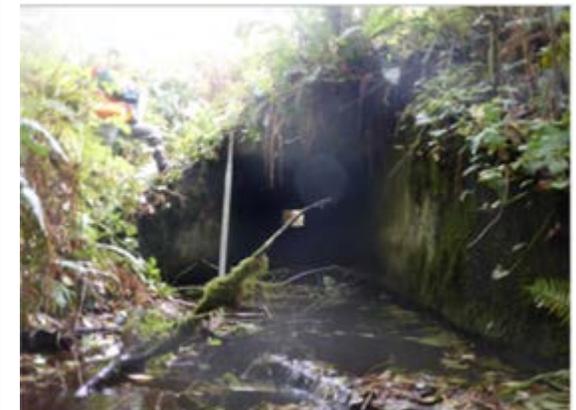
<p>Needs Improvement: Rotate the photo and remove the vegetation at the outlet.</p> 	<p>Preferred</p> 
<p>Needs Improvement: Photograph from the channel facing the culvert inlet or outlet. Avoid fingers in the frame.</p> 	<p>Preferred</p> 
<p>Needs Improvement: Use the camera flash to illuminate the baffles. Avoid lens flares.</p> 	<p>Preferred</p> 

Figure 1. The pictures above illustrated preferred and less desirable photographs of the same site.

APPENDIX G

Measuring Bankfull Width

This appendix provides a method for measuring bankfull width (BFW) when performing fish passage inventories and assessments. Bankfull width is the preferred channel measurement when assessing the barrier status of human-made crossings.

Note: The instructions detailed below are only for the purpose of Level A assessments and periodic BFW measurements as part of a habitat survey. The instructions should not be used in water crossing design or compliance evaluations. For more detailed instructions for measuring bankfull width, or identifying potential bankfull indicators consult the following: “Bankfull width estimation procedure for culvert design and monitoring,” (Atha and Wilhere, 2016), the Water Crossing Design Guidelines (WDFW 2013), TFW Monitoring Program: Method Manual for the Reference Point Survey (Pleus and Hames, 1998).

Bankfull Channel

Bankfull channel is defined as “the stage when water just begins to overflow into the active floodplain” (Water Crossing Design Guidelines, WDFW 2013). On average, bankfull discharges occur every 1.2 to 1.5 years in natural systems in Western Washington. The semi-annual discharges create a distinct active channel with a topographic break as the margin of the bankfull channel meets the floodplain, and a change in vegetation as bankfull discharges wash away perennial vegetation and organic matter.

Many channels in Washington are incised or modified, which makes it difficult to identify the margins of the bankfull channel using only floodplain indicators. The following indicators may also be used to identify the margins of a bankfull channel:

Vegetation – The bankfull channel is often bare of vegetation, or is dominated by aquatic, semi-aquatic, or annual vegetation. Look for the lower limit of perennial vegetation, such as ferns or moss to identify the edges of the bankfull channel. Transitions between soft stemmed and woody stemmed vegetation can also be a good indicator.

Soil – Look at the transition of soil material and particle size as you move up the bank (gravel/cobble to sands/fines). Look for organic material in the soil. Decaying vegetation that has not been washed out of place in 1-2 years is one indicator that you are no longer within the bankfull channel.

Stains/Lichens – Look for stains on boulders which indicate semi-annual high flows, and the lowest line of lichens or moss.

Deposition – Look for depositions of material at the inside of meanders, especially at the top of a point bar. The deposited material indicates the top of the bankfull channel.

Where to Measure Bankfull Width

Bankfull width measurements should be representative of the 1.2 – 1.5 year discharges which shape the bankfull channel. Measure bankfull widths at straight segments of the channel. Avoid stream segments whose margins have been constrained or expanded by impermeable features,

sharp bends, active bank erosion, braids/side channels, beaver ponds, or wetlands. Measure outside of the influence of any human-made features, and between any upstream or downstream tributaries (so as only to account for the discharge which passes through your culvert, bridge, etc.).

Measuring Bankfull Width

Once you have identified the margins of a bankfull channel in a representative segment of stream, take several measurements of the bankfull width. Measure bankfull width horizontally across the bankfull channel and perpendicular to the thalweg. Take several measurements of the bankfull width, both upstream and downstream of the feature, and average the values.

If bankfull indicators are apparent on one bank, but not the other, stretch the stadia rod or surveyor's tape from the lowest bankfull indicator on one bank, horizontally into the other bank (Figure 1). This often happens when one bank is steeply incised, and the other has an apparent floodplain.

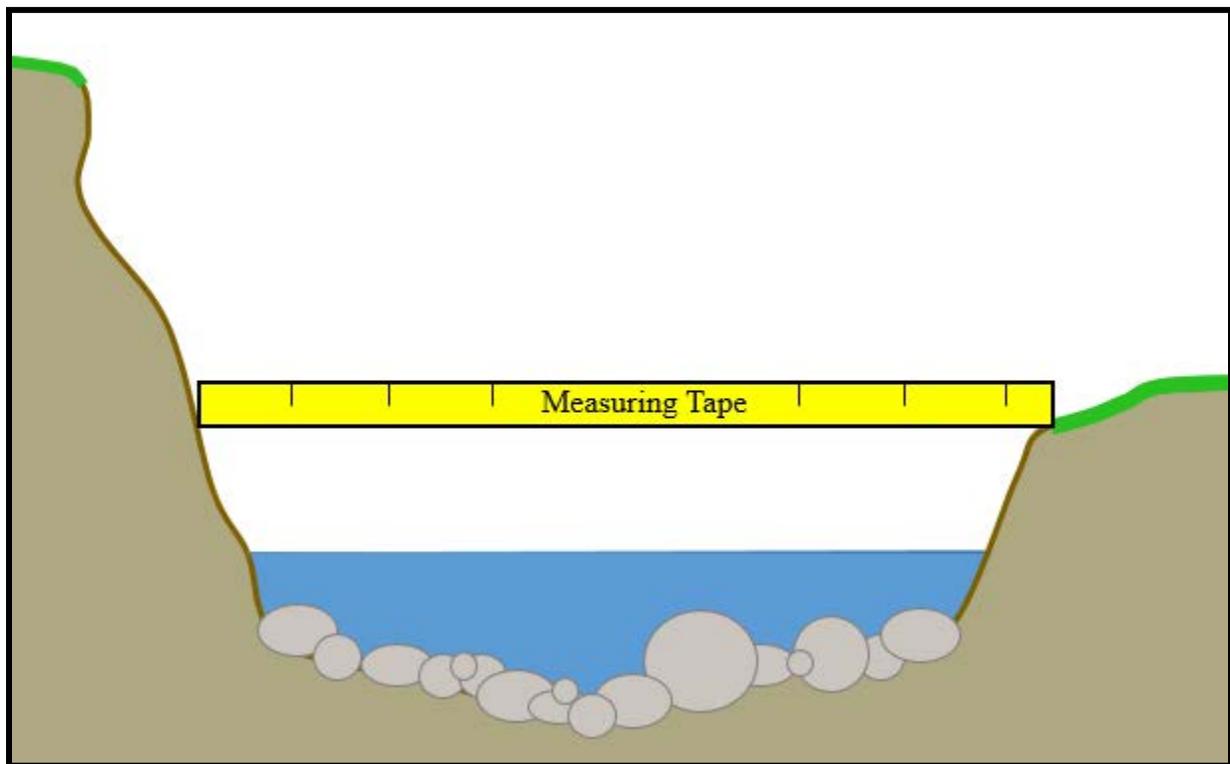


Fig. 1. Bankfull width measurements on an asymmetrical cross-section. Bankfull width is measured horizontally from the lowest bankfull indicator.

References

Atha, J.B., and G.F. Wilhere. 2016. Bankfull width estimation procedure for culvert design and monitoring. Habitat Program, Washington Department of Fish and Wildlife, Olympia, WA.

Barnard, R.J., J. Johnson, P. Brooks, K.M. Bates, B. Heiner, J.P. Klavas, P.C. Ponder, P.D. Smith, and P.D. Powers. 2013. Water Crossing Design Guidelines. Habitat Program, Washington Department of Fish and Wildlife, Olympia, WA.

Pleus, A.E., and D. Schuett-Hames. 1998. TFW Monitoring Program: Method Manual for the Reference Point Survey. Prepared for the Washington State Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-98-002. DNR #104. May.

