Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual

WASHINGTON DEPARTMENT OF FISH & WILDLIFE

HABITAT PROGRAM

Technical Applications (TAPPS) Division

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This document was submitted to numerous entities for review, including the Washington State Department of Transportation (WSDOT), the Washington State Recreation and Conservation Office (RCO), Tribes, groups who received training by WDFW and have used the methods outlined in earlier versions of the inventory manual, and other interested parties.

Updates, Feedback, Questions

The *Fish Passage Barrier and Surface Water Diversion Screening and Prioritization Manual* is a work in progress. It has been updated twice since first published in 1998. We welcome comments and ideas that would make the contents more useful. Questions, comments, or ideas regarding the manual can be e-mailed to:

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Information about the TAPPS Division, projects, additional technical assistance contacts, reports and guidelines are located on the Internet at http://wdfw.wa.gov/hab/tapps/index.htm.

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FISH PASSAGE BARRIER AND SURFACE WATER DIVERSION SCREENING ASSESSMENT AND PRIORITIZATION MANUAL

CHAPTER 1

Revised 12/21/09

INTRODUCTION

This manual was originally written in 1998 to provide a standardized methodology for evaluating fish passage at road crossings. The manual has since been expanded to include evaluation of additional instream features, including dams, fishways, other human-made instream structures, natural barriers, and surface water diversions. Revisions to the prior version of this manual (August 2000) are summarized in Table 1.1. A glossary of words, terms, and abbreviations used in this manual can be found in Appendix A.

1.1 Purpose

This manual is intended to provide guidance for conducting fish passage and surface water diversion inventories. Fish passage inventories lead to identification and assessment of instream features and prioritization of fish passage barriers based on amount, quality, and species utilization of habitat upstream of the barrier. Surface water diversion inventories allow for the identification, assessment, and prioritization of unscreened or inadequately screened diversions in need of correction.

1.2 Overview

This chapter introduces the general inventory concepts and discusses inventory planning. The second chapter of the manual covers information needed to describe the location, fish use, and ownership information for each site evaluated for fish passage and/or screening. Chapters 3-8 describe data collection and methods for evaluating different features encountered during the inventory. Finally, chapters 9 and 10 cover habitat assessment methods and prioritization for fish passage and screening projects, respectively.

The methods described herein have been widely used since the late 1990s by Washington Department of Fish and Wildlife (WDFW), tribes, local governments, the Salmon Recovery Funding Board (SRFB), regional fisheries enhancement groups, and others. WDFW provides training on the protocols contained in this manual to groups conducting inventories.

WDFW maintains a database of data collected using the protocols described in this manual. The WDFW Fish Passage and Diversion Screening Inventory (FPDSI) database functions as a central repository for information resulting from inventories conducted throughout the state. This information can be used to select and implement fish passage and screening projects vital to the recovery of Washington’s salmonids.

Table 1.1 Summary of significant updates to the Fish Passage Barrier and Surface Water Diversion Screening and Prioritization Manual

Location	**Title**	**Details of the update**
Chapter 3	Road Crossing Structures – Culverts	Added table for guidance in estimating the percent passability for barrier culverts. Also includes photo examples of different road crossings.
Chapter 3	Non-culvert Road Crossings	New section.
Chapter 3	Level A flow chart	Updated flow chart of the Level A culvert analysis.
Chapter 3	Photo Examples	New figures, including photo examples of different road crossing structures, and tide and flood gates.
Chapter 4	Dams	Expanded discussion on dams, including feature description and evaluating fish passage. Added data collection attributes table. Included photo examples of different dam structures.
Chapter 5	Miscellaneous Obstructions	New section on 'Other' human-made fish passage features (that are not classified as culverts or dams). Includes photo examples of miscellaneous obstructions.
Chapter 6	Natural Barriers	New section.
Chapter 7	Fishways	Added section on evaluating fishways associated with culverts, dams, and other features. Included data collection attributes table.
Chapter 7	Photo Examples of Fishways	New figure.
Chapter 8	Surface Water Diversion/Screen Evaluation	Updated text, figures, and data collection table. Includes photo examples of common screens.
Chapter 9	Habitat Assessment	Eliminated the Expanded Threshold Determination (ETD) option for estimating habitat gain. This method had a very low confidence level due to several factors. A map-based assessment does not identify additional upstream and downstream human-made barriers, or natural barriers that may prematurely end a habitat survey. The actual length of fish bearing waters is difficult to accurately assess using the map-based method, leading to the possibility of overestimation or underestimation of actual habitat.
Chapter 9	Physical Habitat Survey	Discontinued using the term Ordinary High Water (OHW). Now using the term Scour Line Width (SLW), referring to one of the channel width measurements taken for making fish passage and habitat assessments. Refer to Glossary in Appendix A for definitions of terms.
Appendix A	Glossary of Terms	New.
Appendix B	Recommended Equipment List	New.
Appendix D	Measuring Channel Width (Appendix 'H' from the *Design of Road Culverts for Fish Passage)*	Added.
Appendix E	Basic Culvert Surveying Techniques	New.

Fish Passage Features

The manual sections pertaining to fish passage barriers provide guidance about how to identify, assess, and prioritize human-made instream features that preclude or impede upstream passage to fish. For the purpose of this manual, fish passage features fall under one of the following categories: road crossing structures, dams, and other miscellaneous obstructions. Natural barriers may also be assessed for fish passage, however they are not prioritized for correction.

Fishways may be attached to road crossings, dams, natural barriers, and other features to facilitate fish passage at barriers. If the barrier feature has a fishway associated with it, both the primary feature and the fishway are evaluated together when determining fish passage.

Fish passage assessments are only conducted on streams with known or potential fish use. For each feature encountered a unique site identification number (Site ID) is assigned and basic site information is collected (Chapter 2). Detailed physical measurements of the feature and stream are taken to allow for barrier analysis; this is covered in subsequent chapters depending on the type of feature encountered. An overview of the barrier assessment process, using a culvert as an example, is shown in Figure 1.1.

Percent passability is estimated for all fish passage features, and uses a combination of professional judgment and species ability to negotiate water surface drop, velocity, and depth. A feature may be evaluated as a total barrier (0% passable), a partial barrier (33% passable; some passage), a less severe partial barrier (67% passable), or a non-barrier (100% passable; passable during all times when flow is present, up to the high fish passage flow). The guidance provided in subsequent chapters is based upon the abilities of a 15.24 centimeter (6 inch) trout, so it should not be construed as an absolute value for all salmonid species and life stages. The percent passability estimates are intended to represent general categories of passability, not actual estimates of the number of fish that may pass. The percent passability is one factor used for prioritizing barrier correction.

If the feature is a barrier and prioritization is an objective of the inventory, it will be necessary to assess the potential habitat gain that would be realized if the barrier is corrected. Once the potential habitat gain has been quantified, then it is possible to prioritize the project using the Priority Index (PI) model. The Priority Index (PI) takes into account the severity of the barrier (percent passability), the habitat gain, the species mobility (anadromous vs. resident), the stock status (based upon the most current SaSI updates), and the projected cost of the project. The PI is a valuable tool to be used with other relevant factors to select projects for correction, such as Endangered Species Act (ESA) status, community support for the project, additional human-made features located downstream or upstream that also require repair, other restoration efforts conducted in the watershed, etc.

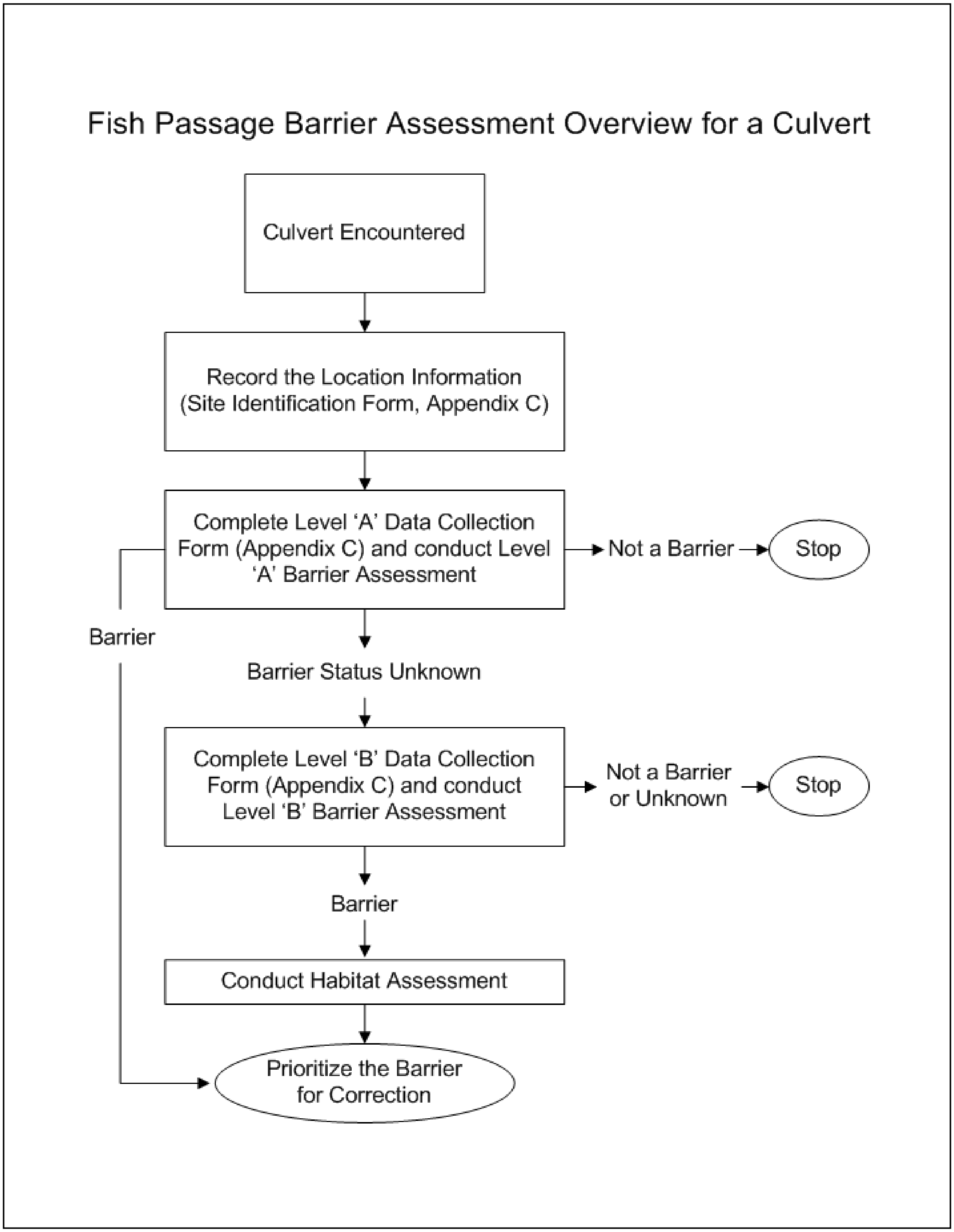


Figure 1.1 Overview of the barrier assessment protocol for a culvert feature.

Surface Water Diversions

The manual section pertaining to surface water diversions is intended to provide guidance on procedures for identifying, describing, and prioritizing gravity and pump surface water diversions. Surface water diversions should be screened to exclude all life stages of salmonids in order to provide protection from mortality, injury, and migratory delay.

Figure 1.2 gives an overview of the entire water diversion/screening assessment process from locating the diversion through prioritizing the diversion for correction. Once the location of the point-of-diversion (POD) has been identified and given a unique site identification number (Site ID), GPS coordinates are taken for the site and detailed physical measurements are taken to describe the site and allow for the assessment of fish protection.

The Screening Priority Index (SPI) is used to prioritize the correction of unscreened and/or inadequately screened diversions. The SPI takes into account the size of the diversion (amount of water diverted), the probability of an individual of a given species encountering the screen, and additional modifiers for: 1) species mobility (anadromous vs. resident), 2) stock status, and 3) estimated screening cost.

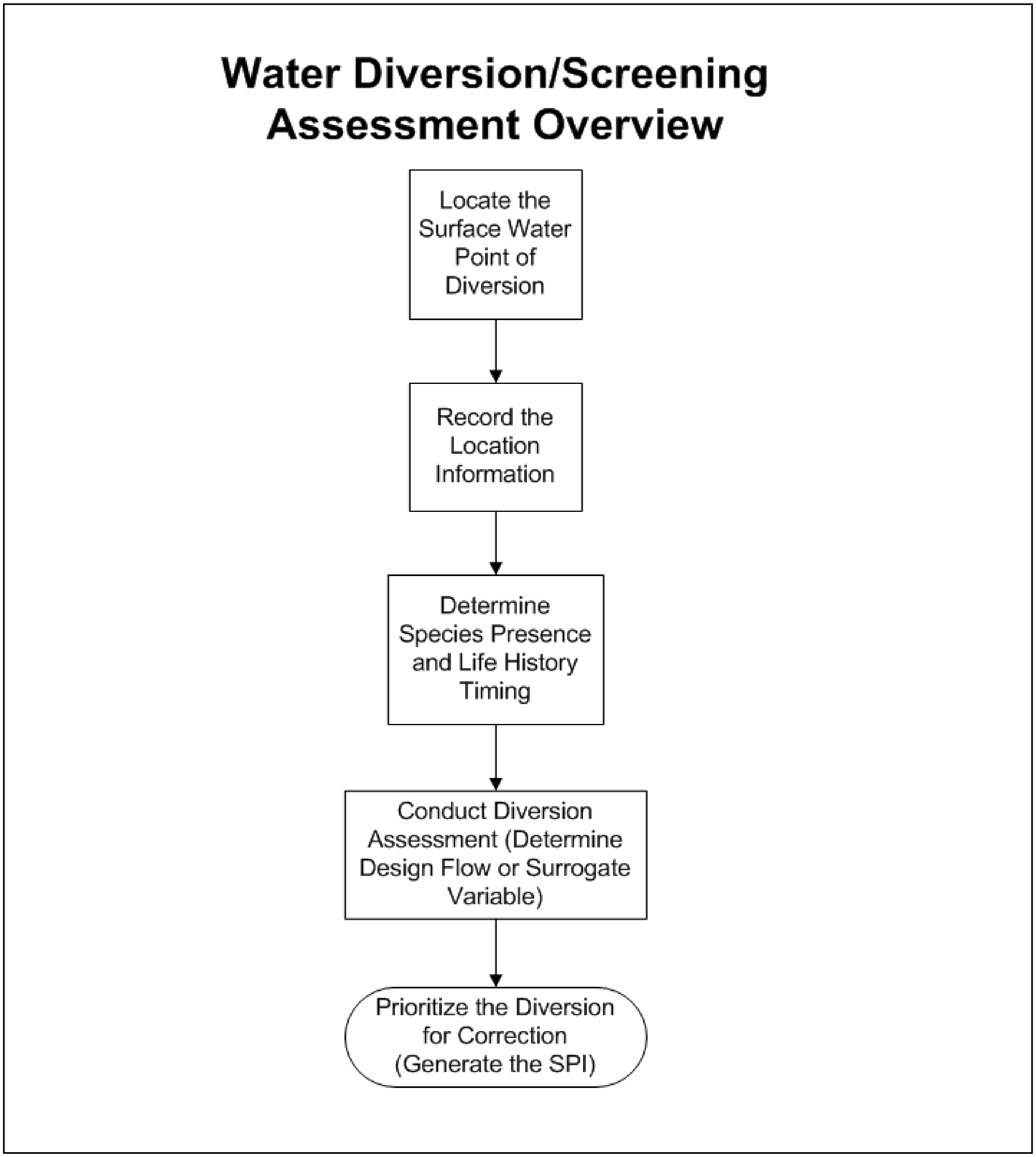


Figure 1.2. Overview of the water diversion/screening assessment protocol

1.3 Planning Fish Passage and Surface Water Diversion Inventories

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

Develop Scope and Goals for the Project

The goals of the project should be clearly identified in the scope of work. Is the goal simply to inventory all culverts or unscreened surface water diversions within a given jurisdiction, or to identify all fish passage and diversion features within a watershed?

Detailed objectives should be developed supporting the goals of the project. For example, during a comprehensive inventory, all human-made fish passage barriers and surface water diversions are assessed and prioritized for correction within the watershed. This would include both anadromous and resident fish bearing water.

Table 1.2 gives a comparison of different inventory efforts, followed by examples of different inventory efforts highlighting the advantages and disadvantages of each effort. WDFW recommends conducting inventories at the most comprehensive level possible to avoid having data gaps which will need to be filled in later. However, it is recognized that the scope of the inventory can be limited due to numerous factors, such as funding constraints or jurisdiction.

Table 1.2. Comparison of different inventory efforts.

Inventory Effort*	Scope of Work	Diversions Inventoried	Culverts Inventoried	All Fish Passage Features Inventoried	Natural Barriers Identified	Project Prioritization
Surface Water Diversion Inventory	Ownership-based	√				
Culvert Inventory	Road-based and/or jurisdictional/ ownership		√			
Culvert Inventory <u>with</u> Habitat Assessment & Prioritization	Road-based and/or jurisdictional/ ownership		√	**√	**√	√
Comprehensive Fish Passage & Surface Water Diversion Inventory & Prioritization	Watershed-based	√	√	√	√	√

*Inventory may be conducted in watersheds with anadromous access only, or for all species.

** Only on streams where a jurisdictional barrier was found and a habitat assessment was conducted.

Road-based Culvert Inventory – Ownership-based or Jurisdictional

Advantages of a road-based culvert inventory include:

- Easy access by vehicle
- Can assess all accessible road crossings for a particular jurisdiction or landowner
- Quicker than conducting an inventory by foot
- Less costly than conducting a comprehensive inventory

Disadvantages of a road-based culvert inventory include:

- Missed crossings at abandoned roads not accessible by vehicle
- No other instream features (human-made and natural) are assessed
- Barriers located downstream and upstream of the jurisdictional culverts are not identified
- No habitat assessment
- Cannot prioritize barriers for correction using the Priority Index (PI) model

In 1998, a road-based culvert inventory was conducted in Grays Harbor County. Figure 1.3 illustrates an example of the road-based inventory, where only county-owned culverts were inventoried. The green dots represent passable or non-fish bearing culverts; the red dots are barriers. While the county-owned culverts were inventoried, there is no information about any barriers downstream or upstream of the Grays Harbor County-owned barriers.