APPENDIX H

Basic Surveying Techniques (Laser Rangefinders and Rotary Laser Levels)

Overview

To measure the slope of culverts we adapted a surveying process called “Differential Leveling”; we use the same language, but the methods vary slightly from the standard. Differential Leveling is the process of measuring relative elevations at various points.

For most of the surveying we perform (such as a Level A), the relative elevation is the vertical distance (VD) between a point, and the height of a surveying instrument (IH). Vertical distances may be measured with either laser rangefinders or rotary laser levels. Horizontal distances (HD) between points are used to calculate lengths. Horizontal distances can be measured using laser rangefinders or surveyor’s tape. The slope is then calculated as the difference in relative elevations between two points, divided by the horizontal distance between the two points (difference in relative elevations / length). For more complex surveying (such as a Level B), we may also establish a temporary benchmark with an arbitrary elevation (See Chapter 3, and “Multiple-Shot Measurements” below).

Before using the laser rangefinder or rotary laser level to measure a culvert, familiarize yourself with the owner’s manual, and how the measurements are collected.

Measuring Culvert Length and Slope with a Laser Rangefinder

Equipment

- Laser rangefinder (minimum 0.01 m horizontal and vertical distance precision).
- Monopod with bubble level bracket
- Stadia rod (in meters)
- Reflector

Measurements

Laser rangefinders measure both vertical distances, and horizontal distances, making it possible to simultaneously measure the length of a culvert, and calculate the slope (Figure 1).

Mount the laser rangefinder on a monopod. Set up the laser directly over the culvert where visibility is good to both the inlet and outlet of the structure. Position the laser level in line with the culvert to get the most accurate length. Mark the location of the monopod foot in case it has to be moved or set-down for any reason.

Mount the reflector at the top of the stadia rod, making sure that it is tightly aligned with the top of the rod. Position the stadia rod at the outlet invert of the structure. By starting at the outlet invert, you are likely to have sufficient reflector height at the upstream end. Raise the rod until it is visible through the laser rangefinder scope. Extend the rod as little as possible to minimize error caused by the tilt of the rod. Extend the top section first if you have a meter rod that measures from the top down.

Level the laser rangefinder using the bubble level on the bracket. Take measurements from the top edge of the reflector. Record the horizontal distance (HD) and vertical distance (VD) for the shot. Make sure to record the number sign of the vertical distance measurements, e.g., -0.23 or +0.023. Repeat the shots at least two more times and record the values. The readings should all be within 0.05 meters of each other. If not, continue taking measurements until you have a group of three shots that are within 0.05 meters of each other. Record the height of the stadia rod (RH). Average the HD and VD of the three measurements.

Repeat the same process for the culvert inlet: collect at least three shots with HD and VD values within 0.05 meters, record the instrument height, and average the HD and VDs. Make sure not to move the laser rangefinder or adjust the instrument height between the measurements of both ends. Your measurements notes should look something like the example below:

	DS	$RH_1 = 2$	US	$RH_2 = 1.5$
	<u>HD₁ (m)</u>	<u>VD₁ (m)</u>	<u>HD₂ (m)</u>	<u>VD₂ (m)</u>
	5.60	-0.03	7.12	+0.05
	5.67	-0.08	7.15	+0.07
	5.63	-0.04	7.19	+0.06
	5.62	-0.01	7.14	+0.05
Average	5.62	-0.03	7.14	+0.06

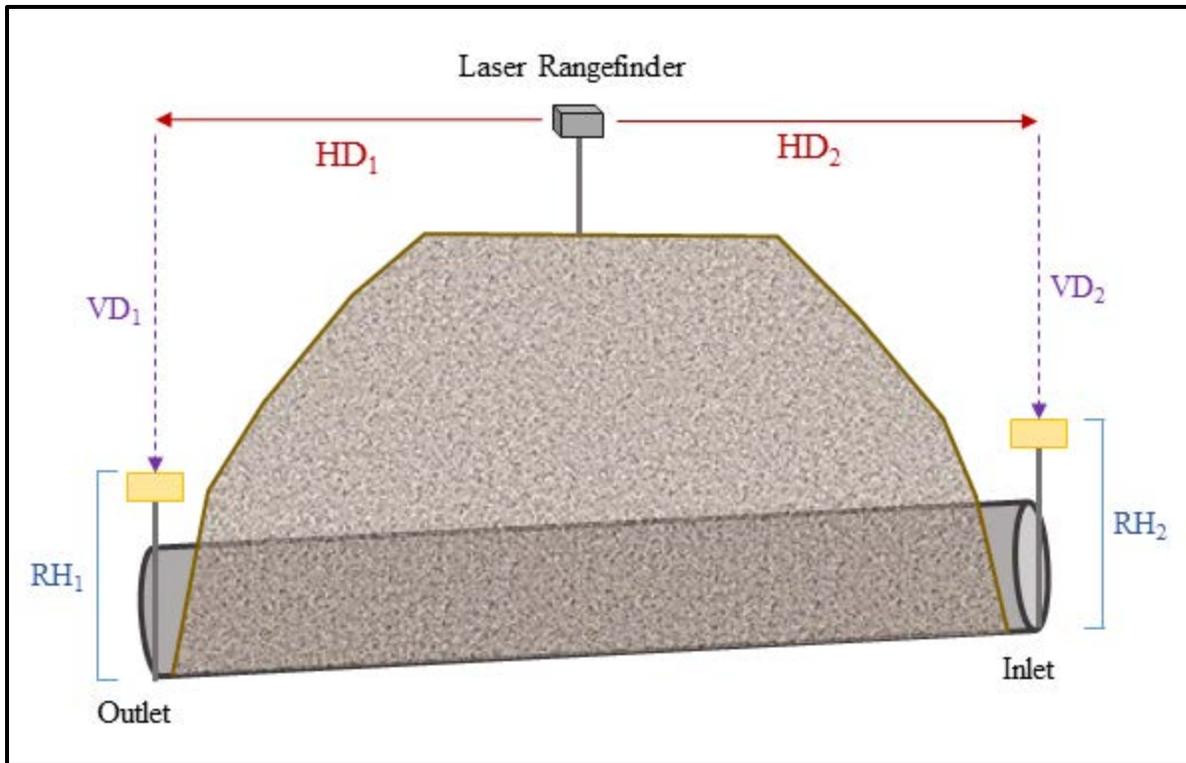


Fig. 1. Typical measurements and their abbreviations for measuring length and relative elevations with a laser rangefinder. HD = Horizontal Distance, VD = Vertical Distance, RH = Rod Height.

Calculations -

Length: To calculate the length of the culvert, add the averaged outlet and inlet HDs. This is the “run” value in the slope calculation.

Elevations: To calculate the difference in relative elevation between the inlet and outlet, subtract the rod height from the averaged VD at each end of the culvert – this should always result in a negative number if the laser rangefinder is set above the culvert invert. Subtract the relative elevation of the inlet from the relative elevation of the outlet. Remember to include the positive or negative number signs. If the difference in relative elevation is a positive value, the inlet is higher than the outlet. If the difference in relative elevation is a negative value, the outlet is higher than the inlet. This is the “rise” value in a slope calculation.

Slope: To calculate the slope, divide the rise by the run, i.e., divide the difference in relative elevation by the length of the culvert, and multiply the value by 100 to display the slope as a percentage. Remember to use your number signs!

$$\% \text{ Slope} = [(\text{USI Relative Elevation} - \text{DSI Relative Elevation}) / \text{Length}] * 100$$

The final slope calculations in the example above will look like this:

Length: $HD_1 + HD_2 = 5.62 + 7.14 = 12.76$ m (for record keeping we round this value to 12.8 m)

Downstream relative elevation: $VD_1 - RH_1 = -0.03 - 2 = -2.03$ m

Upstream relative elevation: $VD_2 - RH_2 = +0.06 - 1.5 = -1.44$ m

Difference in relative elevation: $-1.44 - (-2.03) = +0.59$ m

Slope: $(\text{Rise/Run}) * 100 = (+0.59 / 12.76) * 100 = +4.62\%$

Measuring Culvert Slope with a Rotary Laser Level

Equipment

- Laser rangefinder or surveyor's tape for length measurements
- Rotary Laser Level
- Laser Receiver
- Tripod
- Stadia rod that extends from the top (in meters)

Measurements

Rotary laser levels are a more accurate alternative for measuring vertical distances, i.e., relative elevations, at a fish passage feature (Figure 2). Unfortunately they cannot measure horizontal distances. When measuring and calculating the slope of the fish passage feature, the length will have to be measured using a laser rangefinder, or physically measured with a surveyor's tape.

Mount the rotary laser level on a tripod. Place the laser in a location with a clear view of both the inlet and outlet of the fish passage feature. Level the rotary laser: some rotary lasers are self-levelling, and others have to be levelled manually.

Mount the laser receiver at the top of a top extending stadia rod. Most receivers have arrows indicating where the laser receiver should align with the top of the stadia rod.

Rotary laser levels project a horizontal plane around the laser as it spins. This horizontal plane is called the "instrument height". The laser receiver that are included with the rotary lasers emit different tones based on whether the receiver is above or below the instrument's horizontal plane. Extend the rod, raising the top section first, until the receiver emits a solid tone. The solid tone indicates that the receiver is level with the instrument. Record the rod height measurement at the solid tone. The rod height measurement is the vertical distance between the instrument height, and the outlet invert. Rod height measurements are recorded as negative values, because they are below the instrument.

Repeat the same process at the inlet of the pipe, recording the rod height measurement at the solid tone. Your measurement notes will only include an RH value at the inlet and outlet.

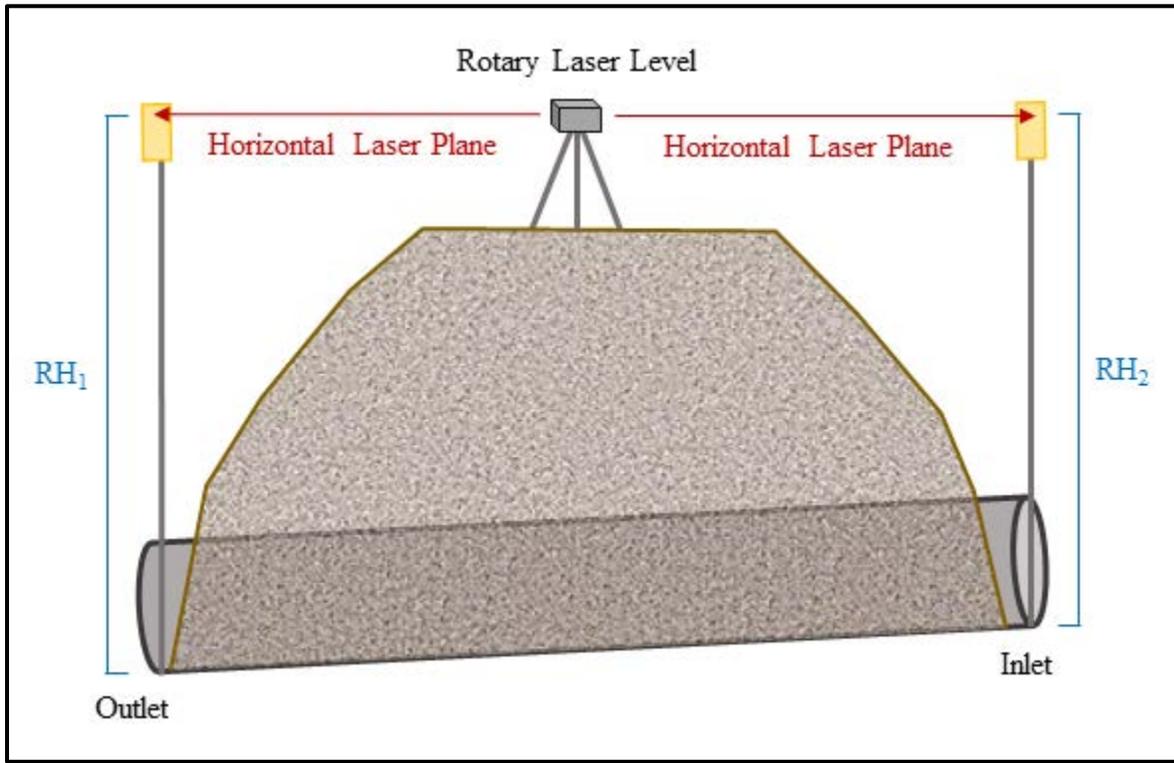


Fig. 2. Typical measurements and their abbreviations for measuring length and relative elevations with a rotary laser level. RH = Rod Height, which is equivalent to the vertical distance between the instrument height, and the culvert inlet or outlet invert.

Calculations

Length: Measure the length using a laser rangefinder or surveyor’s tape. When using a surveyor’s tape measure the length straight *through* the culvert. The length of the structure is the “run” in the slope calculation.

Elevations: To calculate the difference in relative elevations, subtract the relative elevation of the inlet from the relative elevation of the outlet. Remember to include the negative number signs. If the difference in relative elevation is a positive value, the inlet is higher than the outlet. If the difference in relative elevation is a negative value, the outlet is higher than the inlet. The difference in rod heights is the “rise” in the slope calculation.

Slope: To calculate the slope, divide the rise by the run, i.e., divide the difference in relative elevation by the length of the fish passage feature, and multiply the value by 100 to display the slope as a percentage. Remember to use your number signs!

$$\% \text{ Slope} = [(\text{USI Relative Elevation} - \text{DSI Relative Elevation}) / \text{Length}] * 100$$

Example: When surveying a culvert the length was directly measured as 10.23 m using a surveyor's tape. The rod height at the outlet of the culvert (RH₁) was -2.36. The rod height at the inlet of the culvert (RH₂) was -2.45.

Length: 10.23 m

Difference in relative elevation: $RH_2 - RH_1 = -2.45 - (-2.36) = -0.09$ m

Slope: $(\text{Rise/Run}) * 100 = (-0.09 / 10.23) * 100 = \mathbf{-0.88\%}$

The negative slope indicates that the inlet of the culvert was lower than the outlet.

Special Cases

There are a number of situations that complicate measuring horizontal or vertical distances directly from the invert of a structure using both laser rangefinders and rotary laser levels. The following examples provide some guidance on how to proceed when you encounter some of these special circumstances:

Bed Material

If a fish passage feature is filled with bed material, use a gravel probe to find the invert of the structure. Once the gravel probe is in contact with the structure invert, balance the stadia rod on top of the probe to obtain the HD and VD measurements. Remember to add the height of the gravel probe to the rod height whenever it is used.

If the bed material of a structure is too deep to reach the invert with a gravel probe, it is permissible to measure the length and slope from the soffit of the structure. It is not the preferred method though. If the length and slope are measured from the soffit, make a note in the feature comments.

Aprons or Beveled Ends

If a fish passage feature has an apron or is beveled at the inlet or outlet, the HD and VD measurements are collected at the furthest downstream and upstream ends of the structure invert (Figure 3). In other words, when measuring the length and slope of a structure, we are specifically looking for the length and slope of the structure's invert.