In 2003, another road-based culvert inventory was conducted in Grays Harbor County, including multiple road ownerships. The yellow dots in Figure 1.4 represent the additional culvert crossings located during the 2003 inventory, while the red and green dots represent the 1998 jurisdictional inventory. Although additional road crossings were evaluated in 2003, habitat assessment was not done and streams were not walked, so there is no information about any additional instream features that are not culverts accessible by road.

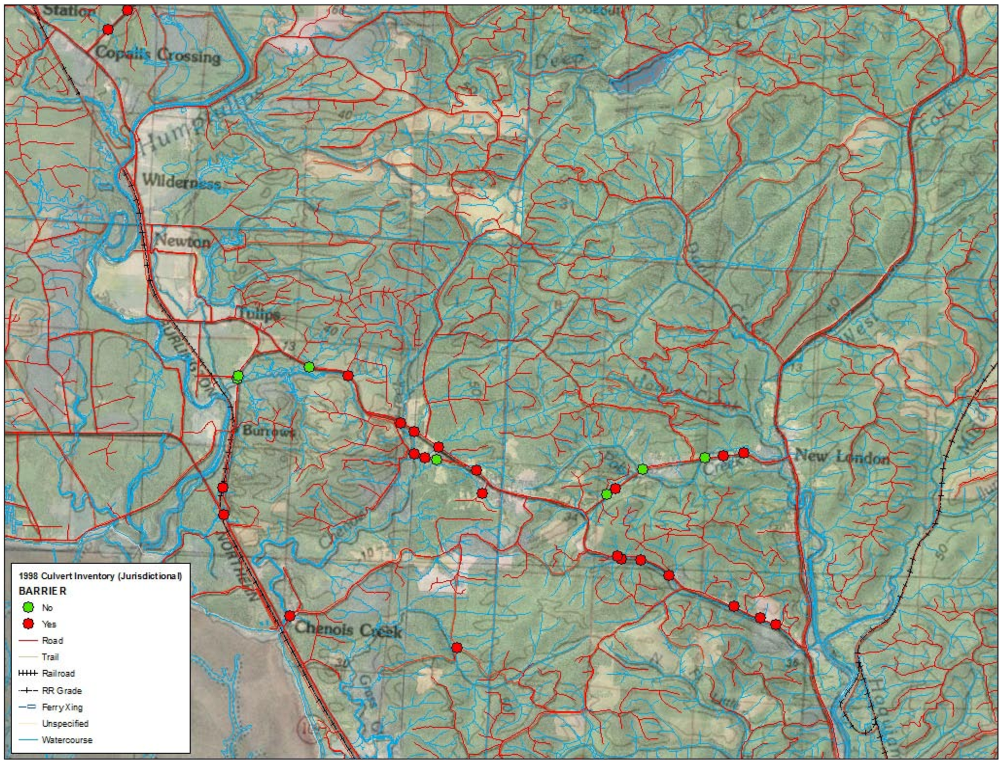


Figure 1.3. Road-based culvert inventory of Grays Harbor County-owned barriers, without habitat assessment.

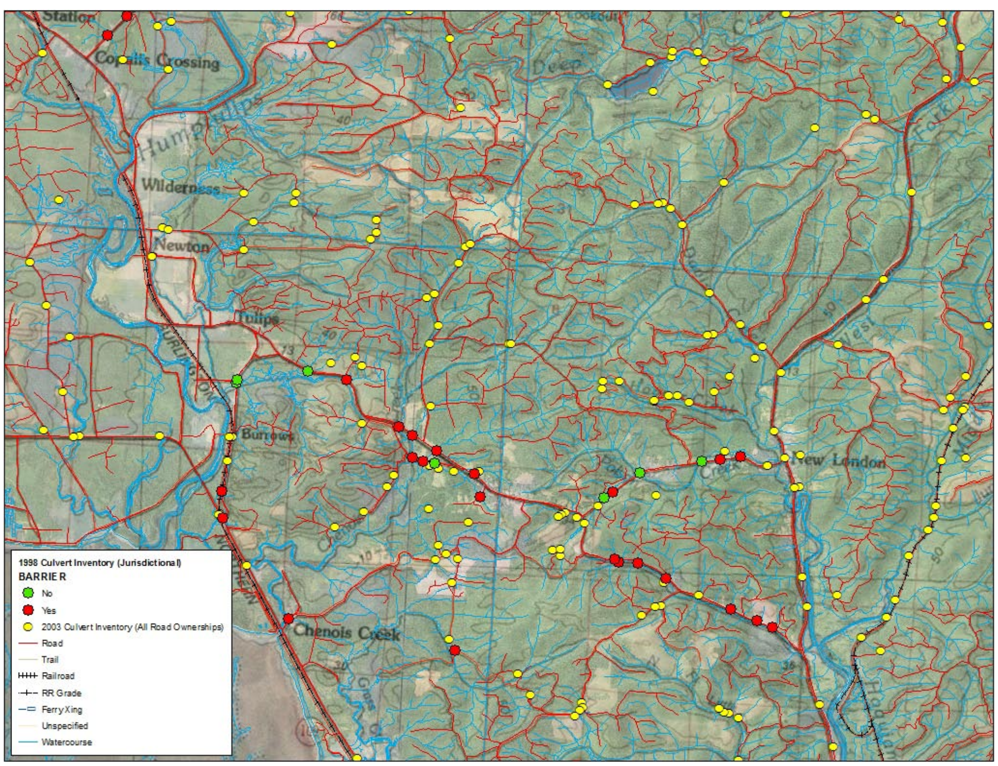


Figure 1.4. Updated road-based culvert inventory in Grays Harbor County, without habitat assessment.

Road-based Culvert Inventory with Habitat Assessment at Barriers
Culvert Inventory with Habitat Assessment & Prioritization

- Advantages
    - Easy access
    - Can assess all accessible road crossings for a particular jurisdiction or landowner
    - Quicker than conducting an inventory by foot
    - Can identify additional features downstream and upstream of the culvert barrier being prioritized
- Disadvantages
    - Missed crossings at abandoned roads not accessible by vehicle
    - No other instream features (human-made and natural) are assessed
    - Barriers located downstream and upstream of the passable culverts are not identified

The Jefferson County inventory included habitat assessment, which identified additional fish passage barriers, but there are still gaps in the data. Whereas additional barriers were identified upstream and downstream of Jefferson County-owned barriers, features located upstream and downstream of passable Jefferson County culverts and bridges were not identified (Figure 1.5). Someone will need to go back and complete this work.

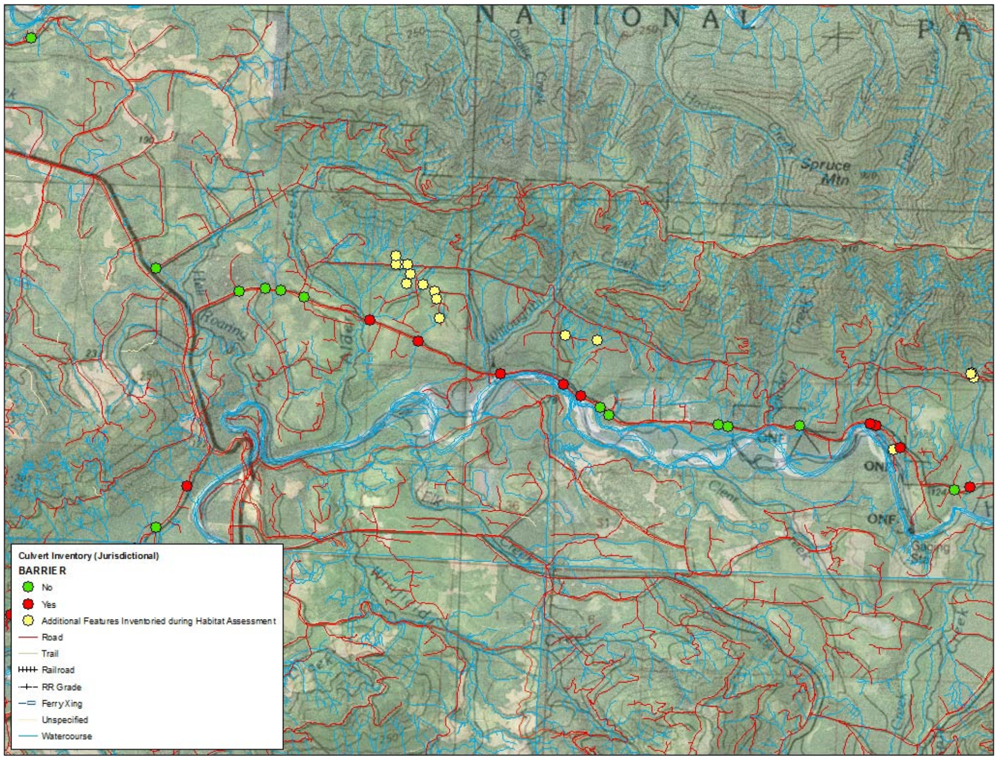


Figure 1.5. Road-based, jurisdictional culvert inventory with fish habitat assessment.

Surface Water Diversion Inventory – Ownership-based or Jurisdictional

- Advantages
  - Identify unscreened or inadequately screened surface water diversions at known locations
  - Quicker than conducting an inventory by foot
  - Less costly than conducting a comprehensive inventory
- Disadvantages
  - Does not document unknown diversions or other instream features

Figure 1.6 shows an example of a state-ownership surface water diversion inventory conducted without evaluating any fish passage or instream features. The yellow dots represent the surface water diversions inventoried. As you can see from the map, there are numerous road crossings and no information about other features in the watershed.

Comprehensive, Watershed-based Fish Passage and Surface Water Diversion Inventory

A watershed-based fish passage inventory was conducted on Beaver Creek, a tributary to the Methow River (Figure 1.7). All fish bearing streams within the Beaver Creek watershed, 58 miles including the mainstem and tributaries, were walked across private, county, state, and federal ownerships. While all fish bearing water was being walked, habitat data was collected in order to prioritize the fish passage barriers for correction.

One hundred sixty eight features were identified during the watershed-based inventory including:

- 84 culverts; 53 of which were barrier culverts,
- 44 dams, of which 23 were fish passage barriers, and
- 40 surface water diversions including
  - 14 pump diversions (3 associated with dam features); none were adequately screened to protect fish,
  - 26 gravity diversions (18 associated with dams), of which one was adequately screened.

The Beaver Creek inventory took 3 months to complete, and was completed by a very industrious work crew. WDFW recommends conducting watershed-based inventories to identify all fish passage and screening features within a watershed. This type of inventory won’t require anyone going back to fill in data gaps, since all fish bearing water is walked. While the initial time investment is great, this type of inventory is a more efficient use of time and resources in the long run and supports a well reasoned salmonid recovery strategy.

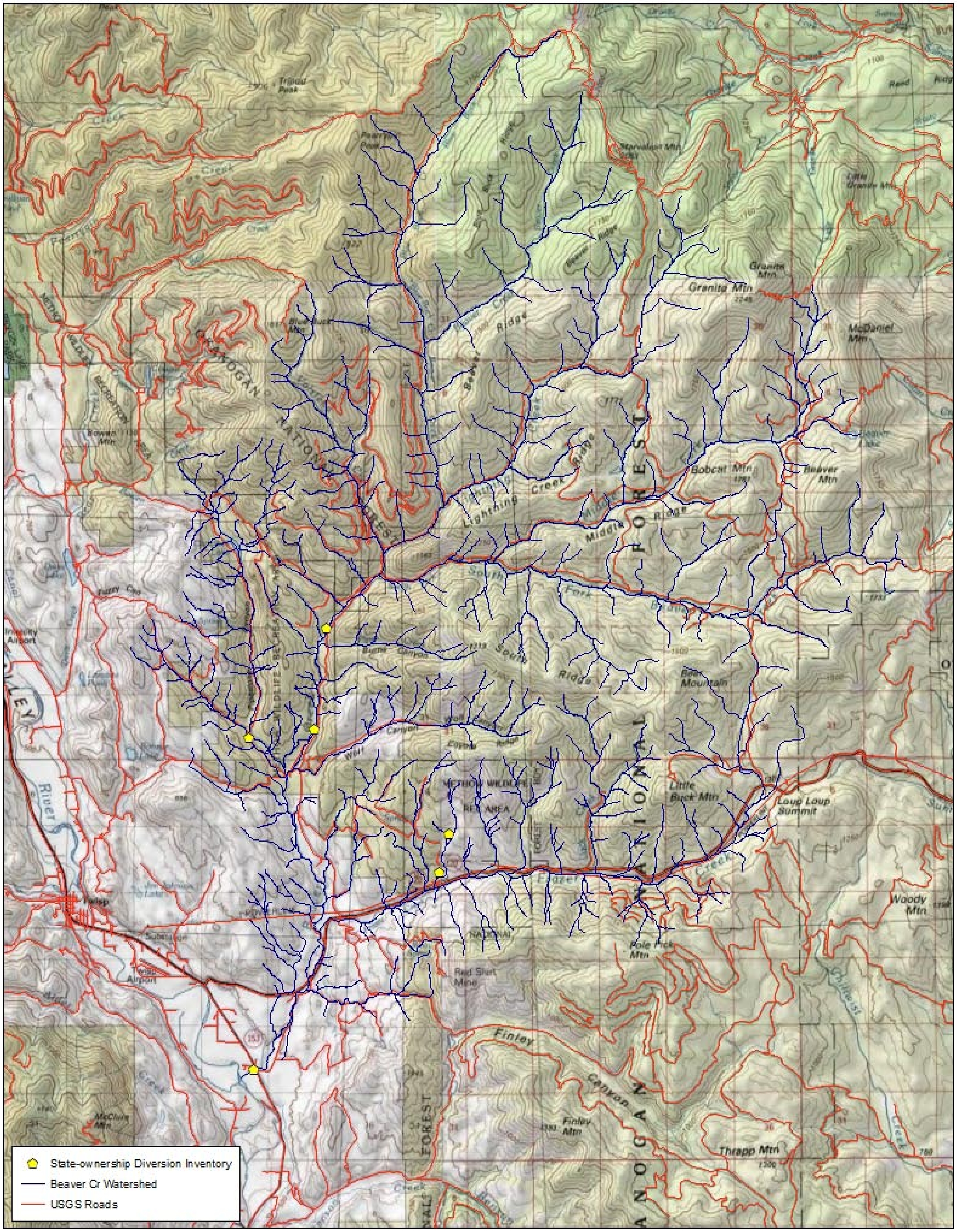


Figure 1.6. Surface water diversion inventory on state-owned lands, without fish passage inventory.

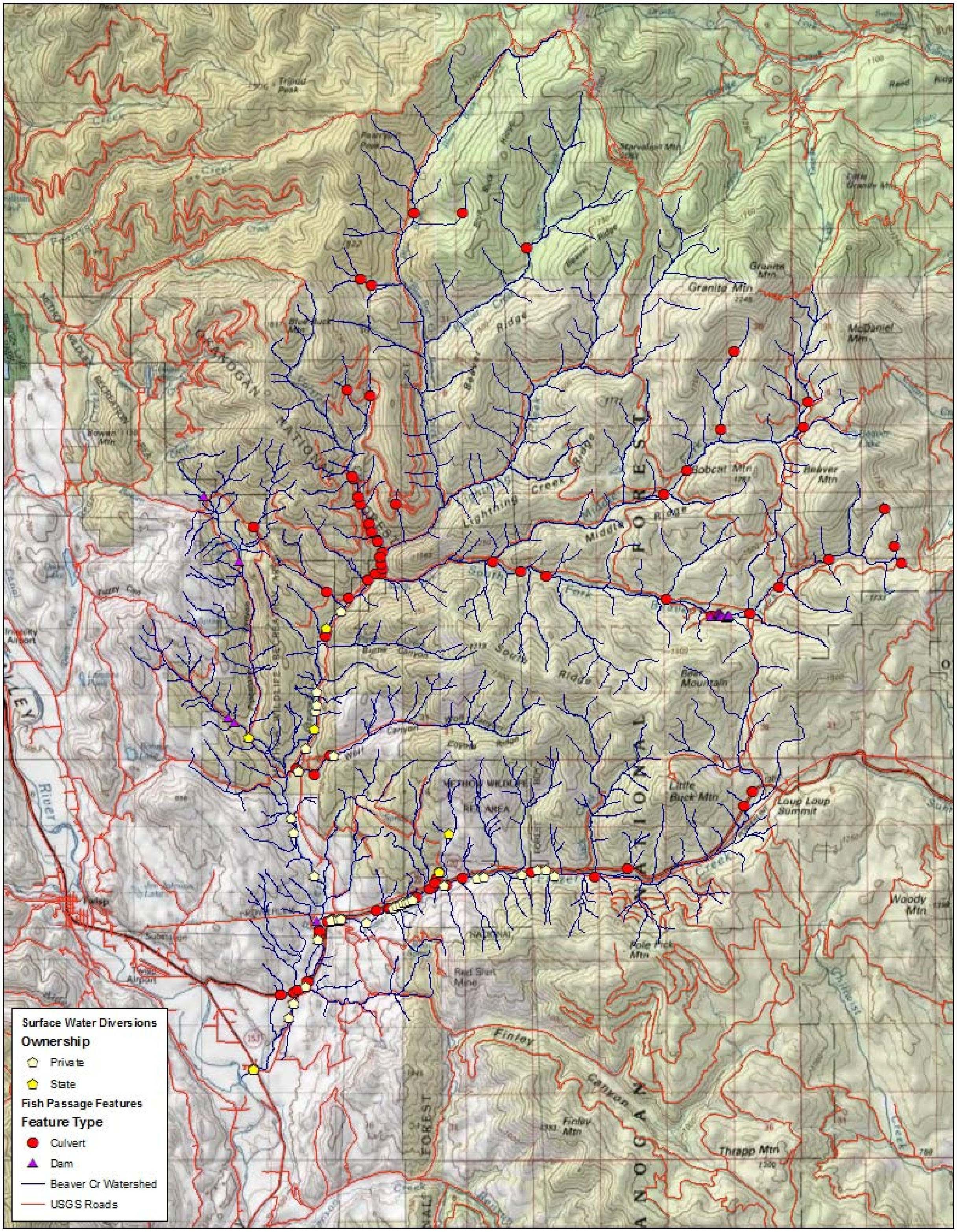


Figure 1.7. Watershed-based fish passage and surface water diversion inventory with habitat assessment.