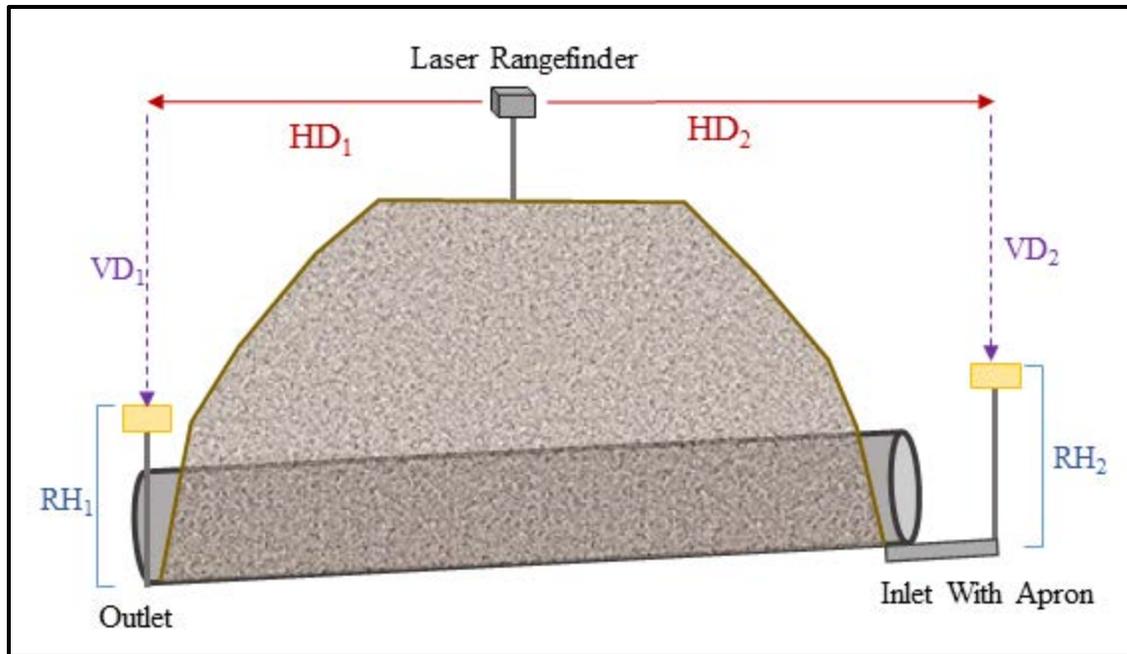


Fig. 3. Length and relative elevation measurements on a culvert with an apron. Notice that the reflector is held at the farthest upstream (or downstream) end of the structure. RH = Rod Height, VD = Vertical Distance, HD = Horizontal Distance.

Bottomless

When a structure is bottomless, such as in the case of arch culverts, measure the slope of the structure from the thalweg at the outlet and inlet of the pipe. Slope should not be measured from the top. With bottomless culverts it is more informative to know what streambed gradient conditions the fish encounters when moving upstream through the structure.

Level B

Level B measurements are described in detail in Chapter 3.

Multiple-Shot Length and Slope Measurements

When deep fill, obstructions to the line-of-sight, or very long fish passage features make it impossible to measure length and slope with just two shots, it will be necessary to employ turning points. This allows us to move the instrument one or more times to measure the relative difference in elevations between the inlet and outlet. With multiple shots, it is necessary to think in terms of instruments heights and turning point elevations. It is possible to perform multiple-shot measurements with either a laser rangefinder or a rotary laser level. Both devices require slightly different measurements. Regardless of equipment a typical multiple-shot measurement involves the following steps:

- Starting at either end of a fish passage feature, assign an arbitrary benchmark (BM) elevation. Typically we assign an elevation of 100 m to the inlet invert.
- Calculate the first instrument height (IH₁) based on vertical distance measurements to the BM and the BM elevation.
- Designate a turning point (TP), and calculate the elevation based on the IH₁ elevation and the vertical distance measurements to the TP.
- Move the instrument to a point where you can see the turning point and the opposite end of the fish passage feature (or to the next turning point, if your measurements will require multiple turning points). Calculate the second instrument height (IH₂) based on the elevation of the TP, and vertical distance measurements to the TP.
- Calculate the outlet invert elevation based on the IH₂ elevation, and vertical distance measurements to the outlet invert.
- Calculate the length of the fish passage feature by summing HD values with a laser rangefinder, or directly measuring the feature with a surveyor's tape.
- Subtract the outlet elevation from the inlet elevation: **Inlet Elevation – Outlet Elevation = Elevation Difference**
- If the difference in elevations is a positive value, the inlet is higher than the outlet. If the difference in elevations is a negative value, the outlet is higher than the inlet.
- Calculate the slope: **% Slope = [(USI Elevation – DSI Elevation) / Length] * 100**

Multiple-Shot Measurements with a Laser Rangefinder

When using a laser rangefinder to perform multiple-shot measurements, it is necessary to employ a four-shot method (Figure 4).

The standard equations when doing multiple-shot measurements with a laser rangefinder are as follows:

When Calculating an Instrument Height (IH) (aka “back-sight”):

$$\text{IH} = \text{Benchmark (BM)/ Turning Point (TP) Elevation} + \text{Rod Height (RH)} - \text{Vertical Distance (VD)} = \text{BM/TP} + \text{RH} - \text{VD}$$

When Calculating a Turning Point (TP) or Structural Elevation (aka “fore-sight”):

$$\text{Elevation} = \text{IH} - (\text{RH} - \text{VD})$$

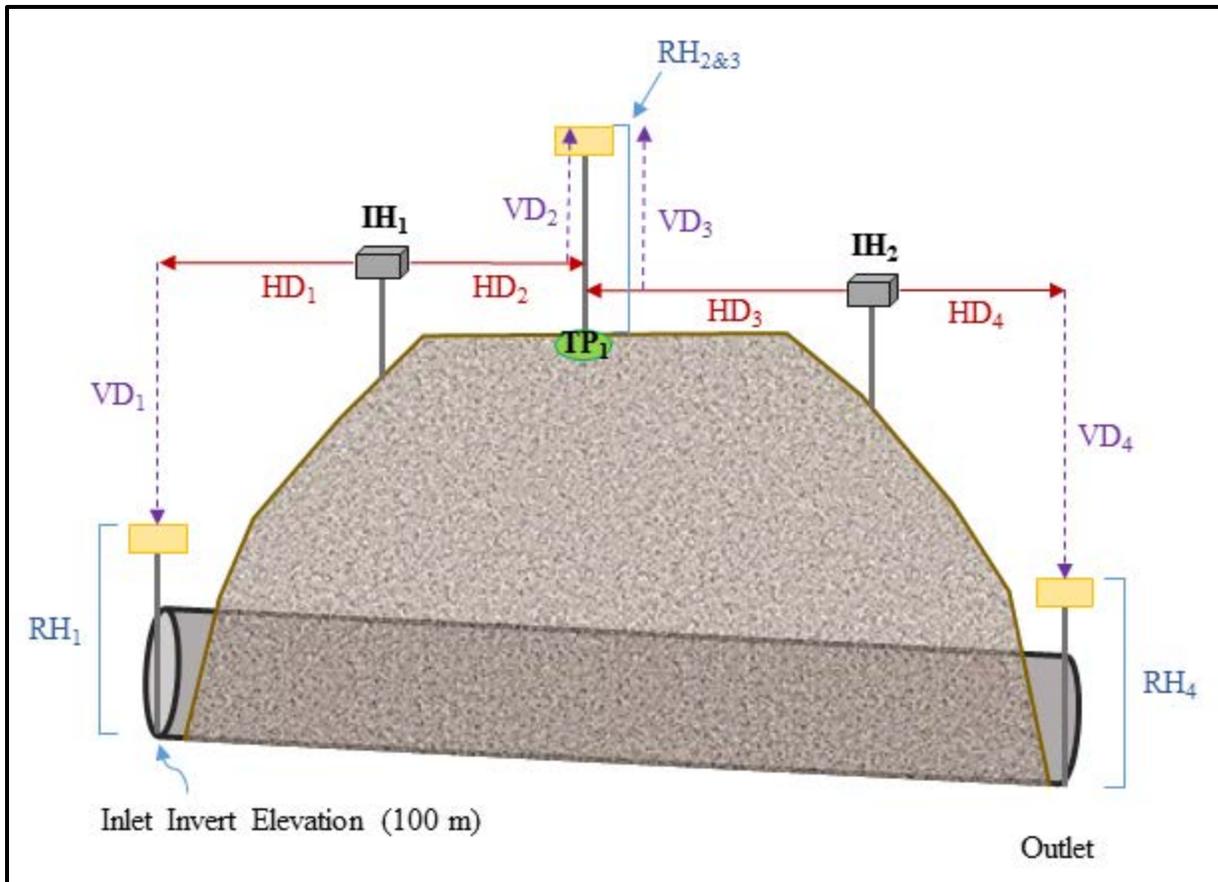


Fig. 4. Multiple-shot length and elevation measurements with a laser rangefinder.

Measurements taken using a four-shot method. RH = Rod Height, VD = Vertical Distance, HD = Horizontal Distance, IH = Instrument Height, TP = Turning Point. In this illustrated example, the rod height at the turning point did not change.

When taking multiple-shot length and elevation measurements we typically start at the upstream end of the culvert. An arbitrary benchmark elevation (BM) of 100 m is assigned to the upstream invert. Set up the laser where you can see the stadia rod at the upstream inlet. Position the laser in line with the culvert to get the most accurate length. Mark the location of the monopod foot in case it has to be moved or set-down for any reason.

Collect the first horizontal distance (HD₁), rod height (RH₁) and vertical distance measurement (VD₁) using the same three-shot average method as described in the laser rangefinder section above. Calculate the height of the instrument using the following formula (remember number signs!):

$$\mathbf{IH_1 = BM + RH_1 - VD_1}$$

For example: If the BM elevation is 100 m, the RH₁ is 2 m, and the VD₁ measurement is +0.5, the first instrument height is:

$$\mathbf{IH_1 = 100 + 2 - (+0.5) = 101.5}$$

Maintain the instrument height at IH_1 until you have calculated the elevation of the turning point.

When designating a turning point, select something solid and conspicuous to measure from. The turning point elevation should not change while you are collecting measurements, i.e., don't designate something soft and squishy as the as your turning point (No jellyfish!).

Collect the horizontal distance (HD_2), rod height (RH_2) and vertical distance (VD_2) measurements to the turning point. If you anticipate that the rod height will change between the first and second instrument heights, then collect the rod height measurement as well. Otherwise, we recommend maintaining the same rod height for all of the turning point elevation measurements. Calculate the elevation of the turning point (TP) at the base of the rod.

$$\text{TP Elevation} = IH_1 - (RH_2 - VD_2)$$

Without moving the turning point, relocate the laser to a position where you have an unobstructed view of the turning point, and the outlet of the fish passage feature. Position the laser in line with the culvert. Shoot back to the turning point, measuring the horizontal distance (HD_3), rod height (RH_3), and vertical distance (VD_3) to the turning point elevation. Calculate the second instrument height (IH_2).

$$IH_2 = \text{Turning Point Elevation} + RH_3 - VD_3$$

Pivot the instrument without changing the elevation and measure the horizontal distance (HD_4), rod height (RH_4) and vertical distance (VD_4) to the fish passage feature outlet invert. Calculate the elevation of the outlet invert.

$$\text{Outlet Invert Elevation} = IH_2 - (RH_4 - VD_4)$$

Sum HD_1 through HD_4 to calculate the total length of the fish passage feature. Subtract the outlet invert elevation from the inlet invert elevation (100 m) to get the elevation difference between the inlet and outlet. Calculate the slope of the feature:

$$\% \text{ Slope} = [(USI \text{ Elevation} - DSI \text{ Elevation}) / \text{Length}] * 100$$

If more shots are needed, it's possible to add more turning points and instrument heights following the same calculations as above (e.g. $TP_2 \text{ Elevation} = IH_2 - (RH_4 - VD_4)$; $IH_3 = TP_2 \text{ Elevation} + RH_5 - VD_5$, etc.).

Multiple-Shot Measurements with a Rotary Laser Level

The rotary laser level is a more accurate alternative to measuring vertical distances with a laser rangefinder. Rotary laser levels typically have a greater range when measuring long structures, and the measurements are less prone to error when multiple turning points are required. They are also useful when having to circumnavigate an obstruction to measure the relative elevations of a site. Because the rotary laser levels do not measure horizontal distances it is necessary to measure the length of the culvert using either a laser rangefinder or surveyor's tape.

When placing the rotary laser instrument, always position it above the any fish passage elevations or turning points you wish to measure. Because the rotary laser only projects a

horizontal plane, it is not possible to measure elevations above the instrument. Typically multiple shot measurements using a rotary laser level require more than one turning point. The example below illustrates a two turning point scenario (Figure 5).

The standard equations when using a rotary laser level to measure elevations are as follows:

IH Elevation (aka “back-sight”) = BM/TP + RH

TP or Structural Elevations (aka “fore-sight”) = IH - RH

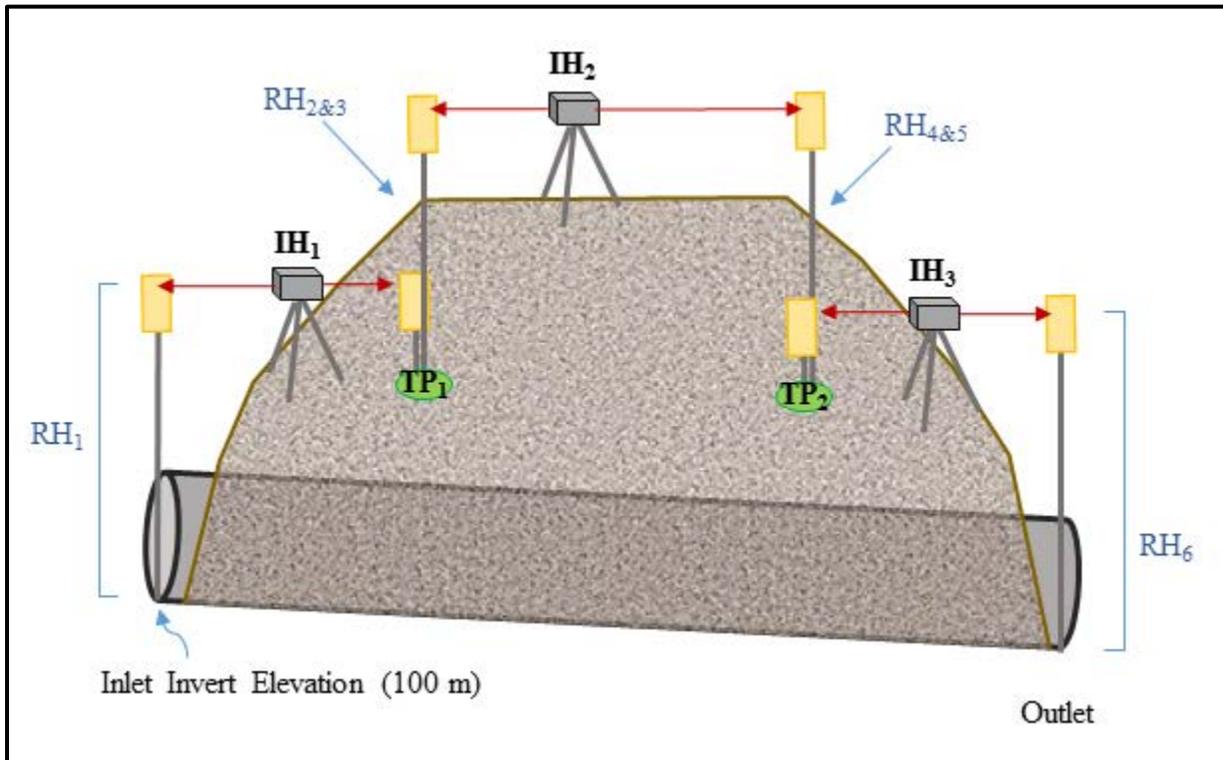


Fig. 5. Multiple-shot elevation measurements with a rotary laser level. Measurements were taken using two turning points. RH = Rod Height, IH = Instrument Height, TP = Turning Point. Notice that the instrument is always higher than the elevations of adjoining inverts or turning points.

When taking multiple-shot length and elevation measurements we typically start at the upstream end of the culvert. An arbitrary benchmark (BM) elevation of 100 m is assigned to the upstream invert. Mount the laser on a tripod, level it, and set it above the fish passage structure invert, in a location where you can see the stadia rod at the upstream inlet.

Calculate the instrument height (IH1) by measuring the rod height (RH1) to the inlet invert (BM).

$$IH_1 = BM + RH_1$$

Moving toward the outlet of the fish passage feature, designate a solid and conspicuous turning point (TP₁). Measure the rod height (RH₂) between IH₁ and TP₁. Calculate the elevation of TP₁.

$$\mathbf{TP_1 \text{ Elevation} = IH_1 - RH_2}$$

Without moving the stadia rod from the turning point, move the instrument to the location where you want your second instrument height. Measure the rod height (RH₃) between the instrument (IH₂) and the turning point (TP₁). Calculate the elevation of the instrument.

$$\mathbf{IH_2 = TP_1 + RH_3}$$

Moving further toward the outlet of the fish passage feature, designate a solid and conspicuous second turning point (TP₂). Measure the rod height (RH₄) between IH₂ and TP₂. Calculate the elevation of TP₂.

$$\mathbf{TP_2 \text{ Elevation} = IH_2 - RH_4}$$

Without moving the stadia rod from the turning point, move the instrument to the location where you can measure the RH to the outlet of the fish passage feature. Measure the rod height (RH₅) between the instrument (IH₃) and the turning point (TP₂). Calculate the elevation of the instrument.

$$\mathbf{IH_3 = TP_2 + RH_5}$$

Now measure the rod height (RH₆) between IH₃ and the outlet invert of the fish passage feature.

$$\mathbf{Outlet \text{ Invert Elevation} = IH_3 - RH_6}$$

Subtract the outlet invert elevation from the inlet invert elevation (100 m) to get the elevation difference between the inlet and outlet. Calculate the slope of the feature based on the length measured with a laser rangefinder or surveyor's tape.

$$\mathbf{\% \text{ Slope} = [(USI \text{ Elevation} - DSI \text{ Elevation}) / \text{Length}] * 100}$$

If more shots are needed, it's possible to add more turning points and instrument heights following the same calculations as above (e.g. TP₃ Elevation = IH₃ - RH₇; IH₄ = TP₃ + RH₈, etc.)