Inventory Scope

When determining the geographical scope of your inventory, be sure to consider your goals, priorities, budget, staffing, and other factors. For example, you may want to walk all stream habitat within a particular ownership or watershed. Whatever you determine as the scope of your inventory, remember that all fish bearing water should be walked in order to ensure that all fish passage and surface water diversion features are encountered.

If your goal is to conduct a thorough inventory of all instream features within a watershed, then be sure to request enough funds to do the work, or scale back your goal accordingly. Remember, inventories can be funded and completed over multiple years.

Since all fish bearing water will be walked during a comprehensive inventory, as a part of the planning effort you could estimate the number of stream kilometers that may be walked by measuring stream distances off a map. The Department of Natural Resources (DNR) Water Typing Project is a good source for identifying fish bearing streams**.** View the water typing in your area of interest on the Forest Practices Application and Review System (FPARS) Mapping Website: http://www.dnr.wa.gov/BusinessPermits/Topics/ForestPracticesApplications/Pages/fp_watertyping.aspx). Keep in mind that there are numerous unmapped drainages statewide, so the stream distances may be greater.

WDFW crews inventory an average of 1.6 lineal stream kilometers per day. The distance traveled can be more or less, depending on terrain, access, vegetation density, number of instream features to inventory, and other factors. It generally takes 45 minutes to inventory each feature. Travel time to and from streams should also be considered. A similar exercise can be used for planning road-based inventories in estimating the amount of time it will take to travel roads, along with estimating the number of road crossings that may be encountered.

Existing Data

Prior to conducting an inventory, contact WDFW to obtain existing data. This will speed up data collection, since field crews may only need to verify and update information for previously inventoried features or stream surveys.

Equipment

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

Obtaining Landowner Permission

Landowner permission needs to be secured to conduct a complete inventory of the watershed. Respect private property. 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, as it's important to report which areas of the watershed have not been inventoried.

Estimating the Potential Habitat Gain

If a prioritized list of barriers is an objective of the inventory, then it will be necessary to quantify the potential habitat gain that would be realized if the barrier were corrected. Two methodologies to determine the estimated habitat gain are discussed: a full physical survey and a reduced sample physical survey (Chapter 9). Both require walking the stream until a natural barrier is reached or the stream becomes non-fish bearing. The full physical survey requires more extensive sampling than the reduced sampling physical survey. When planning your inventory, expect to cover about 1.6 stream kilometers per day for a full physical survey and slightly more for a reduced sampling physical survey.

Additionally, when conducting a road-based inventory, a threshold determination (TD) may be conducted to verify a significant reach of habitat, or at least 200 meters of useable fish habitat, downstream and upstream of a barrier feature. While this won't allow you to estimate potential habitat gain beyond the 200 meters, it will give you a general idea of the habitat in the vicinity of the feature and allow you to identify additional features within 200 meters downstream and upstream which could affect barrier correction.

Training

Formal training on conducting fish passage and surface water diversion inventories is provided by WDFW. The three-day training follows methods outlined in this manual and combines formal classroom lecture with in-the-field experience. A hard copy of the manual is distributed to each training participant. A CD containing a distribution copy of the FPDSI database, field forms (Appendix C), spreadsheets used for habitat calculations, and the Level B analysis spreadsheet will be provided to each participating inventory group. Contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov, to arrange for training or for technical assistance.

Coordination

Fish passage and screening inventories fill important data gaps in Limiting Factors Analysis (LFA), Lead Entity (LE) strategies, and species recovery plans. It is important to have the inventory project manager provide the inventory data to WDFW for incorporation into the fish passage and screening database where it will be available to a variety of entities interested in salmonid recovery.

Updating an Inventory

Inventory groups should consider how the inventory would be updated and used in the future. In general, due to the dynamic nature of the stream environment, inventories have a limited life expectancy. These inventory projects should be updated periodically as barriers are corrected, new culverts are installed, and culverts previously assessed as passable become barriers.

Since WDFW maintains a statewide, fish passage and screening inventory database, they should be contacted whenever fish passage barriers are corrected and diversions are adequately screened.

1.5 References Cited

Washington Department of Fish and Wildlife. Salmonid Stock Inventory (SaSI). Olympia, WA. Available at http://wdfw.wa.gov/fish/sasi/.

CHAPTER 2

Revised 12/21/09

SITE INFORMATION

Whenever a human-made instream feature or natural barrier is encountered, basic information will be collected to describe the site where the feature is located. Site information describes the location, ownership, fish utilization or potential fish utilization, and feature type.

2.1 Location, Fish Use and Other Basic Site Information

There are three main aspects to collecting the site information:

- Determine potential fish use for the site.
- Complete the Site Description Form found in Appendix C.
- Photograph the site.

Determining Fish Use

It may be difficult to determine fish use at a site based upon the direct observation of salmonids. Due to poor visibility, low escapement levels, the existence of human-made barriers, or other factors, you may not observe fish during your field visit. There are a number of methods to determine if a site has the potential to provide fish habitat. Satisfaction of one or more of the following criteria qualifies a water body as fish bearing or potential fish habitat. Make every effort to determine fish use potential while in the field. If you are unsure about the fish bearing status, carefully evaluate the physical criteria before placing the stream into the "unknown" potential fish habitat category.

Fish Use Criteria

- Watercourses having average scour line widths (SLW) in excess of 0.6 meters (2 feet) in Western Washington and 0.9 meters (3 feet) in Eastern Washington, provided the stream gradient is less than 20 percent. Figure 3.3 in Chapter 3 shows where different channel measurements are taken for a typical stream channel. Take several stream width measurements within the vicinity to get a good average.
- Streams identified as fish habitat by the Department of Natural Resources (DNR) Water Typing Project**.** View the water typing in your area of interest on the Forest Practices Application and Review System (FPARS) Mapping Website: http://www.dnr.wa.gov/BusinessPermits/Topics/ForestPracticesApplications/Pages/fp_watertyping.aspx). The Forest Practices Rule (WAC 222-16-031) is used to define water types. Since water typing updates are continually accepted by DNR, consult more than one source when verifying fish use using FPARS.
- Watercourses with documented salmonid use determined by visual observation, electrofishing, or verification by local biologists.
- Watercourses listed as fish bearing in *SalmonScape* (http://wdfw.wa.gov/mapping/salmonscape/).

- Water courses identified in WDFW's Priority Habitat and Species (PHS) database (2008)

Additional Tips for Determining Fish Use

Seasonally dry streams (ephemeral or intermittent) can provide fish habitat during periods of flow. When evaluating dry stream channels, consider the physical characteristics of the channel and proximity to known fish-bearing water. Also, consider the timing of fish presence for species in the area that may enter the habitat when flow is present. For example, chum salmon often use streams that may only flow for a few months out of the year; they will spawn in the channel during the fall when flow is present and fry will outmigrate in the spring immediately after emergence. In another example, off-channel rearing habitat and floodplain habitat may be used by juvenile salmonids during winter months, even though the channel is dry during the summer.

Data Collection

Upon encountering a new feature on fish bearing or potentially fish bearing waters, complete the Site Description Form found in Appendix C. Explanations of the data fields found on the form are summarized in Table 2.1. Try to enter as much information as possible while in the field. It is best to obtain latitude and longitude while in the field using a GPS unit to avoid confusion about the feature location. Some information may be obtained back in the office, such as stream name, WRIA number, species utilization, and ownership information.

Location

The latitude and longitude of the feature site must be identified in decimal degrees and based upon the World Geodetic Survey 1984 datum (WGS84). It is preferred that this be obtained using a differentially correctable GPS unit. If the latitude and longitude are recorded in a different format, then the coordinates must be converted to the WGS84 datum.

Photographing the Site

Photographs provide information about the site and feature that supplement the field data. Photograph the general setting, an overview of the area showing the feature from a distance, close-up shots of the feature, habitat in the vicinity, fish or wildlife present, etc. You may have a person or an object placed in the background for scale. With a digital camera, you can take several photographs and easily discard any images you don't want later.

Non-Fish Bearing Crossings

If a road-based inventory is being conducted rather than a watershed-based inventory, then you may encounter road crossings at non-fish bearing watercourses. In this case, upon encountering a culvert crossing at a natural drainage, regardless of fish use, complete the Site Description Form (Appendix C). If the site is non-fish bearing, then also complete the associated feature form, but do not evaluate for fish passage or screening.

Table 2.1. Data collection attributes for the Site Description Form (Appendix C). Predefined field values are indicated in bold text.

Form Field Name	Description
Site ID	Unique identifier for each feature; used to associate feature field forms with the site information. **Required Format**: XXXYYYY, where XXX = three digit inventory code assigned by WDFW, YYYY = feature number, assigned sequentially, starting with 0000 (e.g., 1110000, 1110001, etc.).
Latitude	Northerly geographic position of feature in decimal degrees (WGS84) using 9 decimal places. Latitude should be expressed as a positive number without the sign (e.g., 48.873459247). Do not include N.
Longitude	Westerly geographic position of feature in decimal degrees (WGS84) using 9 decimal places. Longitude should be expressed as a negative number (e.g., -122.098217359). Do not include W.
Road Name	Name of road, includes WSDOT Highway numbers.
Highway Mile Post	Highway milepost (to 0.01 mile) where feature is located.
Location	Location of feature relative to landmarks or driving directions.
Stream Name	Name of the stream where the feature is located. If the stream is unnamed, enter unnamed.
Tributary To	Name of the water body to which stream (above) is connected. If unnamed, enter unnamed. May include WRIA & stream number (e.g., unnamed 04.0373).
WRIA	Water Resource Inventory Area number for stream (above), 8-character maximum consisting of 6 digits, 1 decimal point, and 1 upper case letter (e.g., 00.0000A), where applicable. The first two digits are the WRIA number (1-62), the remaining 4 digits and alpha character are the stream number. If the stream has no number enter at least the WRIA number. Do not use X's as place holders.
River Mile	Distance from mouth of stream to the feature location. Reported in miles to the nearest 0.01.
Potential Fish Habitat	Indicator of potential fish habitat or known fish use in stream where feature is located. Determines level of feature evaluation. Values are **Yes, No, or Unknown.**
Habitat Potential Criteria	Basis for potential fish habitat determination: **Mapped** indicates that stream is mapped as fish-bearing (e.g., Limiting Factors Analysis maps, SalmonScape, typed as fish bearing on DNR water type maps, etc.), **Physical** means the stream meets the minimum physical dimensions specified in the Forest Practices Regulations, **Biological** means fish have been directly observed, and **Other** means criteria other than those listed were used (explain in comments). A "Yes" determination may be based on mapped, physical, biological, or other criteria. If unknown leave blank.
Species Potential	Salmon and trout species known or assumed to be present or historically present. Species include: Chinook , Chum, Sockeye/Kokanee, Coho, Pink, Steelhead, Resident Cutthroat/Rainbow Trout, Searun Cutthroat, Bull/Dolly Varden Trout.

Table 2.1. (continued). Data collection attributes for the Site Description Form (Appendix C).

Form Field Name	Description
Associated Features	Type of feature being assessed. Choices are: Culvert, Non-Culvert Crossing, Dam, Other, Natural Barrier, Fishway, and Surface Water Diversion.
Owner Type	General category of ownership. Values are **Private, State, Federal, Tribal, County, City, Unknown**.
Owner Name	Name of landowner, if privately-owned; last name, first name. Or, name of corporate or governmental owner. Leave blank if unknown.
Address	Street address of feature owner.
Secondary Address	Mailing or secondary address of feature owner if different from street address.
City	Name of city.
State	Two character abbreviation for state (e.g., WA).
Zip	Standard Zip code or zip+4.
Phone	Include area code in phone number. Format (123) 456-7890.
Contact	Name of contact if different from owner.
Contact Phone	Phone number for contact if different from owner.
Comments	Concise comments pertinent to the site.

2.2 References Cited

WDFW. 2008. Priority Habitat and Species (PHSPOLY) Polygon Database. Washington Department of Fish and Wildlife. Olympia, Washington. http://wdfw.wa.gov/hab/phspage.htm

WDFW. 2008. SalmonScape. http://wdfw.wa.gov/mapping/salmonscape/

Washington Department of Natural Resources. 2008. Forest Practices Water Typing. http://www.dnr.wa.gov/BusinessPermits/Topics/ForestPracticesApplications/Pages/fp_watertyping.aspx

CHAPTER 3

Revised 12/21/09

ROAD CROSSING STRUCTURES

This manual chapter addresses inventory and evaluation of road crossing structures, including culverts and non-culvert structures. For the purpose of this manual, non-culvert structures include bridges, fords, abandoned crossings, washed-out culverts, and fill or puncheon culverts.

This chapter primarily focuses on culverts, since they are the predominate structure on the landscape. However, common concepts applied to all road crossings include feature description (shape, height, width, length, material constructed of), fish passage criteria (velocity, depth, and water surface drop), and whether or not there is a fishway associated with the feature.

Some road crossings encountered may not be on fish bearing streams, particularly if a road-based inventory (see Chapter 1) is being conducted. In the case of road-based inventories, it is important to document all crossings in all natural (and/or modified) drainages, regardless of fish use, to be sure that no crossings were missed during the inventory. Also, since streams are not walked during a road-based inventory, it may be difficult to determine fish use during the site visit.

Contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov, to arrange for training or for technical assistance with evaluating road crossing structures.

3.1 Culverts – Data Collection

Conduct the following for each road culvert crossing encountered:

- Complete the Site Description Form found in Appendix C (see Chapter 2).
- Photograph the feature and the general setting.
- Record descriptive information and core physical measurements using the appropriate field forms found in Appendix C:
    - Culvert Level A Form for a culvert (data attributes explained in Table 3.1)
    - Culvert Level B Form, if necessary (data attributes explained in Table 3.2)
    - Associated Fishway Form, if fishway is present (Chapter 7)
- Proceed to Culvert Barrier Analysis.
- If culvert is a fish passage barrier and prioritization for barrier correction is desired, then conduct habitat assessment (Chapter 9)

Safety Considerations

Due to safety considerations, do not enter the culvert to collect this information. When measuring the water depth inside the culvert, stand at the downstream end of the culvert and measure the depth an arms length inside of the culvert. Always use extreme caution when working in and around the stream due to the instability of stream banks and the slippery nature *of the streambed. Safety considerations always override the data collection protocol outlined in this manual. It is recommended that eye protection be worn by field personnel due to the risk of eye injury from streamside vegetation.*

Multiple Culverts

When multiple culverts are encountered at a single site, complete one site form (Chapter 2) and complete culvert forms (Tables 3.1 and 3.2) for each non-overflow culvert, using the culvert number to distinguish between culverts. If the culverts are set at approximately the same elevation (non-overflow pipe) then add their widths together to calculate the culvert span to channel width ratio. If one or more culverts are set significantly higher[1] than the other culvert(s), then only use the lower culvert(s) in the barrier assessment. The higher elevation culvert is considered an overflow culvert and should only be noted in the comments (see examples of overflow culverts in Figure 3.1). The overflow culverts generally contain flow only during high flow periods.

Figure 3.1. Examples of overflow culverts.

Physical Measurements

Figure 3.2 shows examples of different culvert descriptors and physical measurements. The information in Table 3.1 must be collected for a Level A analysis and the information in Tables 3.1 *and* 3.2 must be collected for a Level B analysis. Figure 3.3 shows where to measure different channel widths.

An example of a culvert evaluation field form can be found in Appendix C. It is advisable to initially collect only the information in Table 3.1 and conduct the Level A analysis while at the site. This will often determine the barrier status without using the parameters needed for a Level B analysis.

If the barrier status of the culvert is not determined by the Level A analysis, proceed with the collection of field data required for the Level B analysis (Table 3.2). The actual Level B analysis is conducted in the office using the Level B spreadsheet. Please read Section 3.2 carefully to understand when it is necessary to collect the data outlined in Table 3.2.

[1] "Significantly higher" is defined as when the upstream invert elevation is greater than the upstream invert elevation of the lower culvert plus 50% of the lower culvert's rise.

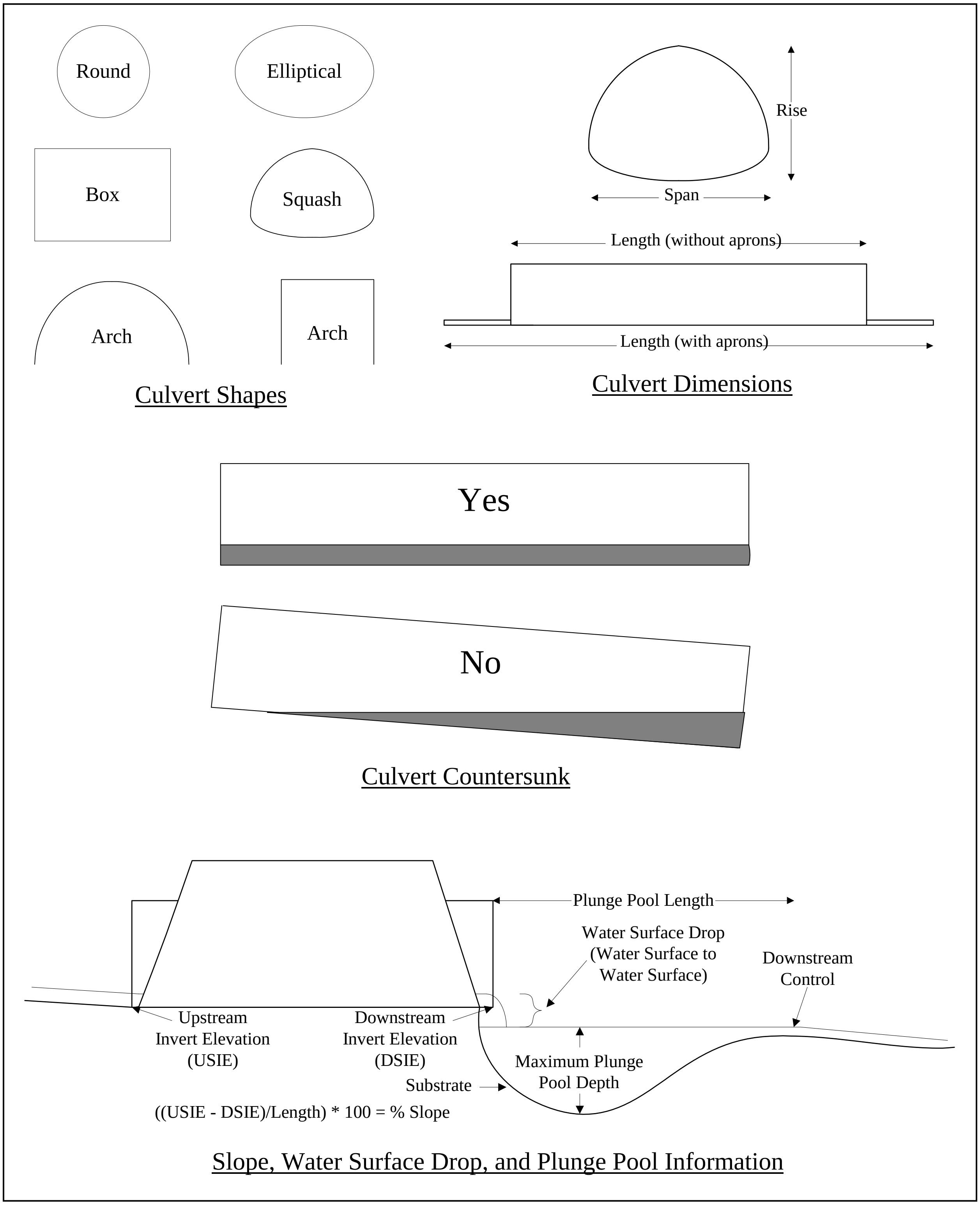
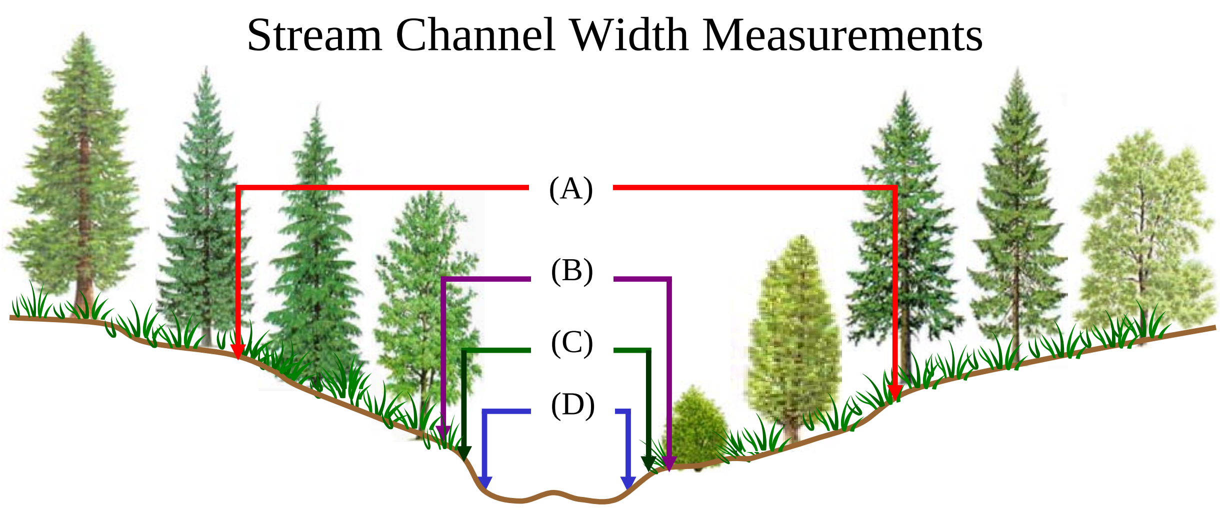


Figure 3.2. Examples of culvert descriptors and physical measurements.



Legend: *Not to Scale*

A) Floodplain

Indicators: vegetation tolerable to intermittent flooding; wood debris and loose soils (such as silt or sand) may be present from recent flood events; salmonids may occupy area during flood events.

B) Channel Width

Indicators: topographic breaks along banks; change to upland vegetation; stage where water just begins to overflow into active floodplain.

C) Scour Line Width

Indicators: bank scour or erosion; debris, pollen or silt line; coarse stream materials may be present; vegetation changes from predominantly emergent to predominantly terrestrial; salmonid spawning and/or rearing habitat available.

D) Toe Width

Indicators: Indicators: streambed material present; emergent/aquatic vegetation; wetted during periods of flow; salmonid spawning and/or rearing habitat present.

Figure 3.3. Examples of stream channel width measurements.

Table 3.1. Data collection attributes for the **Culvert Level A Form** (Appendix C). Predefined field values are indicated in **bold** text.

Form Field Name	Description
Site ID	Unique identifier for each stream crossing. Must be identical to the Site ID for the site.
Culvert Number	Identifies individual culverts at multiple culvert stream crossings. Format X.Y, where X = specific culvert number and Y = total number of culverts in crossing. For example, at a triple culvert crossing, the first pipe would be 1.3, the second 2.3 and the third 3.3. Used in conjunction with Site ID to create a unique record ID. If culverts are subsequently added to the site, the second digit of the sequencer must be updated for each culvert to reflect the increased number.
Data Source	Name of group or agency reporting the feature data.
Field Crew	Last names of individuals responsible for collecting field data on culverts. Separate names with a semicolon. (e.g. Johnson;Collins)
Field Review Date	Date of the field review. **MM/DD/YYYY** format.
Shape	Specifies the shape of the culvert using one of the following codes: **RND** = round, **BOX** = rectangular or square, **ARCH** = bottomless arch, **SQSH** = squash (pipe arch), **ELL** = ellipse, **OTH** = other. See Figure 3.2 for examples of different culvert descriptors and physical measurements.
Material	Specifies the material the culvert is constructed of using one of the following codes; **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.
Span	The horizontal dimension of the culvert. Expressed in meters to the nearest 0.01. Used in conjunction with Channel Width to calculate Culvert Span to Channel Width Ratio.
Rise	The vertical dimension of the culvert. Expressed in meters to the nearest 0.01. For round culverts, this value will be the same as the span. *For countersunk culverts, if bottom of structure cannot be determined, then measure from top of culvert to top of streambed and explain in comments.*
Water Depth In Culvert	Depth of water inside the culvert, measured at the downstream end. Expressed in meters to the nearest 0.01.
Water Surface Drop	Distance from the water surface at the downstream end of the culvert to the water surface of the plunge pool. Water surface drop can also occur within the culvert and at the culvert inlet. Expressed in meters to the nearest 0.01.
Drop Location	Location of water surface drop. Inlet, Outlet, Interior. *Indicate in the comments section if water surface drop occurs at more than one location.*
Length	The length of the culvert measured in meters to the nearest 0.1. Include aprons if present.
Slope	Slope of the culvert, reported in percent (*e.g.* 4.3). May be positive or negative number.
Countersunk	Indicates whether the culvert is countersunk in the streambed. For the culvert to be considered countersunk, the downstream culvert bottom must be embedded (countersunk) below the channel bed by a minimum of 20% of the culvert diameter or rise, and streambed material must be present *throughout* the length of the culvert. Values are **Yes** or **No**.

Table 3.1 (continued). Data collection attributes for the **Culvert Level A Form.**

Form Field Name	Description
Apron	Indicates presence and location of an apron. Values are **No =** none, **US =** upstream**, DS =** downstream, **BE =** both ends.
Tidegate	Indicates presence of a tidegate or floodgate. Values are **Yes** or **No.**
Fishway Present	Indicates the presence of a Fishway. Values are **Yes** and **No**.
Baffle Number	Number of baffles in the culvert.
Baffle Type	Type of baffle. Values include **Concrete**, **Metal**, **Wood**, **Rock**, **Plastic**, and **Other**.
Road Fill Depth	Depth of road fill over culvert.. Measured in meters to nearest 1.0.
Plunge Pool Length	Distance from the outlet of the culvert to the downstream control. Measured in meters to the nearest 0.01.
Plunge Pool Depth	Maximum depth of plunge pool. Expressed in meters to the nearest 0.01.
Plunge Pool Scour Line Width	Width of the plunge pool at its widest point measured at the scour line width. Expressed in meters to the nearest 0.01.
Channel Width	The average width of the stream channel, or "channel width". Typically measured at the second riffle downstream of the culvert. Used in conjunction with culvert span to calculate Culvert Span to Channel Width Ratio. See Figure 3.3 for an example of different channel width measurements for a typical stream channel.
Culvert span to Channel Width Ratio	The ratio of the culvert width (span or diameter) to channel width. Derived by dividing culvert span by the average channel width. If multiple culverts are present at the site, use the sum of all culvert spans divided by the average channel width. Expressed as a decimal fraction between 0 and 1.
Barrier	Results of the Level A or B fish passage assessment. Values are **Yes** = culvert is a barrier; **No** = culvert is not a barrier; **Unk** = unknown**.**
Method	Assessment method used to determine barrier status (culverts only). Values are **Level A, Level B**, **Other**, and **Fishway** (**FW**).
Percent Passable	Percent passability of features located in fish bearing streams. Values are **0, 33, 67, 100**. This value is used in the PI model to derive B (proportion of fish passage improvement). Refer to Table 3.3 criteria for assigning passability to culverts that are assessed as barriers.
Significant Reach	Indicates the presence of a significant reach of habitat. Defined as 200 meters of habitat free of any natural barriers upstream and downstream of the feature. Values are **yes**, **no**, and **unknown**.
Problem	Factor that determined barrier status. Applies only to barrier culverts. Values include **WS Drop, Slope, Velocity, Depth, Tidegate (floodgate), Debris and Other.** Enter WS Drop if the measured water surface drop is > 0.24m or enter slope if the slope is > 1% (Level A analysis). The results of the hydraulic analysis (Level B) will indicate whether water depth or velocity do not meet the WAC criteria. Choice dependent on Method.
Culvert Comments	Concise comments and explanation of any attribute where **Other** or **Unknown** was selected.

Table 3.2. Data collection attributes for the **Culvert Level B Form** (Appendix C). Predefined field values are indicated in **bold** text.

Form Field Name	Description
Site ID	Unique identifier for each stream crossing. Must be identical to the Site ID for the site.
Field Crew	Last names of individuals responsible for collecting field data on culverts. Separate names with a semicolon.
Field Review Date	Date of the field review. **MM/DD/YYYY** format.
Datum	Reference Point Datum. Specify the datum of the reference point (benchmark). Expressed in meters to the nearest 0.01. May be an established datum or a local assumed datum (e.g. 100).
Datum Location	Reference Point Location. Describe the location of the survey reference point (benchmark).
Basin Area	Total drainage area above feature. Reported in square miles to the nearest 0.01. Calculate from 7.5-minute USGS quadrangles or by using computer mapping software.
Basin Precipitation	Average annual or 2-year 24-hour precipitation dependent on region. See Average Annual Precipitation map of Washington (Appendix H).
Corrugation	Dimensions of culvert corrugations. Used in the hydraulic model to determine roughness coefficient. Dimensions are depth by width (peak to peak), measured in inches. The following three corrugations will cover 95% of corrugated pipes; **0.5 x 2.66**, **1 x 3**, and **2 x 6**. If different specify using the same format. For concrete culverts, enter **Concrete**. If the corrugations at the culvert invert are completely covered with asphalt or concrete, enter **Paved.** For non-corrugated pipes, enter **Smooth**. Anything else, enter **Other** and explain in comments.
Upstream Invert Elevation	Culvert Invert Elevation - Upstream. Elevation of the culvert bottom (invert) at the upstream end. Expressed in meters to the nearest 0.01. See Figure 3.2.
Upstream Culvert Bed Elevation	Culvert Streambed Elevation - Upstream. The surface elevation of any streambed material inside the culvert at the upstream end. Expressed in meters to the nearest 0.01. Used to determine culvert bed slope and actual flow area in hydraulic model. If streambed material is not present, then leave blank. See Figure 3.2.
Downstream Invert Elevation	Culvert Invert Elevation - Downstream. Elevation of the culvert bottom (invert) at the downstream end. Expressed in meters to the nearest 0.01. See Figure 3.2.
Downstream Culvert Bed Elevation	Culvert Streambed Elevation - Downstream. The surface elevation of any streambed material inside the culvert at the downstream end. Expressed in meters to the nearest 0.01. Used to determine culvert bed slope and actual flow area in hydraulic model. If streambed material is not present, then leave blank. See Figure 3.2.
Downstream Control Cross -Section	The downstream control is typically the head of the first riffle below the culvert (3 – 10m downstream). The cross section is derived from 7 points (stations) across the channel. Data is recorded for each station in distance and elevation. Start at the top of the left bank (Top LB), looking downstream, and work to the right. Measure elevations at the top of each bank, each toe, the thalweg, and other grade breaks. The distance value for Top LB will always be 0. Values for the other stations will be the distance in meters measured to the nearest 0.01 from Top LB. Elevations are measured in meters to the nearest 0.01. Each station and elevation is a separate field in the associated table. Fields Dsst0 - Dsst6 contain the distances and fields Dsel0 – Dsel6 contain the elevations. See Figure 3.7 for an example of different cross-section channel measurements for a typical stream channel.

Table 3.2. (continued). Data collection attributes for the **Culvert Level B Form** (Appendix C).

Form Field Name	Description
Downstream Control Water Surface Elevation	Elevation of the water surface at the downstream control. Measured in meters to the nearest 0.01. Derived by adding the average water depth to the bed elevations at the control. See Figure 3.7.
Scour Line Width (SLW) Elevation at the Downstream Control	Elevation of the scour line at the downstream control. Measured in meters to the nearest 0.01. See Figure 3.3 for an example of different channel width measurements for a typical stream channel.
Water Surface Elevation 15m Downstream of Downstream Control	Water surface elevation at the channel centerline, 15m downstream of the downstream control. Measured in meters to the nearest 0.01. Derived by adding Downstream Bed Elevation and water depth. Used in hydraulic model. Also used in conjunction with upstream water surface elevation to estimate stream gradient through the reach.
Channel Substrate	Best description of the dominant substrate in the channel between the downstream control and the point 15m downstream of the downstream control. Values are; **riprap**, **boulder**, **cobble**, **gravel**, **sand**, **mud**, and **bedrock**. Needed for the hydraulic model.

Table 3.3. Criteria for assigning passability to culverts that are assessed as barriers. When more than one parameter applies, use the more restrictive passability value.

Parameter	Value	Range	Passability
Water Surface Drop	≥0.24 meters	≥0.24 m & <0.5 m	0.67
		≥0.5 m & <1.0 m	0.33
		≥1.0 m	0
Slope (Culverts ≤18.3 meters length)	≥1.0%	≥1.0% & <2.0%	0.67
		≥2.0% & <4.0%	0.33
		≥4.0%	0
Slope (Culvert >18.3 meters length)	≥1.0%	≥1.0% & <2.0%	0.33
		≥2.0%	0
Velocity (Level B Result)	Exceeds WAC 220-110-070 velocity criterion for 15 cm (6 inch) trout <u>Culvert Length (m) Velocity (mps)</u> <30.5 ≤1.22 30.5-61.0 ≤0.91 >61.0 ≤0.61	<0.61 mps over criterion for 15 cm trout	0.67
		≥0.61 mps over criterion for 15 cm trout	0.33
Depth (Level B Result)	**<0.30 meters**	**≥0.15 m & <0.30 m**	**0.67**
		≥0.05 m & <0.15 m	0.33
		<0.05 m	0
Tidegate or Floodgate	Gate Style	Flap gate	0
		Self-regulating	0.33

Survey Techniques

Performing a Level A or Level B analysis requires taking a number of measurements using basic surveying techniques. The survey techniques discussed below provide basic instructions for measuring culvert elevations. Appendix E provides detailed information on surveying techniques used to collect data for the Level A and Level B analysis. For more detailed instructions on surveying, including making multiple turning points and moving the level, WDFW recommends consulting one of the many basic surveying books available. Basic surveying techniques as related to barrier assessment are covered during the WDFW training.

Benchmark

Establish a benchmark at a location that is stable and easy to relocate. Select a location for the level that has good visibility upstream and downstream of the culvert. If such a location cannot be found then the level will have to be moved to obtain all the desired readings. Set up the level, place the stadia rod on the benchmark, and backsight to the benchmark. Normally the elevation of the benchmark is arbitrarily set at 100.00 meters.

Height of Instrument

If a standard level attached to a tripod is being used, take the reading off the stadia rod; add it to the benchmark elevation to get the instrument height. If a laser level is being used, read the vertical distance to the reflector. If the vertical distance is positive, subtract it from the reflector height and add the difference to the benchmark elevation to get the instrument height. If the vertical distance is negative, add it to the reflector height and add the sum to the benchmark elevation to obtain the instrument height.

Measuring Elevations

When taking streambed or culvert elevation readings using a standard level, subtract the reading from the stadia rod from the instrument height to get the elevation. When taking streambed or culvert elevations using the laser level, if the vertical distance is positive, subtract it from the reflector height and subtract the difference from the instrument height. If the vertical distance is negative, subtract it and the reflector height from the instrument height to get the desired elevation. If the reflector is mounted to an adjustable stadia rod, then record the height of the reflector if it is being moved up or down between measurements. Mounting the reflector to an adjustable rod can facilitate taking readings by moving the reflector up or down to avoid obstacles.

In some instances, it will not be possible to get all the elevations necessary without moving the level. If it is necessary to move the level, have the rod holder position the rod in a stable location (turning point) that is visible from the present location of the level and the location the level is to be moved. Get the elevation of the point at which the rod is located. Move the instrument to the new location and backsight to the rod to determine the new instrument height. Proceed with taking the necessary elevations. When all elevations have been taken, reverse the procedure that was followed to move the instrument and move it back to its original location. Check the elevation of the benchmark; it should be 100.00 meters. If it's not, then an error was made and the whole process should be repeated since the elevations are erroneous. In some locations, it may be necessary to have more than one turning point. Make sure to check for errors.

3.2 Culverts – Barrier Assessment

Barrier determination is a step-wise process of data collection and analysis. There are two barrier assessment methods for culverts, the Level A and Level B.