APPENDIX I

Physical Habitat Survey Data Entry Spreadsheet Input, Output, Fish Access Comments, and
Upstream Comments with Sample Data

Input Pages

WDFW - Habitat Program PHYSICAL HABITAT SURVEY - INPUT FILE (Ver.5)	
Survey ID:	ExampleID
Date:	8/8/2016
Observer(s):	Adams; Jefferson
Stream Name:	Example Cr
Tributary To:	Lake Imagination
WRIA #:	8.0166
Survey Extent:	US of site 881881 to end of fish use.
Filename:	881881.xls

REACH #1 FIELD DATA	
REACH #1	Begin(m): 0 End(m): 369 Reach Length(m): 369
Habitat Quality Modifier	Position: US of site 881881
Spawning: 0.33	Instream Cover: Medium
Rearing: 0.67	Thermal Cover: 85%, Big-leaf Maple and Sword Fern
T (C):	Juvenile Abundance: Low
	Limiting Factors: Embedded fines in spawning gravel, highway stormwater runoff
	Culvert Site IDs: 881882
	Total Culverted Length: 5.5 m Est. Drainage Area: 2.31 mi ²

Species Expected to Benefit (x=Yes, blank = No)									
Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull	
	x		x	x		x	x		

Spring influences are (see below): <i>(absent-0, slight-1, mod.-2, pronounced-3)</i> 1.) relatively regular, rectangular cross-section, minor variations in depth 2.) Poorly defined bars and thalweg / very low, flat floodplain 3.) bank vegetation along a distinct line, at a small distance <i>above the H2O surface; moss on exposed surfaces of rocks</i>	1	Reg. Constant (for 60-d low flow calc.): <i>Olympic/Coastal = 0.49</i> <i>Cascade/E. Puget = 1.04</i> <i>Columbia/E. WA=0.12</i> <i>Northern/NE Mts.=0.097</i>	1.04
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REACH #1 HABITAT MEASUREMENT										
TYPE	L	W	SLW	D	GRAD	B	C	G	F	
RF	17.8	1.48	1.82	0.06	0.02	0	0	30	70	
PL	3.1	1	1.51	0.12		0	0	30	70	
RF	4.5	1.59	1.94	0.05		0	0	40	60	
PL	5.4	2.05	2.08	0.7		0	0	20	80	
RF	4.5									
PL	1.7									
RF	13.1									
PL	2.9									
RF	6.7									
PL	0.3									

REACH #2 FIELD DATA	
REACH #2	Begin(m): 369 End(m): 470 Reach Length(m): 101
Habitat Quality Modifier	Position: US of change in thermal cover, and beginning of wetland channel type.
Spawning: 0	Instream Cover: Medium
Rearing: 0.67	Thermal Cover: 40%, Alder
T (C):	Juvenile Abundance: None Observed
	Limiting Factors: Low thermal cover. No spawning gravel.
	Culvert Site IDs:
	Total Culverted Length: 0 m Est. Drainage Area: 1.95 mi ²

Species Expected to Benefit (x=Yes, blank = No)									
Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res CT/RB	Bull	
			x	x		x	x		

Spring influences are (see below): <i>(absent-0, slight-1, mod.-2, pronounced-3)</i> 1.) relatively regular, rectangular cross-section, minor variations in depth 2.) Poorly defined bars and thalweg / very low, flat floodplain 3.) bank vegetation along a distinct line, at a small distance <i>above the H2O surface; moss on exposed surfaces of rocks</i>	1	Reg. Constant (for 60-d low flow calc.): <i>Olympic/Coastal = 0.49</i> <i>Cascade/E. Puget = 1.04</i> <i>Columbia/E. WA=0.12</i> <i>Northern/NE Mts.=0.097</i>	1.04
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REACH #2 HABITAT MEASUREMENT										
TYPE	L	W	SLW	D	GRAD	B	C	G	F	
PL	60	1.7	1.7	0.33	0.005	0	0	0	100	

Output Pages

WDFW - HABITAT PROGRAM
PHYSICAL SURVEY OF POTENTIAL HABITAT (Ver. 4e)

Survey ID:	ExampleID	Survey Extent:	US of site 881881 to end of fish use.
Date:	8/8/2016		
Observer(s):	Adams; Jefferson		0
Stream Name:	Example Cr	Filename:	881881.xls
Tributary To:	8.0166		
WRIA #:	0		

Summary of Information - Total Stream Length

Total Length Surveyed:	470.00 m	Tot. Length Culverted:	5.50 m
Total Length Sampled:	120.00 m	Percent of Stream Length	
Percent Sampled:	25.53 %	Culverted:	1.17 %

Measured Pool Area:	295.50 m ²	Total Spawning Area: 73.32 m² Total Rearing Area: 473.00 m²
Measured Riffle Area:	433.36 m ²	
Measured Rapid Area:	0.00 m ²	
Measured Pond Area:	0.00 m ²	
Total Measured Stream Area:	728.86 m²	

POOL : RIFFLE : RAPID : POND RATIO (%)

Pool= 40.54 Riffle= 59.46 Rapid= 0.00 Pond= 0.00

PRODUCTION AREA CALCULATIONS (Do Not Use For PI Calculations)

	Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull
Reach 1	0.00	73.32	0.00	373.30	373.30	0.00	373.30	373.30	0.00
Reach 2	0.00	0.00	0.00	99.70	99.70	0.00	99.70	99.70	0.00
Reach 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total area*	0.00	73.32	0.00	473.00	473.00	0.00	473.00	473.00	0.00

* Spawning habitat used for sockeye, chum and pink, rearing used for all other species.

ADJUSTED PRODUCTION AREAS (Use for PI Calculations)

	Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull
Reach 1	0.00	73.32	0.00	330.14	330.14	0.00	330.14	373.30	0.00
Reach 2	0.00	0.00	0.00	88.18	88.18	0.00	88.18	99.70	0.00
Reach 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reach 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total area*	0.00	73.32	0.00	418.32	418.32	0.00	418.32	473.00	0.00

Summary of Information - Reach #2

Starting Position: US of change in thermal cover, and beginning of wetland c Length of Reach Culverted: 0.00 m
 Length of Reach: 101.00 m Percent of Reach Culverted: 0.0 %
 Length Sampled: 60.00 m Estimated drainage area: 1.95 mi²

Instream Cover: Medium
 Thermal Cover: 40%, Alder
 Juv. Abundance: None Observed
 Limiting Factors: Low thermal cover. No spawning gravel.
 Culvert Site IDs: 0

Spring influences are (see below): 1 Reg. Constant (for 60-d low flow calc.): 1.04
(absent-0, slight-1, mod-2, pronounced-3)
 1.) *Relatively regular, rectangular cross-section, minor variations in depth*
 2.) *Poorly defined bars and thalweg*
 3.) *Bank vegetation along a distinct line, at a small distance above the H2O surface; moss on exposed surfaces of rocks*
 Olympic / Coastal = 0.49
 Cascade / E. Puget = 1.04
 Columbia / E. WA = 0.12
 Northern / NE Mts. = 0.097

Species Expected to Benefit

	Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull
	no	no	no	yes	yes	no	yes	yes	no

Pool : Riffle : Rapid : Pond Ratio (%)

Pool= 100.00 Riffle= 0.00 Rapid= 0.00 Pond= 0.00

Pool L sampled: 60.00 m Pool Gravel %: 0.00
 Riffle L sampled: 0.00 m Riffle Gravel %: 0.00
 Rapid L sampled: 0.00 m Rapid Gravel %: 0.00
 Pond L sampled: 0.00 m Pond Gravel %: 0.00
 Ave. Pool Depth: 0.33 m Flow: cfs
 Ave. Riffle Depth: 0.00 m Ave. Grad.: 0.50 %
 Ave. Rapid Depth: 0.00 m Ave. Temp: 0.0 °C
 Ave. Pond Depth: 0.00 m

Substrate Composition (%): Boulder = 0.00 Cobble = 0.00 Gravel = 0.00 Fines = 100.00

Wetted (Measured) Area

Ave. Pool Width: 1.70 m Pool Area (W) 171.70 m²
 Ave. Riffle Width: 0.00 m Riffle Area (W): 0.00 m²
 Ave. Rapid Width: 0.00 m Rapid Area (W): 0.00 m²
 Ave. Pond Width: 0.00 m Pond Area (W): 0.00 m²
Total Reach Area (W): 171.70 m²

Scour Line Width Area

Ave. Pool W(SLW): 1.70 m Pool Area (SLW): 171.70 m²
 Ave. Riffle W(SLW): 0.00 m Riffle Area (SLW): 0.00 m²
 Ave. Rapid W(SLW): 0.00 m Rapid Area (SLW): 0.00 m²
 Ave. Pond W(SLW): 0.00 m Pond Area (SLW): 0.00 m²
Total Reach Area(SLW): 171.70 m²

60-day Low Flow Area

60-day Low Flow: 0.057 cfs Pool Area (60dLF): 148.81 m²
 Low-Flow Depth: #DIV/0! m Riffle Area (60dLF): 0.00 m²
 Low-Flow Width: #DIV/0! m Rapid Area (60dLF): 0.00 m²
 Pond Area (60dLF): 0.00 m²
 Pool Factor 0.80
 Riffle/Rapid Factor: 0.62 **Total Reach Area (60dLF): 148.81 m²**
 Pond Factor: 1.00

HABITAT QUALITY MODIFIERS:

Spawning: 0.00 **Spawning Area: 0.00 m²**
 Rearing: 0.67 **Rearing Area: 99.70 m²**

Fish Access Comments

WDF W H A B I T A T P R O G R A M - P H Y S I C A L S U R V E Y O F P O T E N T I A L H A B I T A T F I S H A C C E S S C H E C K C O M M E N T S

Survey ID:	ExampleID	Survey Extent:	Outlet of 881881 to confluence with Lake Imagination
Date:	8/8/2016		
Observer(s):	Adams; Jefferson		
Stream Name:	Example Cr	Total Length (m):	125
Tributary To:	Lake Imagination		
WRIA #:	8.0166	Filename:	881881.xls

Hip Chain	Comment
0	Outlet of target site 881881. 30% thermal cover - primarily alder. Low overhanging reed canary grass.
15	BFW = 2.98, Gradient = 1%
47	Inlet of culvert 881880 (RND, C ST, 0.61 m Rise/Span, Slope = 1.57% , 67% pass able)
52.3	Outlet of culvert 881880.
73	Channel becoming wider. BFW = 3.65.
85	Water in channel has decreased. US was likely partially spring fed.
100	Increased gravel. LB erosion. Increased deciduous canopy cover (60%)
	
125	Confluence with Lake Imagination. Anadromous access verified.

Upstream Comments

WDFW HABITAT PROGRAM - PHYSICAL SURVEY OF POTENTIAL HABITAT UPSTREAM SURVEY COMMENTS

Survey ID:	ExampleID	Survey Extent:	US of site 881881 to end of fish use.
Date:	8/8/2016		0
Observer(s):	Adams; Jefferson		
Stream Name:	Example Cr	Total Length:	470
Tributary To:	Lake Imagination		
WRIA #:	8	Filename:	881881.xls

Hip Chain	Comment
REACH 1	
0	<p>Begin survey at inlet of Site 881881 under Hypothetical Ave. Stream flows through mixed alder and maple canopy. Embedded gravel, and fine substrate. Eroded banks.</p> 
20	<p>Non fish-bearing trib on RB. Big-leaf maple shading the creek. Tributary is composed mostly of gravel and cobbles.</p>
30	<p>Bankfull width = 2.23 m</p>
59	<p>Gradient 3%</p>
87	<p>LB is unstable and eroding away, depositing fines into channel. Highway above left bank.</p>
132	<p>Juvenile salmonid observed. Unable to determine species.</p> 

171

Waterfall - 0.47 m WSDrop over clay bottom channel. Plunge pool depth = 0.50 m.



285

More erosion on both banks.

301

Inlet of culvert 881882. (ARCH, SPS, Span = 3.27 m, Rise = 1.45 m, 100% passable).
No reach break. Culvert was 100% passable.

306.5

Outlet of culvert 881882.

350

Waterfall - 1.55 m WSDrop. Undercut behind falls. Plunge pool depth = 0.70 m.



369

WSDrop is likely a barrier to chum salmon migration (not included in subsequent reaches).
Change in canopy cover. Channel becomes more wetland habitat. **End Reach**

REACH 2

369

Begin Reach

398

Bankfull width = 1.35 m. Reed canary grass choking the channel with alder overstory.



408

Bridge site 881883. Steel deck on concrete footings. 8 m span. 100% passable.

435

Gradient = 0%

440

Wetland channel with very little thermal cover. No spawning habitat. Cattails common.



448
454
470

Skunk cabbage starting to appear near and within the channel.
Boulder armoring on left bank.
End of fish use. Confluence of two non fish bearing tributaries.
Scour widths <0.61 m.



END SURVEY

APPENDIX J

Instantaneous Flow Rate Measurements

If a human-made structure is a suspected velocity barrier, but the Level A or Level B hydraulic analysis is not possible, you may use flow rate measurements to determine if the culvert is a velocity barrier given current flow conditions. You may use a measured average cross-sectional velocity, a stream discharge measurement, and the high fish passage flow regression equation to determine if the current discharge is within fish passage flows, and if the velocities exceed allowable criteria. *Note: This method only works if you can calculate high Q_{fp} for a site.*

Review Chapter 3, Section 3.5 before applying these methods.

Measure Culvert Cross-Sectional Mean Velocity

Measure and record the cross-sectional mean velocity in feet/second at the fastest flowing end of the structure, or within the structure if possible. If there is any question where the highest velocity is located, test it with the flow meter.

Note: typically within the first few feet of the inlet flows will merge creating a higher velocity than right at the inlet, so, if you can take measurements within the culvert, this is a good spot to measure velocity on the upstream end.

At the point of highest velocity measure the average cross-sectional velocity of the culvert as follows:

Set up the culvert cross-section

Stretch a tape across the widest point of the culvert horizontally.

Divide the wetted width within the culvert into approximately 1 foot cells. For pipes 2 feet wide or greater, divide the pipe into odd numbered cells. Adjust the cell widths as needed to ensure that you capture the velocity above the invert of the pipe. Figure 1 illustrates where to set up cross-sections and different water depths.

Take cross-section measurements

Starting at the Left Bank *wetted* edge record the following data (in feet), for each cell (Figure 1):

- Width of cell
- Depth – water depth in middle of cell.
- Velocity – multiply the water depth by 0.4 and measure velocity at that depth in the middle of the cell. E.g., if the depth of the water is 1.0 ft, measure the velocity at 0.4 ft above the culvert invert. *Note: this calculated depth is known to be the best position to measure an average velocity because it avoids the highest velocities at the surface and the slowest velocities near the streambed that result from the substrate roughness.*