The Level A method, which evaluates hydraulic drop and slope, is the first level of assessment. This is where the data collection begins and most culverts fall out as barriers or non-barriers.

When barrier status cannot be determined using the Level A method, then the Level B method will be used to determine the barrier status of the culvert in question. The Level B analysis will indicate whether the culvert is a velocity or depth barrier, by evaluating flow and water depth.

Once the barrier assessment has been determined using either the Level A or Level B analysis, refer to Table 3.3 for guidance in estimating the percent passability for barrier culverts.

Level A Barrier Assessment

Follow this key for a Level A barrier assessment after all the information in Table 3.1 has been collected (also diagramed in Figure 3.4):

1. Is there a water surface drop > 0.24 meters at the inlet, outlet or anywhere inside the culvert?
   A) If yes, the culvert is a *barrier*, additional analysis is not required. Finish the measurements in Table 3.1. Refer to Table 3.3 for guidance in assigning percent passability estimate.
   B) If no, go to 2.

2. Is the culvert countersunk?
   A) If yes, go to 3.
   B) If no, go to 4.

3. If the culvert is countersunk, is the culvert width (span) at least 75% of the average channel width measured at a representative riffle located out of the influence of the culvert? *The channel width can be measured either downstream or upstream of the culvert, depending on which location is more representative of the stream reach within the culvert vicinity.*
   A) If yes, the culvert is *passable*, additional analysis is not required. Finish the measurements in Table 3.1.
   B) If no, proceed to the Level B analysis.

4. Is the culvert backwatered to the upstream end of the culvert? *A backwatered condition within a culvert is where a pool with little or no current exists throughout the entire length of the culvert.*
   A) If yes, proceed to the Level B analysis.
   B) If no, go to 5.

5. Is the culvert slope greater than or equal to 1%?
   A) If yes, the culvert is a *barrier***,** additional analysis not required. Refer to Table 3.3 for guidance in assigning percent passability estimate.
   B) If no, proceed to the Level B analysis.

Level B Barrier Assessment

The Level B analysis is applied when the barrier status of a culvert cannot be determined using the Level A analysis. The purpose of the Level B hydraulic analysis is to calculate the average velocity and corresponding depth in the culvert at the high fish passage design flow and compare the values to Table 1 in WAC 220-110-070 section 3(b)(ii) for Adult Trout in Appendix F. The values shown for velocity in Table 1 in the WAC are the maximum allowable average velocities within the culvert. If the culvert is not backwatered, the calculation can be done using Manning's equation for normal depth. Using normal depth ensures the maximum velocity will be calculated. If the culvert is backwatered, then a backwater analysis must be done to find the velocity.

Level B Applicability

1. Is there a grade break in the culvert?[1]

   A) If yes, then a Level B analysis is not possible and the barrier status is unknown.[2]

   B) If no, go to 2.

2. Is the culvert tidally influenced[3] or is there a large pond or wetland downstream of the culvert making it difficult or impossible to obtain the downstream control cross-section information?

   A) If yes, then a Level B analysis is not possible and the barrier status is unknown.

   B) If no, go to Level B (hydraulic) (Figure 3.5.)

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[1] This is sometimes the case where a culvert has been extended and the new section is installed at a different elevation or slope than the old culvert. This can also occur when a section of the culvert settles or a joint fails.

[2] In cases where the slope of any portion of the culvert exceeds 1% or the drop inside the culvert exceeds 0.24 meters, then it can be categorized as a barrier. If the slope does not exceed 1% and the drop does not exceed 0.24 meters, or if these parameters cannot be measured, then the barrier status of the culvert is unknown and a higher level of analysis is required.

[3] Presently there is no protocol for evaluating tidally influenced culverts. For tidally influenced culverts, an independent analysis of tidal influence and streamflow is needed. If a culvert is tidally influenced, then passability is unknown until a tidal analysis is completed.

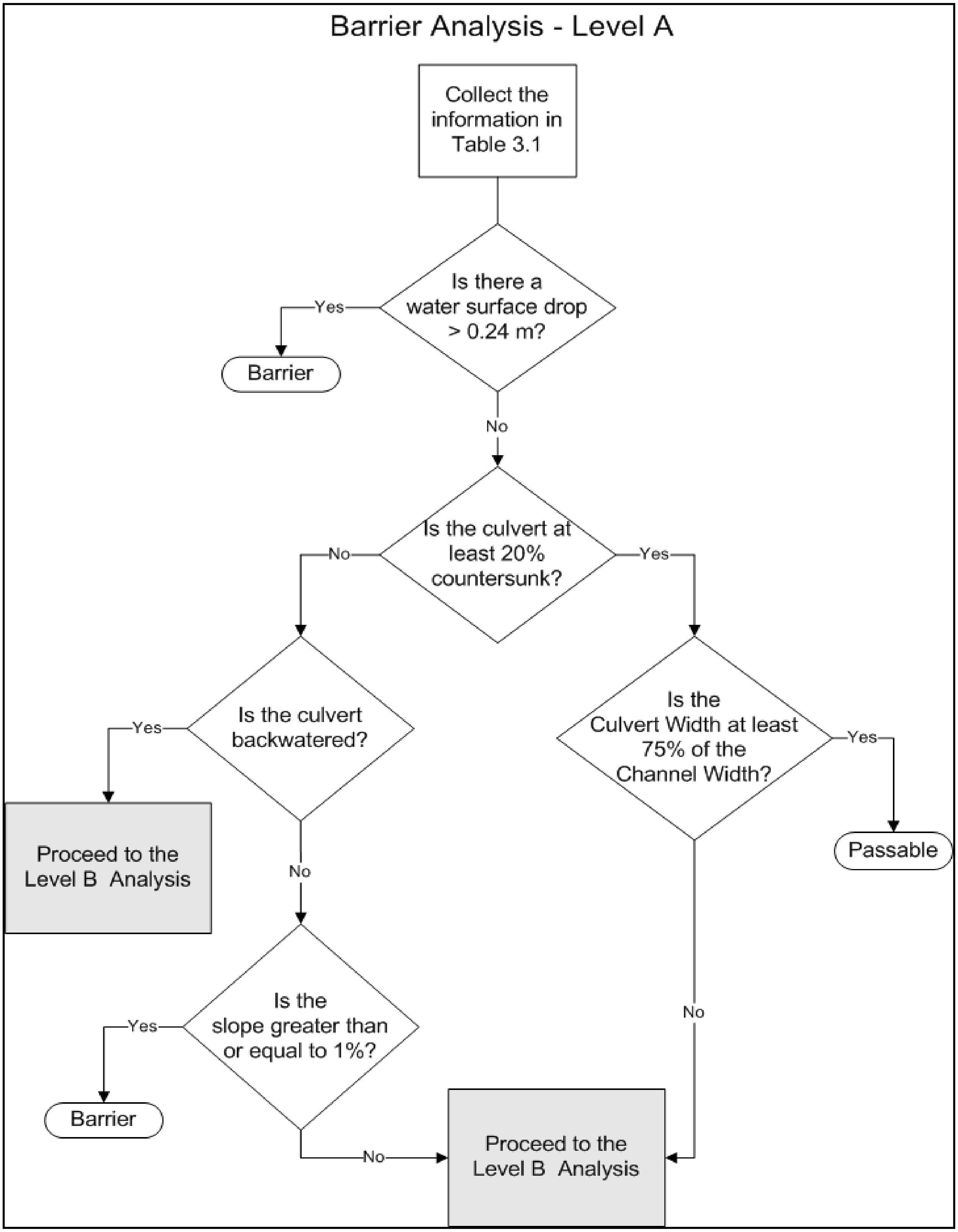


Figure 3.4. Flow chart of the Level A culvert analysis.

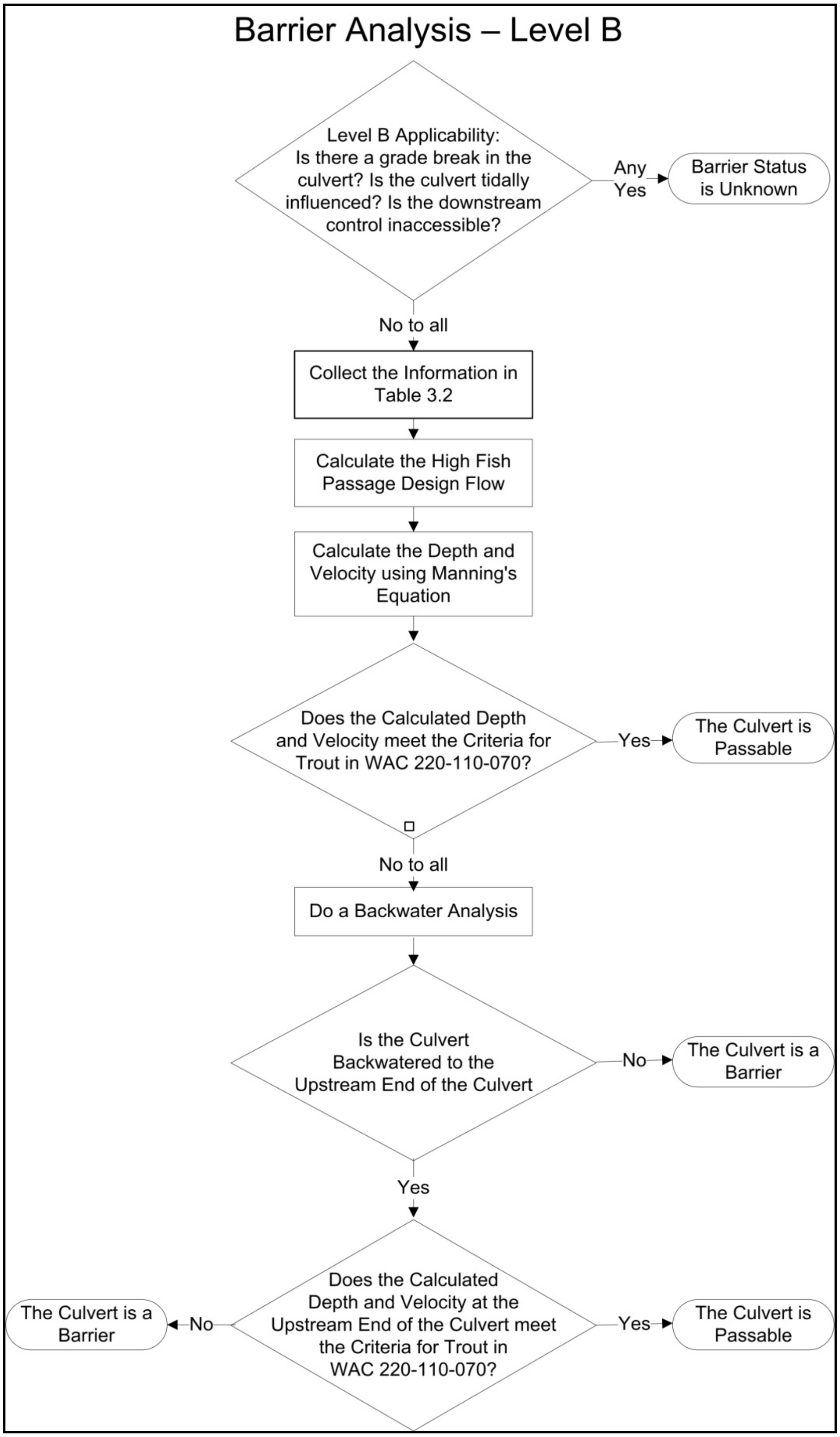


Figure 3.5. Flow chart of the Level B culvert analysis.

Steps for a Level B Analysis

Step 1) Collect field data for a Level B Analysis (Table 3.2).

Step 2) Calculate the high fish passage design flow. *Note: the Level B spreadsheet does this for you.*

Step 3) Calculate the flow characteristics of the stream channel at the high fish passage design flow.

Step 4) Evaluate flow in the culvert, without backwater. Using Manning's Equation calculate flow velocity and depth, and compare to the allowable velocity and depth from Table 1 in the WAC (Appendix F).

Note: If the calculated velocity is less than the allowable velocity from Table 1 in the WAC, and the depth greater than or equal to the required depth from Table 1 in the WAC, then the culvert is considered passable. If the calculated velocity is greater than the allowable velocity or the depth is less than required, then the culvert needs to be checked for backwater.

Step 5) Evaluate flow in the culvert, with backwater (if applicable). If the culvert is backwatered (i.e. the depth at the outlet is greater than the depth calculated from Step 4 -Manning's Equation), then proceed with the backwater calculation. Perform the backwater analysis computation starting at the culvert outlet and proceeding upstream in increments until normal depth or the culvert inlet is reached. If the normal depth is reached before the backwater analysis reaches the culvert inlet (fully backwatered), then the maximum velocity and corresponding depth would be the same as calculated from Step 4 (Manning's Equation). If the culvert is fully backwatered, then select the velocity and depth at the station nearest the upstream end of the culvert.

Step 6) If the culvert is a barrier, refer to Table 3.3 for guidance in estimating the percent passability, used in the Priority Index (PI) equation.

The velocity and depth values in Steps 2 through 5 can be calculated by hand or using commercially available software. WDFW has prepared a spreadsheet for making these calculations. This spreadsheet can be accessed at: http://wdfw.wa.gov/hab/engineer/fishbarr.htm.

The following files are available online for use; examples are presented in Appendix G:

LvlBMet.xls	Excel 97 for Windows, Metric Units version
LvlBEng.xls	Excel 97 for Windows, English Units version

ExampleOneLvlB.Barrier.xls	Example 1, Level B barrier
ExampleTwoLvlB.Pass.xls	Example 2, Level B passable

The spreadsheet has step-by-step directions, beginning on the Instruction page. The spreadsheet may provide inaccurate results if the instructions are not followed.

The spreadsheet is capable of calculations for round, box and pipe arch culvert shapes. Backwater is analyzed with the Direct Step method (distance calculated from depth) from Chow (1959). The calculation starts at a control point (culvert outlet) and proceeds upstream until the normal depth calculated by Manning's Equation is reached. A detailed description of how to use the spreadsheet is in Appendix G.

3.3 Culvert Conditions that Make Assessment Difficult

There are a number of site conditions that make it impossible to conduct the Level A and Level B assessments, or require a more sophisticated analysis than the Level B spreadsheet is capable of. These conditions are addressed below. Contact WDFW for assistance evaluating difficult culverts.

Culverts in Tidal Areas

Currently there is no barrier assessment protocol for tidally influenced culverts. Given the variable conditions of tidally influenced culverts the Level A and Level B assessment methods are not applicable. At this time WDFW suggests that all level A information be collected and photos taken of the culvert outlet at both low and high tide (if possible) and forwarded to WDFW.

Culverts with Tidegates or Floodgates

Tidegates and floodgates are often installed on culverts located in dikes or levees to maintain low water conditions behind the dike or to prevent saltwater intrusion. In this manual, both tidegates and floodgates will be referred to as "tidegates". If a culvert has a tidegate attached, fill out the culvert form, check the 'yes' box for tidegate present, and describe the tidegate in the comments section. Flap gates, swing gates, automatic slidegates, "pet-door" style, and pinch valves are styles of devices used as tide and floodgates (see Figure 3.6 for photo examples of gate styles).

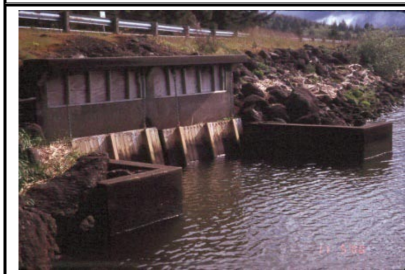
When tidegates are partially or completely closed they are barriers to fish migration, because they block adult salmonids from accessing upstream habitat on the incoming tide and limit passage for juvenile and adult salmonids at other times. Most are also a barrier to migration when they are open because they don't open far enough or frequently enough, they may be perched too high, and/or the water velocity is too high.

In some cases a tidegate may be specially designed to provide for improved fish passage, such as an automatic ("self-regulating") tidegate. 'Automated settings' refers to when the tidegate is adjusted to open or close relative to the tidal elevation. While these types of tidegates may provide improved passage conditions over a traditional tidegate, they may still delay or block passage during some fish migration periods, depending upon the automated settings, management and maintenance of the tidegate. Therefore, when conducting a fish passage inventory, if a tidegate is present, regardless of the gate style, consider the feature to be a barrier and refer to Table 3.3 for guidance on evaluating the passability.

Flap Style Gate

Flap Style Gates

Flap Style Gate



Hanging, Wooden Flap Gates

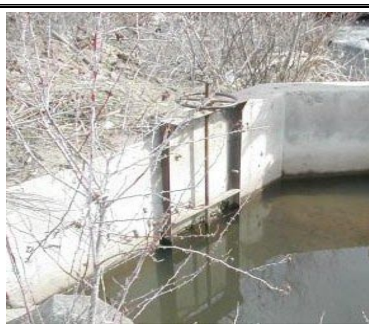
Wooden Slide Gate

Wooden Slide Gate

Swing Gate Style Automatic Gate

Swing Gate Style Automatic (Self-regulating)

Swing Gate Style Automatic (Self-regulating)



Screw Valve Style Gate

Screw Valve Style Gate

Control for Screw Valve Gate

Figure 3.6 Photo examples of tide and flood gate styles.

Culverts with Flow Control Structures

Culverts equipped with a flow control structure intended to impound water, such as a vertical standpipe, flash-board riser (also referred to as a “half-round riser”), or slidegate, should be evaluated as dams (Chapter 4).

Culverts with Associated Fishways

For culverts equipped with a fishway, including baffled culverts, collect all culvert data and proceed to fishway data collection (Chapter 7). Fish passage barrier determination is based on the fishway evaluation. See Chapter 7 for data collection and fish passage evaluation for fishways.

Downstream Control is Inaccessible

In cases where the culvert discharges immediately into a wetland, pond, lake, reservoir, or larger stream, the downstream control may be inaccessible or nonexistent. In these situations, collect the Level B information and measure the water surface elevation at the point where the culvert discharge enters the receiving water (for example, the wetland or larger mainstem stream).

Altered Watercourses that Lack an Obvious Downstream Control

Some streams have been modified to accommodate agricultural or other human land practices and often have uniform channels lacking an obvious downstream control, making it difficult to collect Level B data. In these cases collect the normal Level B data and measure a representative downstream cross section within the first few meters downstream of the culvert. See Figure 3.7 for an example of downstream cross section measurements.

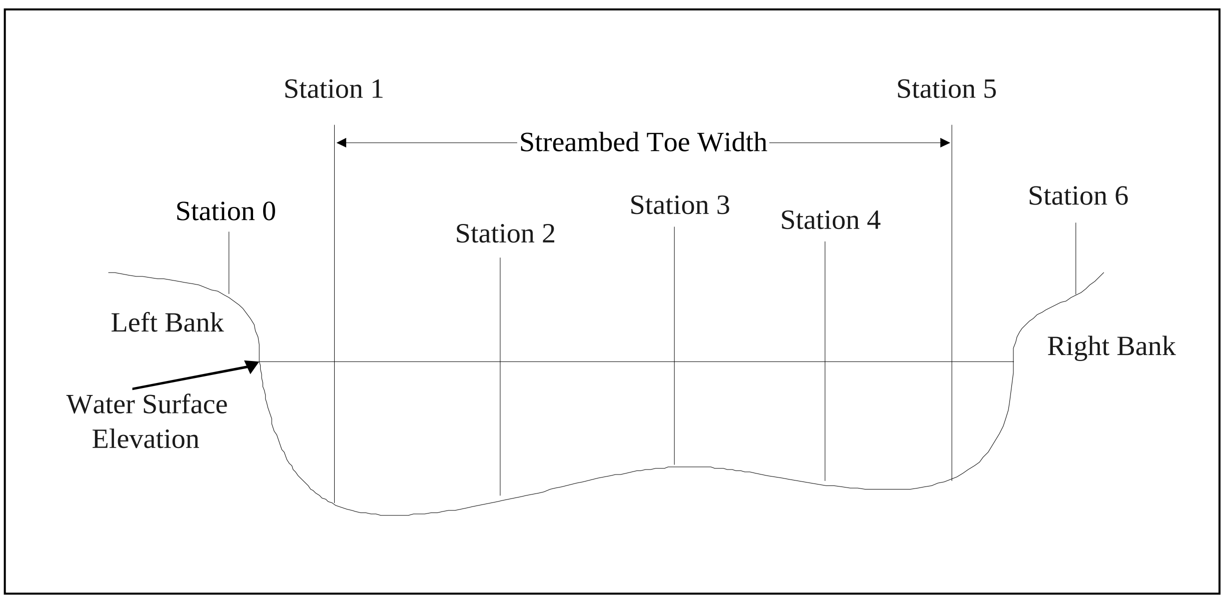


Figure 3.7. Example of Level B cross section measurements.

Assessing Multiple Culverts
The Level B spreadsheet cannot assess multiple culverts. Collect the Level B information and analyze using commercially available software or forward the culvert information to WDFW for analysis.

Countersunk Culverts
Countersunk culverts have bed material throughout and cannot be evaluated using the Level B spreadsheet. Collect the Level B information and analyze using commercially available software or forward the culvert information to WDFW for analysis.

Culverts with Zero or a Negative Slope
The Level B spreadsheet cannot be used on culverts with a zero or a negative slope. Collect the Level B information and analyze using commercially available software or forward the culvert information to WDFW for analysis.

Culverts with an Internal Grade Break
A grade break is a condition where there is a slope change or vertical drop within the culvert; this can occur when a culvert has been extended or a portion of the culvert settles. The culvert is considered a barrier using the Level A analysis if the vertical drop exceeds 0.24 m or if the culvert slope exceeds 1%. A Level B analysis cannot be done when there is a grade break within the culvert.

3.4 Non-culvert Road Crossings – Data Collection

Non-culvert crossings, such as bridges and stream fords, are frequently encountered in the field, especially as culverts are replaced or removed altogether. Other types of non-culvert crossings encountered may be washed-out or abandoned road crossings, and puncheon crossings. Figure 3.8 shows photo examples of some common non-culvert road crossings.

In addition to the site information in Table 2.1 from Chapter 2, complete the Non-culvert Road Crossing Form found in Appendix C. Data attributes for non-culvert road crossings are summarized in Table 3.4.

Identifying Washed-out and Abandoned Road Crossings
Observing some general stream site conditions may indicate the difference between a washed-out crossing and an intentionally abandoned road crossing. A washed-out road crossing occurs during a catastrophic event (e.g. severe flooding, plugged culvert, etc.); often the former crossing structure is found in the vicinity, the streambanks are disturbed, and the stream channel may be incised. An abandoned crossing occurs when a road is formally decommissioned (such as during a forest practices road abandonment management plan). Abandoned road crossings are designed, permitted, and constructed to remove the crossing structure entirely from the stream channel, remove the associated road fill, and stabilize and restore the adjacent stream banks and channel.

3.5 Non-culvert Road Crossings – Barrier Assessment

Barrier determinations for non-culvert road crossings depend on the type of feature present. When evaluating passability, consider the criteria for water surface drop, slope, velocity and depth, outlined in Table 3.3 in this chapter. In addition, if the structure is physically blocking the stream then it is a barrier.

Table 3.4. Field descriptions for the **Non-culvert Road Crossing Form** (Appendix C). Predefined field values are indicated in **bold** text**.**

Field Form Name	Description
Site ID	Unique identifier, must be identical to the Site ID for the site.
Data Source	Name of group or agency reporting the feature data.
Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon.
Field Review Date	Field review date. **MM/DD/YYYY**
Crossing Type	Brief description of feature or structure. Values include **bridge**, **ford**, **fill**, **puncheon**, **abandoned**, **washout**, and **undefined**.
Fishway Present	Indicates the presence of a Fishway. Values are **Yes** or **No**.
Barrier	Results of fish passage evaluation - barrier determination. Values are; **Yes** = feature is a barrier; **No** = feature is not a barrier; **Unk** = barrier status unknown.
Percent Passable	Percent passability of barrier features based on field crews professional judgment. Values are **0, 33, 67**, and **100**. This value is used in the PI model to derive B (proportion of fish passage improvement).
Significant Reach	Indicates the presence of a significant length of habitat. Defined as 200 meters of unobstructed habitat upstream and downstream of the feature. Values are **Yes**, **No**, and **Unk**.
Comments	Brief description of this feature and explanation of any attribute where **other** or **unknown** was selected.

Bridge

Bridge

Washed-out culvert

Abandoned Road Crossing

Puncheon (dilapidated)

Stream Ford

Figure 3.8 Photo examples of some common non-culvert road crossings.

3.6 Additional Reading

Bates, K.; Barnard, R.; Heiner, B.; Klavas, P.; Powers, P. 2003. Design of Road Culverts for Fish Passage. Washington Department of Fish and Wildlife. Olympia, Washington. http://wdfw.wa.gov/hab/engineer/cm/

3.7 References Cited

Chow, V.T. 1959. Open Channel Hydraulics. McGraw-Hill Book Company Inc. 680 pp.

CHAPTER 4

Revised 12/21/09

DAMS

A dam is any human-made structure built to impound or divert water that results in an abrupt change in water surface elevation. For example, a concrete water diversion structure resulting in a 1-meter drop in water surface is considered a dam. Water may be impounded for numerous purposes, including hydroelectric power, irrigation, recreation, and wildlife habitat.

For technical assistance with these methods for evaluating dams for fish passage, contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov.

4.1 Data Collection and Barrier Assessment

Do the following for each dam encountered:

- Complete the Site Description Form found in Appendix C (described in Chapter 2).
- Photograph the feature.
- Complete the Dam Form found in Appendix C.
- Complete associated feature forms, if necessary (such as fishways, see Chapter 7, or, diversions, see Chapter 8).
- Evaluate for fish passage.
- If dam is a fish passage barrier, and prioritization for barrier correction is desired, then conduct habitat assessment (Chapter 9).

Data Collection

Table 4.1 summarizes the data collection attributes for a dam feature. Figure 4.1 shows photo examples of different types of dam structures.

If the dam is associated with a fishway to facilitate fish passage then collect fishway data as outlined in Chapter 8. If the dam is associated with a surface water diversion, then collect the diversion data outlined in Chapter 9 and evaluate fish screening.

As discussed in Chapter 3, culverts equipped with a flow control structure, such as a vertical standpipe, half-round riser, headgate, or slidegate should be evaluated as dams.

Table 4.1. Data collection attribute descriptions for the **Dam Form** (Appendix C). Predefined field values are indicated in **bold** text.

Form Field Name	Description
Site ID	Unique identifier, must be identical to the Site ID for the site.
Data Source	Name of group or agency reporting the feature data.
Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon.
Field Review Date	Field review date. **MM/DD/YYYY**
Dam Name	Recorded legal name or local name.
Reservoir Name	Recorded legal name or local name.
Primary Purpose	Primary purpose of dam, values include, **D** = debris control, **C** = flood control, **H** = hydroelectric, **I** = irrigation, **N** = navigation, **P** = stock or farm pond, **Q** = water quality, **R** = recreation, **S** = water supply, **T** = tailings, **O** = other, **F** = fish propagation, **W** = wildlife habitat.
Dam Type	Type of dam, values include **CN** = concrete, **RE** = earth fill, **MS** = masonry, **MT** = metal, **ER**= rock fill, **TB** = timber, and **OT** = other.
Fishway Present	Indicates the presence of a Fishway. Values are **Yes** or **No**.
Outlet Type	Describes the outlet conditions at the dam. Values are **Spillway**, **Standpipe**, **Flashboard Riser** and **Culvert.**
Operation Timing	Indicates the duration of time that the dam is in operation. Values are **Year Round** and **Seasonal**.
Dam Span	Extent to which the dam extends across the stream, **Full** or **Partial.**
Dam Height	The height from the front base of the dam, to the crest in meters (0.01).
Dam Length	Length of the dam, bank to bank, in meters (0.1).
Water 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 in meters (0.01). If the dam is equipped with a standpipe, leave blank.
Plunge Pool Depth	Depth of plunge pool below dam in meters (0.01).
Barrier	Results of fish passage evaluation - barrier determination. Values are; **Yes** = dam is a barrier; **No** = dam is not a barrier; **Unk** = dam is of unknown barrier status.
Percent Passable	Percent passability of features located in fish bearing streams. Values are **0, 33, 67, and 100**. This value is used in the PI model to derive B (proportion of fish passage improvement).
Significant Reach	Indicates the presence of a significant reach of habitat. Defined as 200 meters of habitat free of natural barriers upstream and downstream of the feature. Values are **Yes**, **No**, and **Unk**.
Description	Description of the dam and any problems associated with it.

Table 4.1. (continued). Data collection attribute descriptions for the **Dam Form** (Appendix C).

Form Field Name	Description
Comments	Concise comments and explanation of any attribute where **Other** or **Unknown** was selected.

Fish Passage Barrier Determination

Barrier determination is based upon the difference in the water surface elevations above and below the dam. If the water surface difference at the dam is greater than 0.24 meters, it is a barrier. Table 4.2 provides guidance on making passability estimates at dams that are barriers.

Dams may impound water year-round or seasonally. If a dam appears to be temporarily breached during the site visit, then passability is unknown. If possible, 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.

Flashboard Risers

Sometimes culverts, such as half-round risers or boxes, have slots for removable wooden boards to control water elevations behind the structure. Since these structures are intended to impound water, they are considered dams. The structure is considered a barrier whenever the boards are put in place and there is a 0.24 m hydraulic drop. If the boards are not in place during the site visit, then the fish passage status for the dam is 'unknown'.

Headgates or Slidegates

Structures equipped with either a headgate or slidegate are considered barriers whenever the gate is closed. If a culvert is equipped with a headgate or slidegate, and the gate is open, then collect the culvert data and evaluate using the Level A Analysis. If the culvert is evaluated as a Level A barrier, then consider the dam a fish passage barrier. Otherwise, the barrier status is 'unknown', unless you know how the facility is managed.

Table 4.2. Criteria for assigning passability to dams that are assessed as barriers.

Parameter	Value	Range	Passability
Water Surface Drop	≥0.24 meters	≥0.24 m & <0.5 m	0.67
		≥0.5 m & <1.0 m	0.33
		≥1.0 m	0

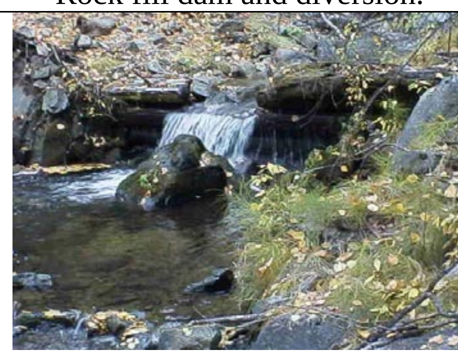
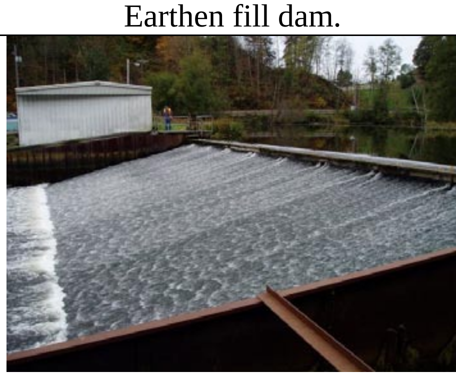
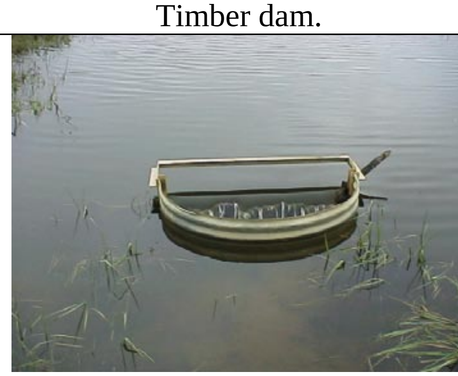
 Full span concrete dam with removable wooden boards.	 A concrete dam with a weir-pool fishway.
 Masonry dam.	 Rock fill dam and diversion.
 Earthen fill dam.	 Timber dam.
 Metal dam constructed of sheet pile.	 Water control structure dam (vertical standpipe with wooden flashboard riser).

Figure 4.1 Photo examples of dam structures.

CHAPTER 5

Revised 12/21/09

MISCELLANEOUS OBSTRUCTIONS

5.1 Miscellaneous Obstructions – Data Collection and Barrier Assessment

Features that are not culverts, fishways, dams, or water diversions are classified as other features or miscellaneous obstructions. Some examples include dikes/levees, erosion control structures, fill/debris, flumes, pipeline crossings, etc. When tidegates are not associated with culverts, then they are also treated as miscellaneous obstructions. Photo examples of some previously inventoried miscellaneous obstructions are found in Figure 5.1.

Data Collection for Miscellaneous Obstructions

For miscellaneous obstructions, also referred to as 'other' features, collect the following:

- Site information in Table 2.1 (Chapter 2); complete the Site Form (Appendix C).
- Feature information summarized in Table 5.1; complete the 'Other' field form found in Appendix C.
- Describe the miscellaneous obstruction in as much detail as possible and evaluate for fish passage.
- Complete additional field forms for associated features (e.g. fishway, diversion, etc), if necessary.
- Photograph the feature and the general site setting.

Fish Passage Assessment for Miscellaneous Obstructions

Barrier determinations for miscellaneous obstructions depend on the type of structure. When evaluating passability, consider the criteria for water surface drop, slope, depth, and accessibility through a physical blockage, as outlined in Table 5.2.

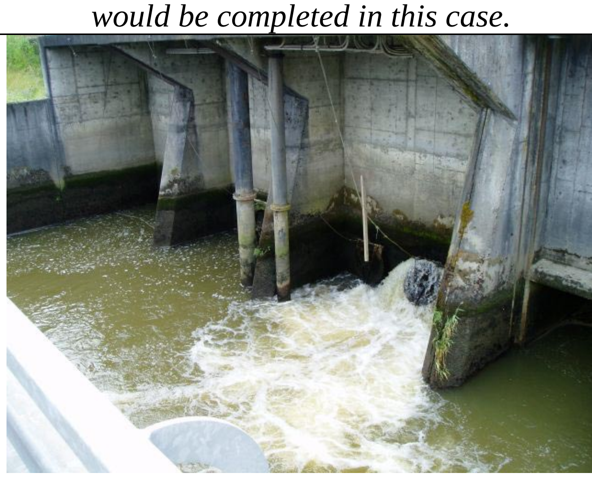
For assistance with evaluating the passability for miscellaneous obstructions, contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov.

Concrete flume.

Debris (riprap, boulders, and concrete) placed in channel to protect undersized foot bridge.

Concrete flume with baffles present. *Note: both the 'other' form and 'fishway' form would be completed in this case.*

Debris (rip-rap boulder jetty; stream flows through gaps in jetty)



Flood control structure equipped with several large pumps and six flood gates.

Pipeline crossing.

Figure 5.1. Examples of some previously inventoried miscellaneous obstructions.

Table 5.1. Data collection attribute descriptions for the **Other Form** (Appendix C). Predefined field values are indicated in **bold** text.

Field Form Name	Description
Site ID	Unique identifier, must be identical to the Site ID for the site.
Data Source	Contains name of group or agency reporting the feature data.
Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon.
Field Review Date	Field review date. **MM/DD/YYYY**
Other Type	Brief description of feature or structure. Values include**: Flume, Roughened Channel, Dike/Levee, Streambed Control, Hatchery, Tide/Flood Gate, Artificial Waterfall, Stormwater, Erosion Control, Fill/Debris, Lake Screen, Pipeline Crossing, Trash Rack, and Misc Obstruction.** May add additional types as encountered.
Fishway Present	Indicates the presence of a Fishway. Values are **Yes** or **No**.
Barrier	Results of fish passage evaluation - barrier determination. Values are; **Yes** = feature is a barrier; **No** = feature is not a barrier; **Unknown** = barrier status unknown,
Percent Passable	Percent passability of features located in fish bearing streams. Values are **0, 33, 67, and 100**. This value is used in the PI model to derive B (proportion of fish passage improvement).
Significant Reach	Indicates the presence of a significant reach of habitat. Defined as 200 meters of habitat free of natural barriers upstream and downstream of the feature. Values are **Yes, No**, and **Unknown**.
Description	Brief description of this feature and explanation of any attribute where OTHER or Unknown was selected.
Reason	Primary factor that determined barrier status. Values include **WS Drop, Depth, Tidegate or Floodgate,** and **Debris.**

Table 5.2. Guidance for estimating percent passability for miscellaneous obstructions.