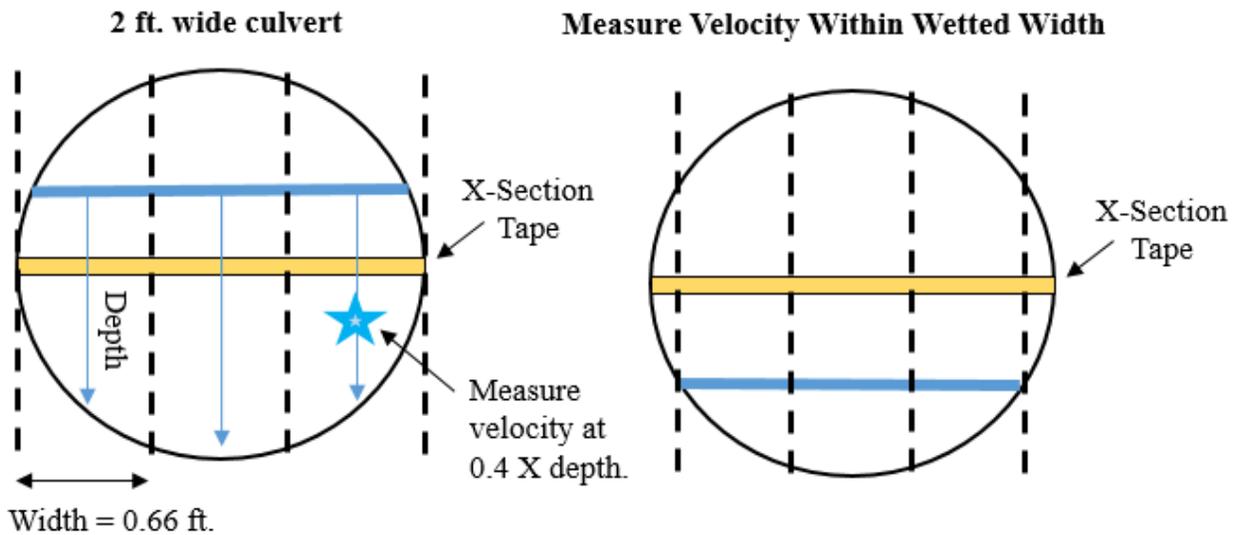


Figure 1. Measuring cross-sectional mean velocity in culverts. The figure illustrates where to set up the cross-section at different water depths and where to measure velocity within each cell.

Calculate the average cross-sectional velocity of the flow

Use the following equation to calculate the average cross-sectional velocity in the culvert using the following equation:

$$\begin{aligned}
 & \left(\text{Velocity of cell}_1 * \left(\frac{\text{Area of cell}_1}{\text{Total area}} \right) \right) + \left(\text{Velocity of cell}_2 * \left(\frac{\text{Area of cell}_2}{\text{Total area}} \right) \right) + \dots \\
 & \dots + \left(\text{Velocity of cell}_x * \left(\frac{\text{Area of cell}_x}{\text{Total area}} \right) \right)
 \end{aligned}$$

Assessing Culvert Velocity

If the average cross-sectional velocity does not exceed the velocity threshold of the structure (Table 1), the barrier status is unknown. An Engineer Review may be recommended, or the site may be revisited at higher flows if you believe that the instantaneous discharge is less than Q_{fp}-High (i.e., 10% exceedance flow) for the site, and it has the potential to exceed the allowable velocity during Q_{fp}. In FPDSI, record the average cross-sectional velocity from the flowmeter and date of flow measurement in the Comments. Record Method = Level A, Barrier = Unknown, Reason = Insufficient Data, Passability (%) = Unknown. Also record in Comments why Level B was not possible.

If the average cross-sectional velocity exceeds the velocity threshold for the structure (Table 1), determine the instantaneous stream discharge as described in the following sections.

Culvert Length	Velocity Threshold
≤ 30.4 meters	≥ 1.22 mps
30.4 – 61 meters	≥ 0.92 mps
≥ 61.1 meters	≥ 0.61 mps

Table 1. Velocity thresholds based on culvert length.

Measuring Instantaneous Stream Discharge

Select a location for the channel cross-section

The cross-section should be set up:

- outside of the influence of the structure
- outside of the influence of any tributaries
- where the stream has mostly uniform flow
 - away from large boulders, logs, or anything that may create back eddies, slack water, turbulence, or disturbed flow
- if setting the cross-section upstream of a structure with multiple tributary inputs, set up a cross-section at each tributary (you will add the discharge from each watercourse)
- if setting the cross-section downstream of structure, do not go downstream of tributaries that are not flowing through the culvert.

Set up the cross-section

Stretch a tape across the stream. The exact location of ends of tape is not important, but must extend beyond the wetted edges.

Measure the wetted width (WW). If WW < 10 feet, divide the WW into 0.5 foot ‘cells’. If WW >10 feet, divide the WW into 1 foot cells.

Taking measurements

Starting at the Left Bank wetted edge record the following data (in feet), for each cell (Figure 2):

- Left Station – location read from tape on left edge of cell
- Right Station – location read from tape on right edge of cell
- Depth – water depth in middle of cell
- Velocity –multiply the Depth by 0.4 and measure velocity at that depth in the middle of the cell. E.g., if the depth of the water is 1.0 ft, measure the velocity at 0.4 ft above the streambed. *Note: this calculated depth is known to be the best position to measure an*

average velocity because it avoids the highest velocities at the surface and the slowest velocities near the streambed that result from the substrate roughness.

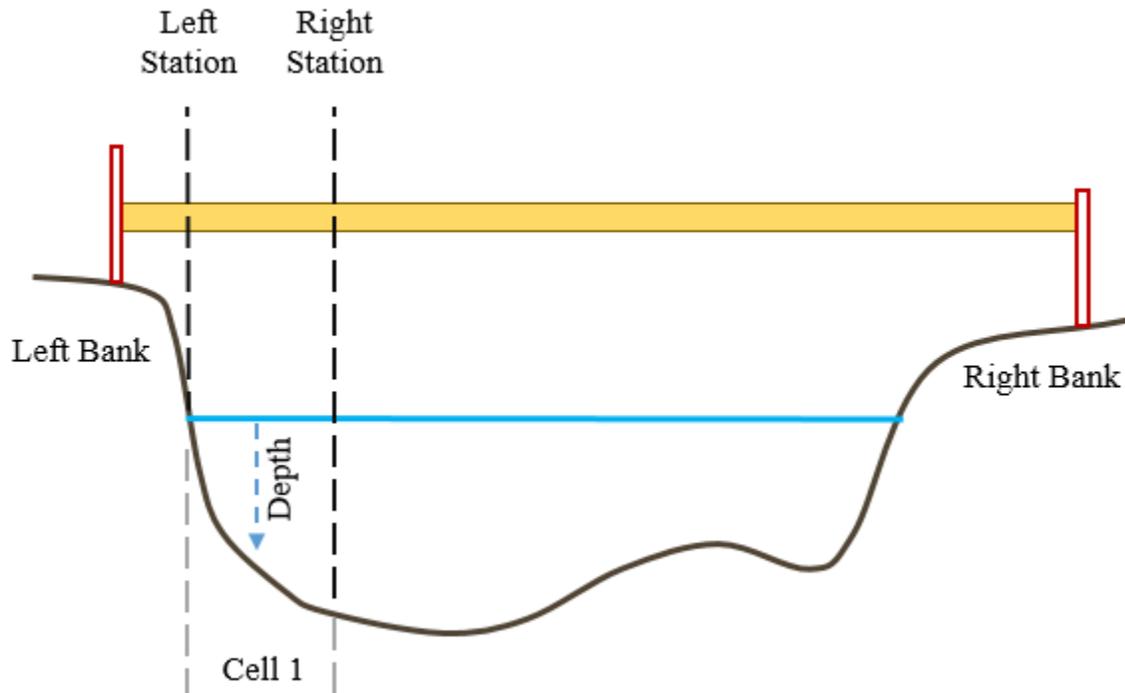


Figure 2. Measuring stream discharge. The figure illustrates where to set up the channel cross-section, the boundaries of cells, and the point at which to measure depth.

Calculating instantaneous discharge in the office

There are a variety of discharge calculators available on the internet and you may also contact WDFW fish passage division for a copy of the stream flow calculator spreadsheet.

Enter Stations, Depths, and Velocities into the discharge calculators

Record the Total Stream Flow output. Estimate high Q_{fp} for the site using the methods described in Appendix C.

Barrier Determination

If the instantaneous discharge measured in the stream channel is greater than the high Q_{fp} , than the stream discharge is greater than fish passage flows, the barrier status is unknown and an Engineer Review may be recommended. Alternately, the site may be revisited at lower flows. Record the average cross-sectional velocity from the flowmeter, date of flow measurement, estimated discharge, and high Q_{fp} in the culvert comments.

If the instantaneous discharge measured in the stream channel is less than or equal to Q_{fp} , than the structure is a velocity barrier. Record the average cross-sectional velocity from the flowmeter, date of flow measurement, estimated discharge, and high Q_{fp} in culvert comments. The site is a fish passage barrier, but the percent passability is unknown.