Parameter	Value	Range	Passability
Water Surface Drop	≥0.24 meters	≥0.24 m & <0.5 m	0.67
		≥0.5 m & <1.0 m	0.33
		≥1.0 m	0
Slope (for concrete flume or other horizontal structure)	≥1.0%	≥1.0% & <2.0%	0.67
		≥2.0% & <4.0%	0.33
		≥4.0%	0
Depth in structure (when streamflow is present)	<0.30 m	<0.17 m	0
		≥0.17 m & <0.24 m	0.33
		≥0.24 m & <0.30 m	0.67
Tidegate or Floodgate	Gate Style	Flap gate	0
		Self-regulating	0.33

FISH PASSAGE BARRIER AND SURFACE WATER DIVERSION SCREENING ASSESSMENT AND PRIORITIZATION MANUAL

CHAPTER 6

Revised 12/21/09

NATURAL BARRIERS

6.1 Natural Barriers

Natural barriers encountered during watershed inventories are documented and evaluated similar to human-made features. Only natural barriers that are considered permanent or long-term are documented, including waterfalls, high gradient stream sections, or subsurface flow. Transitory features such as beaver dams and log jams are not documented for purposes of this manual. Natural instream features that are passable are not documented.

Data Collection for Natural Barriers

Conduct the following:

- Complete the Site Description Form found in Appendix C (see Chapter 2).
- Complete the Natural Barrier field form found in Appendix C (data attributes explained in Table 6.1).
- Complete the Fishway field form (Appendix C) if a fishway is present.
- Evaluate for fish passage.
- Photograph the feature and the general site setting.

Occasionally a fishway may be attached to a natural barrier in order to facilitate fish passage. If a fishway is present, complete the fishway form found in Appendix C. Refer to Chapter 7 for data collection attributes (Table 7.1) and evaluation protocols for fishways.

Fish Passage Assessment for Natural Barriers

Natural barriers, that would exclude most adult salmonids, are defined as:

- a waterfall > 3.7 vertical meters in height,
- a stream reach having a sustained gradient exceeding 20% for 160 or more meters (continuous), or,
- a channel having a sustained gradient >16% for a distance of 160 meters <u>*and*</u> having a width <0.6 meters in Western Washington or <0.9 meters in Eastern Washington **as measured at the scour line** (Chapter 3, Figure 3.3).

While it is recognized that different species have various jumping and swimming abilities, for example, 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 purposes of this manual, the 20% gradient threshold has been accepted as the upper limit for most adult salmonids.

Subsurface Stream Flow
Subsurface stream flow may block fish passage at certain times if stream reaches are not connected except during extremely high flow periods during heavy rain or snowmelt. In these cases, there is no defined stream channel and no evidence of overland flow during any time of the year. Reaches with subsurface stream flow are not documented as a feature for purposes of this methodology.

Table 6.1. Data collection attribute descriptions for the **Natural Barriers Form** (Appendix C). Predefined field values are indicated in **bold** text.

Field Form Name	Description
Site ID	Unique identifier, must be identical to the Site ID for the site.
Data Source	Contains name of group or agency reporting the feature data.
Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon.
Field Review Date	Field review date. **MM/DD/YYYY**
Site Name	Name the natural barrier is commonly referred to on a map, by local residents, or by resource managers.
Natural Barrier Type	Type of natural barrier feature. Valid entries include**: Gradient** , **Waterfall or Subsurface flow.**
Waterfall Height	The height from the front base of the waterfall, to the crest in meters (0.01). If no waterfall present, then leave blank.
Plunge Pool Depth	Maximum depth of plunge pool. Expressed in meters to the nearest 0.01.
Slope	Stream gradient measured in percent. If natural barrier is a waterfall, then leave blank.
Channel Width	Average stream width. Expressed in meters to the nearest 0.01.
Stream Length	The length of the natural barrier, such as a reach of subsurface flow or a reach exceeding 20% gradient, measured in meters to the nearest 0.1. If natural barrier is a waterfall, then leave blank.
Blockage	Degree of fish passage barrier. Values are; **Total, Partial, Unknown.**
Fishway Present	Indicate whether a fishway is present. Values are; **Yes** = fishway is present; **No** = fishway is not present.
Comments	Brief description of this feature.

6.2 References Cited

Cannings, S.G., and J. Ptolemy. 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.

CHAPTER 7

Revised 12/21/09

FISHWAYS

A fishway is any human-made structure that facilitates the passage of fish through, over, or around a barrier. The barrier can be human-made, such as a culvert, low head dam, or concrete flume. The barrier can also be natural in origin such as a falls or cascade.

Note: because fishways are considered retrofits and a temporary correction measure for fish passage barriers, they are not treated as an inventory feature. Rather, this manual will discuss fishways as an attachment to an instream feature, such as a culvert, dam, or other feature. Because fishways are associated with inventoried features, fishway data will be collected along with the primary feature data. Passability will be considered for the entire site; the primary feature and the fishway will have the same passability.

If a streambed control, such as a log, plank, rock, or gabion is encountered, do not report it as a fishway unless its function is to pass fish above, through, or around a barrier. 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. If you come across such structures, evaluate them as miscellaneous obstructions (Chapter 5).

Many attempts have been made by barrier owners and others to construct fishways to improve fish passage. Some of these efforts have been successful but many have been failures. In order for a fish passage facility to be legally recognized as a fishway, it must be both durable and efficient (RCW 77.57.030). In other words, it must be able to withstand extreme flow events along with the associated bedload and woody debris that accompany these events and be able to efficiently pass fish over a wide range of flows.

Fishway designs are complex requiring hydraulic analysis to determine pool volume for energy dissipation necessitating an advanced level of expertise to determine passability. The evaluation guidance provided in this manual is intended to assist inventory crews in identifying common fishway types and any obvious fishway design or maintenance issues that may cause a fish passage delay or barrier. The hydraulic drop is currently the only criterion used by field crews that does not require a higher level of analysis.

For new or previously undocumented fishways, follow the data collection and barrier assessment guidelines outlined below. For technical assistance with fishway evaluation and inspection, contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov.

7.1 Fishways – Data Collection

Conduct the following for each newly (not previously documented) fishway encountered:

- Complete the Site Description Form found in Appendix C (see Chapter 2).
- Record description information and core physical measurements for the primary feature the fishway is associated with;
  - Culvert (Chapter 3)
  - Dam (Chapter 4)
  - Miscellaneous Obstruction (Chapter 5)
  - Natural Barrier (Chapter 6)
- Complete the Fishway Form found in Appendix C (data attributes explained in Table 7.1).
- Photograph the general setting, the primary feature and the attached fishway.

Table 7.1 describes the information and physical measurements necessary to document and evaluate fishways. The fields in Table 7.1 are found on the data collection form found in Appendix C. Most of the fields in the table are self-explanatory, however, a few of the fields do warrant additional discussion.

Photo examples of the most common fishway types can be found in figures 7.1 (baffled culverts and baffled flumes), 7.2 (weir pool fishways), Figure 7.3 (pool chute fishways), Figure 7.4 (streambed control fishways), Figure 7.5 (vertical slot fishways), Figure 7.6 (steep pass fishways), Figure 7.7 (roughened channel culvert fishways), Figure 7.8 (blasted falls fishways), and Figure 7.9 (trap and haul fishway).

Fishway barrier assessment is discussed in Section 7.2.

Fishway Type

The most common fishway types encountered include:

- **Baffled Culvert (BC)**. A culvert with baffles installed. They are designed to pass fish by creating streaming flow during high-water conditions, reduce the average cross section velocity inside the culvert, or by increasing flow depth throughout the culvert.
- **Baffled Flume (BF)**. A stream reach confined in a concrete flume with baffles installed for fish passage.
- **Weir Pool (WP).** The weir pool fishway is the most common style fishway found in the Pacific Northwest. This type of fishway has sufficiently sized pools to dissipate the turbulence and energy of the water entering over the upstream weir. The hydraulic controls between the pools are overflow weirs. The size, shape and material composition of weir pool type fishways can vary greatly.
- **Pool Chute (PC).** A formed and poured concrete fishway. Pool chute fishways have vee-shaped weirs with a horizontal weir set into a notch at the apex of the vee. At high flows, water streams down the center of the fishway, while plunging flow and good fish passage conditions are maintained on the edges of the pools. A pool chute fishway may look similar to, and function like, a weir pool fishway at low flow.
- **Streambed Control (SBC).** Grade controls installed directly in the streambed; may be comprised of wood, rock, or other materials. Streambed controls are placed in channels to accommodate drops by influencing water flow, gradient, sediment, bed elevation, or

other stream functions. They may function like stair steps to backwater culverts or they may promote aggradation of the stream channel to reduce drops.

- **Vertical Slot (VS).** Similar to weir pool fishway, it has distinct steps with hydraulic control provided by a narrow vertical slot opening, often to the full depth of the fishway.
- **Steep Pass (SP).** Type of denil pattern fishway typically constructed of one or more sections of pre-fabricated sheet aluminum, which allows them to be transported and installed at remote locations.
- **Roughened Channel Culvert (RCC).** Boulder-size roughness elements are placed in a pattern to increase channel roughness, which reduces velocities by dissipating energy. Boulders may be placed within the culvert or in steepened reaches downstream and/or upstream of the culvert.
- **Blasted Falls (BL).** Pools blasted in the rock of a waterfall or bedrock cascades.
- **Trap and Haul (TH).** Mechanically operated fishways, which may include lifts (fish elevators), brails, and locks, that can raise fish over a barrier or into a trap or hauling tank on a truck or barge. These facilities are generally used on large rivers with large-scale fish runs.

Table 7.1. Data collection attribute descriptions for the **Fishway Form** (Appendix C). Predefined field values are indicated in **bold** text.

Form Field Name	Description
Site ID	Unique identifier for each stream crossing. Must be identical to the Site ID for the site.
Field Crew	Last names of individuals responsible for collecting field data. Separate names with a semicolon.
Date	Field review date. **MM/DD/YYYY** format.
Construction Year	Year fishway was built. **YYYY** format. If unknown, then leave blank.
Attached To	Structure fishway modified for fish passage: **Culvert, Non-culvert crossing Dam, Other, Natural Barrier.**
Fishway Type	Select from list; **BC** = baffled culvert, **BF** = baffled flume, **PC** = pool chute, **WP** = weir pool, **SP** = steep pass, **VS** = vertical slot, **SBC** = streambed control, **RCC** = roughened channel culvert, **BL** = blasted falls, **TH** = trap and haul, **Unk** = unknown
Number of Pools	The number of pools or steps within the fishway structure.
Entrance Pool Depth	The depth measured outside of the fishway structure at the downstream end. Meters (0.01)
Maximum Water Surface Drop	The maximum hydraulic drop of the measurements taken at each control/weir from water surface to water surface. Meters (0.01)
Number of Weirs	The number of weirs utilized within a formal fishway, not to be confused with baffles or streambed controls.
Weir Type	Material of which the weirs are composed, select from list. **Concrete, Metal, Plastic, Wood, Rock, or Other.**
Streambed Elevation Control Location	Location of streambed elevation controls, select from list. **US =** Upstream**, DS =** Downstream, **BE =** Both Ends. Leave blank if none present.
Control Type	Type of streambed controls, select all from list that apply. **CC** = Concrete, **GC =** Gabion, **RC** = Rock **LC =** Log, **PLC =** Plank**, SCC =** Saccrete.
Number of Controls	Number of streambed controls.
Comments	Additional description or comments. If fishway needs maintenance or is a barrier, then describe here.
Barrier	Results of fish passage evaluation. Values are; **yes** fishway is a barrier, **no** = fishway is not a barrier, **unknown** = fishway passability is unknown.
%Passability	Percent passability based on field crew's professional judgment. Values are: **0, 33, 67, 100**.

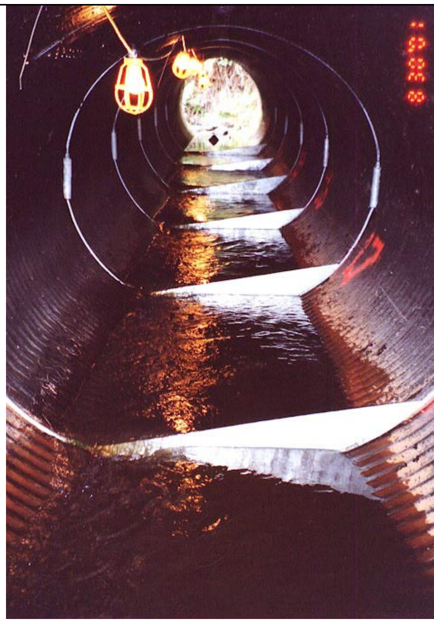
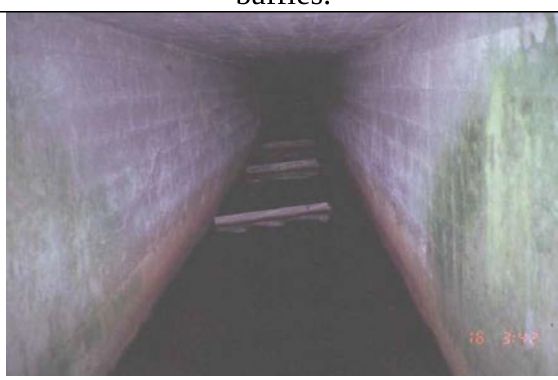
 **Baffled Culvert** Culvert equipped with expansion ring, steel baffles.	 **Baffled Flume** Modified denil fishway in a concrete flume.
 **Baffled Culvert** Angle steel baffles in a concrete box culvert.	 **Baffled Flume** Baffles in a concrete flume.

Figure 7.1. Photo examples of baffled culverts and baffled flumes.

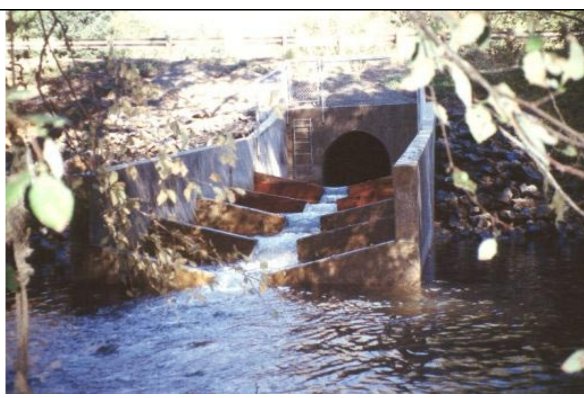
Weir Pool
Sheet pile weir-pool fishway downstream of a culvert.

Weir Pool
A weir pool fishway within a culvert.

Weir Pool
Six-step, concrete, weir-pool fishway with wooden stop-logs attached to a dam.

Weir Pool
Concrete weir-pool fishway around a dam.

Figure 7.2. Photo examples of weir pool fishways.



Pool Chute
A five-step concrete pool-chute fishway downstream of a culvert.

Pool Chute
A 17-step concrete pool-chute fishway attached to a dam.

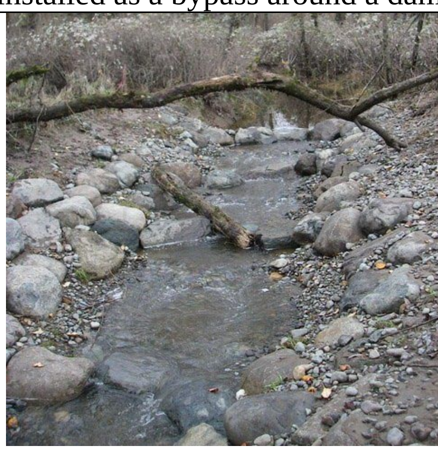
Figure 7.3. Photo examples of pool chute fishways.

Streambed Control
Log controls placed downstream of a culvert to backwater the culvert.

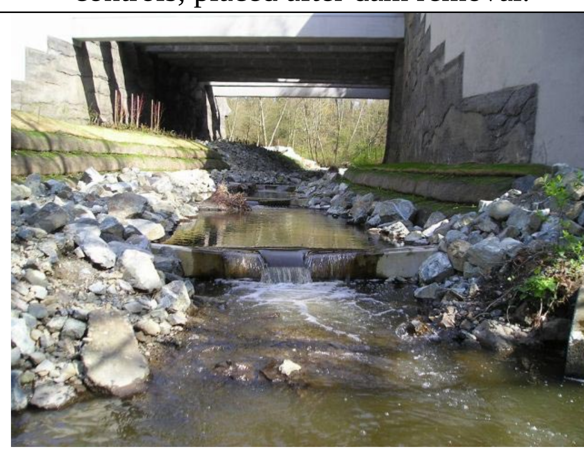
Streambed Control
Concrete controls placed downstream of a culvert to backwater the culvert.

Streambed Control
The fishway consists of 15 log controls installed as a bypass around a dam.

Streambed Control
The fishway consists of 36 full span concrete controls, placed after dam removal.



Streambed Control
Rock control fishway constructed to make up grade, maintain water elevations and facilitate fish passage after dam removal.



Streambed Control
Nine concrete weirs underneath bridge placed to prevent major head cutting.

Figure 7.4. Photo examples of streambed control fishways.

 **Vertical Slot Fishway** Vertical slot fishway attached to diversion dam.	 **Vertical Slot Fishway** A six step concrete vertical slot fishway attached to a low head dam.
 **Vertical Slot Fishway** Attached to natural barrier waterfall; constructed in 1956.	 **Vertical Slot Fishway** A formal vertical slot fishway, 137 m long with 44 vertical slots, attached to natural barrier waterfall.

Figure 7.5. Photo examples of vertical slot fishways.

 **Steep Pass Fishway** Alaska Steep Pass Fishway attached to culvert.	 **Steep Pass Fishway** A 4.5 m long Alaska steep pass ladder over an irrigation diversion dam.

Figure 7.6. Photo examples of steep pass fishways.

 **Roughened Channel Culvert Fishway** Fourteen rock weirs were installed throughout the reach. Three weirs are downstream, five inside the culvert and six upstream (photo).	 **Roughened Channel Culvert Fishway** Rock controls facilitate passage up to the culvert.

Figure 7.7. Photo examples of roughened channel culvert fishways.

 **Blasted Falls Fishway** A four step blasted weir-pool fishway on a 2.4 m high natural bedrock falls. Constructed in 1955.	 **Blasted Falls Fishway** Eight blasted weir-pools in a natural bedrock falls/ cascade area. Constructed in 1952.

Figure 7.8. Photo examples of blasted falls fishways.

Trap and Haul Fishway – Sunset Falls
A trap and brail system traps fish below the first barrier falls, then a tank truck transports fish 5.6 kilometers upstream around a series of three falls where they are released and provided access to more than 145 kilometers of quality spawning and rearing habitat. This unique fishway facility has been in operation since 1958.

Figure 7.9. Photo example of trap and haul fishway.

Weir Pool and Pool Chute Fishway Components

Collect data for the following fields for weir pool and pool chute fishways only:

- For "Number of Pools", enter the total number of plunge pools or steps within the fishway structure, including the entrance pool.
- The "Entrance Pool" is the furthest downstream plunge pool, found below the lowest fishway weir; measure the depth at the center of the entrance pool, if possible.

Note that weir pool and pool chute fishways can be totally contained within a culvert.

Maximum Water Surface Drop

Measure the hydraulic drop at each control/weir present, from water surface to water surface. Report the maximum drop on the data entry form. If the water surface drop for one or more controls/weirs exceeds 0.24 m, record this information in the comments and indicate which control/weir(s) exceeded 0.24 m drop.

Baffled Culverts/Flumes

Baffles in culverts are recorded on the 'culvert' data collection form (see Chapter 3), as well as on the 'fishway' data collection form. Baffled flumes are recorded on the 'miscellaneous obstructions' data collection form (see Chapter 5), as well as on the 'fishway' data collection form. For baffled culverts and baffled flumes, indicate the number of baffles present and the material the baffles are constructed of (e.g., concrete, rock, metal, plastic, wood or other). Describe any broken or missing baffles in the comments section.

Fishway Comments

Describe the fishway conditions in the comments section. Comments should be reserved for fishway descriptions and for deviations from standards, or when 'other' is chosen as a fishway descriptor.

7.2 Fishways – Barrier Assessment

Fish passage conditions within fishways are dynamic and may change overnight, depending on flow conditions, sediment and debris transport, and structural integrity of the fishway itself. Pool volume and depth, water surface drop, turbulence, velocity, and/or physical blockages are all factors affecting fish passage within fishways.

An easily measured parameter that can be used to assess fish passage is hydraulic drop. Measure the water surface drop at each control. For adult salmon and trout (≥ 150 mm), the drop at the water surface should not exceed 0.24 m (0.8 ft).

Consider the fishway a barrier if either of the following conditions exist.

- >0.24 m water surface drop at any of the controls,
- physical blockage present within the fishway (e.g. large wood, debris, sediment, etc.)

7.3 Fishways – Ongoing Inspection

Regular inspections should be conducted by the facility owner or by another party to ensure proper function and passability of the structure. Fish passage conditions within fishways can change annually or even daily, depending on maintenance activities, extreme hydrological events, and other conditions. Fishway inspection is recommended on a weekly basis during the fish migration period and after each significant flood event. While guidance is provided here on evaluating fishways, inventory groups are not expected to conduct regular fishway inspections. Deficiencies to look for are described below. Table 7.2 describes the information and physical measurements to collect when inspecting fishways.

Maintenance Needed to Ensure Fish Passage and Structural Integrity

The fishway facility may be passable for fish yet require general maintenance for safety or structural integrity. If neglected, some general maintenance issues could develop into fish passage or fish stranding problems. The following is a list of common maintenance needs to look for in the field:

- Is there a water surface drop greater than 0.24 m?
- Is there excessive turbulence?
- Are there any logs, debris, or garbage in or around the facility that are impairing fishway function and require removal?
- Are plunge pools or the culvert filling in with sediment and debris to the extent that fishway function or hydraulic capacity is compromised?
- Have beavers constructed a dam at the fishway or within the vicinity?
- Is filter fabric exposed that may need to be trimmed, buried, anchored, or replaced?
- Are any of the baffles loose, missing bolts, or other missing components?
- Are any of the baffles or weirs misaligned or broken?
- Are weirs sealed properly?

- If there is a trash rack at the facility, does it need to be cleaned or repaired?
- Is the access road in need of any repairs?
- Is there any bank erosion associated with the fishway?

Fishway Inspection Results

Upon inspection, one of the following conditions may be observed:

- Fishway is ok; it is passable for fish (there are no excessive drops or blockages), it is durable and efficient.
- Fishway is not necessarily a barrier, but structural maintenance is needed to prevent failure.
- Fishway is a partial barrier, yet only minor, short-term maintenance is needed to ensure fish passage (e.g., debris removal, minor adjustment to stop log, etc.). Once maintenance is completed, the fishway would then be passable.
- Fishway is a barrier because of a design issue or failure (e.g., broken or missing baffles).
- Fishway no longer exists

Table 7.2. Field descriptions for the **Fishway Inspection Form** (Appendix C). Predefined field values are indicated in **bold** text**.**

Form Field Name	Description
Site ID	Unique identifier for each stream crossing. Must be identical to the Site ID for the site. Field is used as a database table key and to create links to associated tables and data.
Observer(s)	Last name(s) of the field inspection team responsible for data and data collection date.
Date	Fishway inspection date. **MM/DD/YYYY** format.
Condition	Fishway condition during site visit. Values are; **OK** – durable and efficient, **MN** – minor maintenance needed, **MNFP** – minor maintenance needed for fish passage, **MNR** – major maintenance or replacement needed for fish passage, **NLE** – fishway no longer exists, **UNK** – condition unknown.
Fishway Maintenance Required	Describe fishway maintenance needs. Photos may help illustrate this. If no maintenance needed, indicate ‘none’.
Additional Comments	Additional description or comments.

CHAPTER 8

Revised 12/21/09

SURFACE WATER DIVERSIONS

Surface water diversions are common instream features in agricultural areas where the water is used for irrigation. Throughout the state, water is also diverted for hydropower, industrial, recreational, residential, municipal, and hatchery purposes. Washington State law (RCW 77.57.070 and RCW 77.57.010) requires that all surface water diversions be screened to prevent fish from being drawn into the diversions where they are at risk for injury or mortality. Appendix I outlines the screening requirements for surface water diversions.

There are three primary inventory goals for 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.

Surface water diversions are often screened to keep debris out, but not necessarily to protect fish. Additionally, many diversions are unscreened.

For technical assistance with evaluating diversions and screening, contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov.

8.1 Locate & Describe

Standard site data (Chapter 2) are collected for all surface water diversions to define the location. Data elements collected in the field to describe the diversion are summarized in Table 8.1, with detailed descriptions of key elements provided below.

Diversion Type

Surface water diversions are categorized into two general types, gravity and pump. Gravity diversions are typically characterized by open channels or canals leading off the stream channel where flow is controlled by differences in elevation (gravity). They are often accompanied by dams that divert flow into the channel. Pump diversions employ mechanical pumps to remove water from the stream. The pumps are either located directly in the stream (submersible) or on land with an intake pipe in the stream.

Access

Identifies the means by which the diversion site can be accessed (e.g. by foot, vehicle, boat, or off-road vehicle).

Point of Diversion
Identifies which stream bank the diversion is located on, right or left, looking downstream.

Intake Location
More detailed description of where the diversion intake is located. The three options are riverbank, offshore, and lagoon. Riverbank means the intake is at or immediately adjacent to the shoreline of the main channel. Offshore indicates the intake is in the channel away from the shoreline. A lagoon is out of the main flow and often isolated from the river by a channel or pipe. Gravity diversion intakes are usually located along the riverbank or offshore (infiltration galleries). Pump intakes are found at all locations.

Diversion Dam
Many diversions use a dam to deflect water into the intake location. This data element is a flag to indicate the presence or absence of a diversion dam. If present, the dam needs to be assessed for fish passage per the protocol in Chapter 4.

Headgate
A headgate is a structure used to control the amount of water being diverted. They are typically associated with gravity diversions and are located upstream of a screen (if present). Headgates can range in form from a simple weir to a screw valve. This data element is a flag indicating the presence or absence of a headgate. Figure 8.1 shows examples of some common headgate styles.

Diversion Comments
The comments section is used to briefly describe important aspects of the diversion not captured by the standard data elements. It is also a space for explanations when “Other” or “Unknown” are selected for items on the field forms.

Screen Presence
This data element indicates the presence or absence of a screen at the diversion. It provides documentation that a screen is present even when access to the screen is restricted and the information in Section 8.2 cannot be collected. If it is not possible to determine if a screen is present or absent (see Section 8.4), “Unknown” should be selected.

Table 8.1. Field descriptions for the Surface Water Diversion data collection form for diversions (Appendix C). Items in bold text represent predefined choices on the form.

Field Form Name	Description
Site ID	Unique identifier for each diversion. Must be identical to the Site ID for the site.
Field Crew	Last names of individuals responsible for collecting field data on culverts. Separate names with a semicolon. (e.g. Johnson;Collins)
Diversion Type	Indicate type of surface water diversion: **Gravity** or **Pump** diversion.
Access	Type of transportation capable of accessing site: **Boat, Vehicle, Foot,** or **ORV** (off-road vehicle).
Point of Diversion	Point of diversion (POD): **LB** = left bank, **RB** = right bank, referenced looking downstream.
Intake Location	**RB** = riverbank (or stream bank), **OS** = offshore, **LN** = lagoon, **CV** = cove. A lagoon is separated from the river by a pipe or channel. A cove is open to the river.
Diversion Dam	Presence of an instream diversion dam structure: **Yes** = present or **No** = not present. If yes, also complete a dam form.
Headgate	Presence of headgate: **Yes** = present or **No** = not present.
Diversion Comments	Diversion specific comments.
Screen Presence	Reports the presence of some type of screening device: **Yes** = present, **No** = not present, or **Unknown** = unable to determine presence or absence.

weir headgate

screw valve headgate

drop slot headgate

screw valve headgate

slide gate

screw valve headgate

Figure 8.1. Examples of common headgate styles.

8.2 Screens

When screens are present, the data elements summarized in Table 8.2 are collected to describe the screen and its general condition. Detailed descriptions of key elements are provided below.

Screen Type

Surface water diversion screens have been classified into a small number of general types; however, each type may have a number of variations due to size and cleaning strategies. Gravity diversion screens are commonly categorized as traveling belt, rotary drum, vertical fixed plate, non-vertical fixed plate, or infiltration gallery. Screens configurations that do not fit these categories are identified as “Other”.

Traveling belt screens (figures 8.2 and 8.3) consist of an endless mesh (wire or plastic) conveyor belt that excludes debris while allowing surface water to be diverted to an irrigation system.

A rotary drum screen (figures 8.4 and 8.5) is a cylindrical drum constructed with mesh (wire or plastic) which allows water to flow through while excluding debris.

Fixed plate screens are simply a flat plate mesh aligned in a stream channel at a gravity diversion. Vertical fixed plate screens (figures 8.6 and 8.7) are aligned vertically in the stream. “Active” cleaning plate screens require an additional debris removal system (e.g. brush or wiper). “Passive” plate screens have no cleaning system. Non-vertical fixed plate screens (figures 8.8 and 8.9) may be aligned horizontally or sloping upward or downward in the direction of the stream flow and typically do not require debris removal systems.

Infiltration galleries (figures 8.10 and 8.11) include one or more horizontal screens, perforated pipe manifolds, or single pipes, buried in a streambed or bank. Another type of infiltration gallery is a “Ranney well”, which is simply a depression dug off-channel (in a stream or river) with a pump and/or pipe present. Infiltration galleries are generally used for pump diversions but can be use for gravity diversions in steep channels. The screen area is the area of the streambed or bank through which the water flows rather than the area of the intake pipe.

Pump diversion screens attached to the end of a pump include box, barrel, cylinder, or cone (figures 8.12 and 8.13). Pump diversions may also be screened by an infiltration gallery.

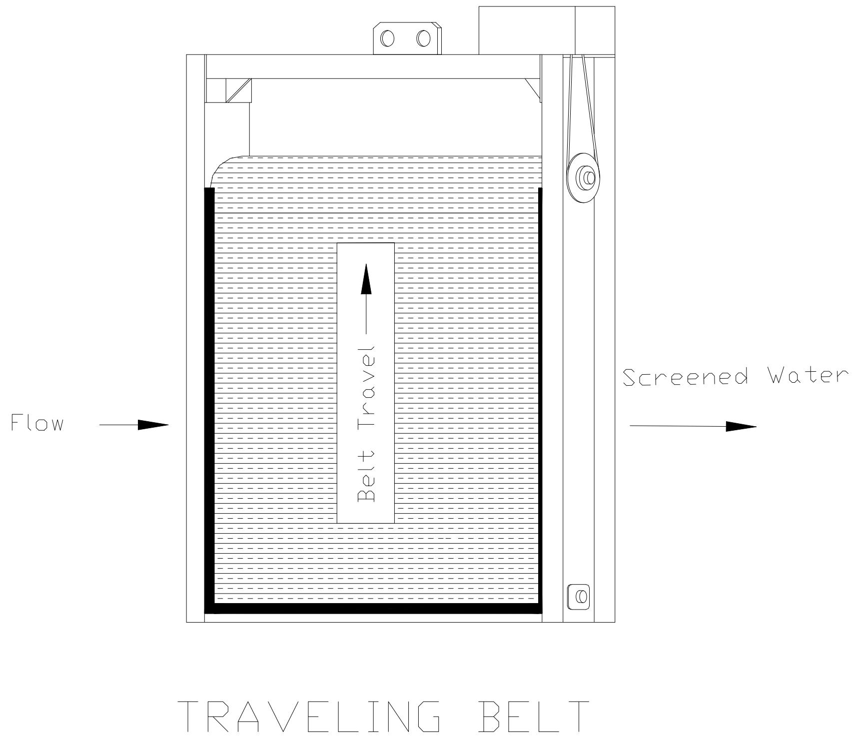
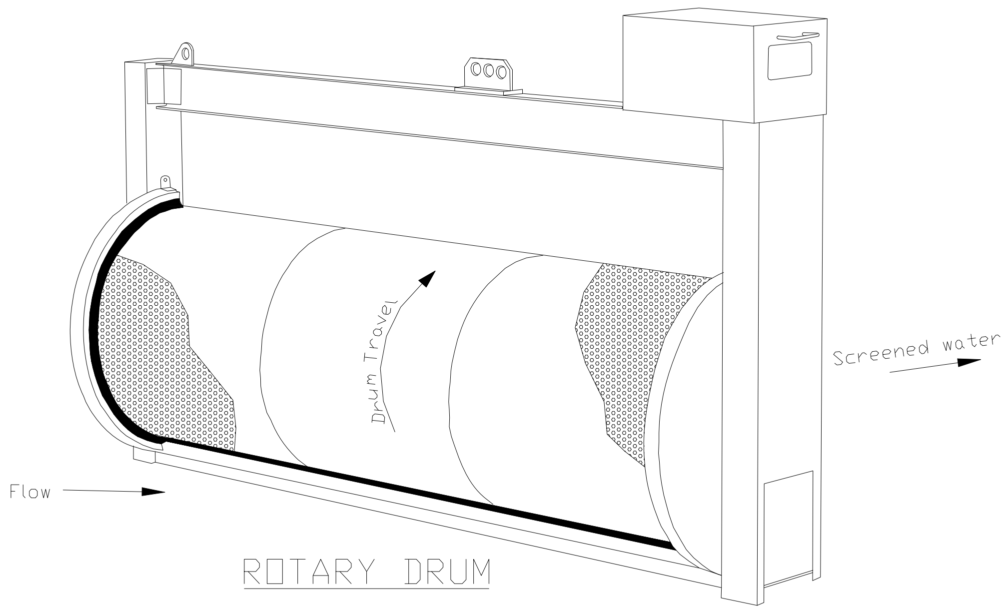


Figure 8.2. Traveling belt screen.

 traveling belt screen	 traveling belt screen shown with cleaning brush

Figure 8.3. Photo examples of traveling belt screens.



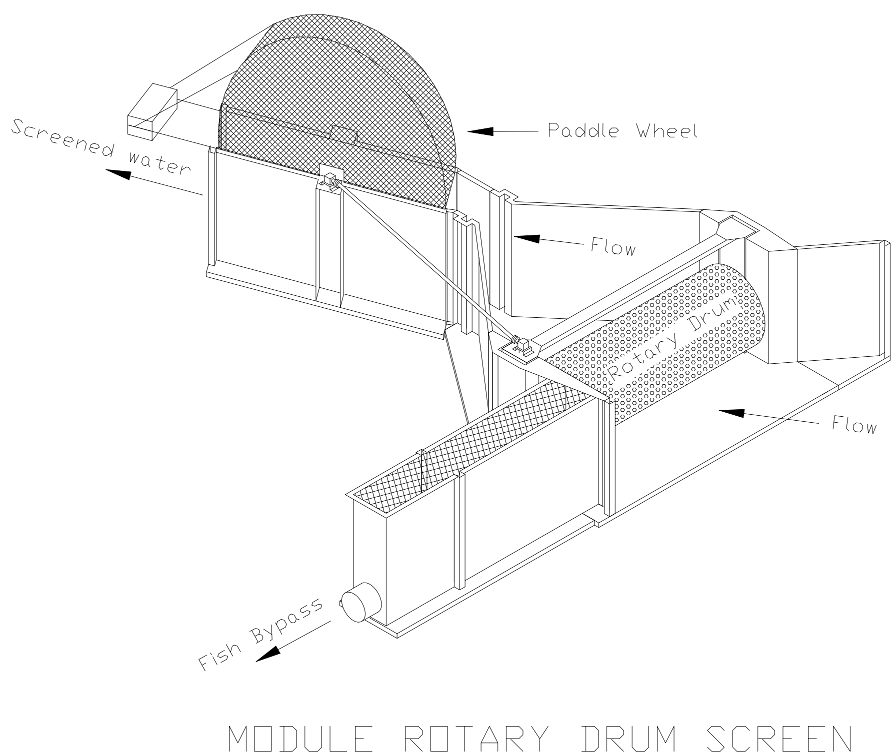


Figure 8.4 Rotary drum screen.

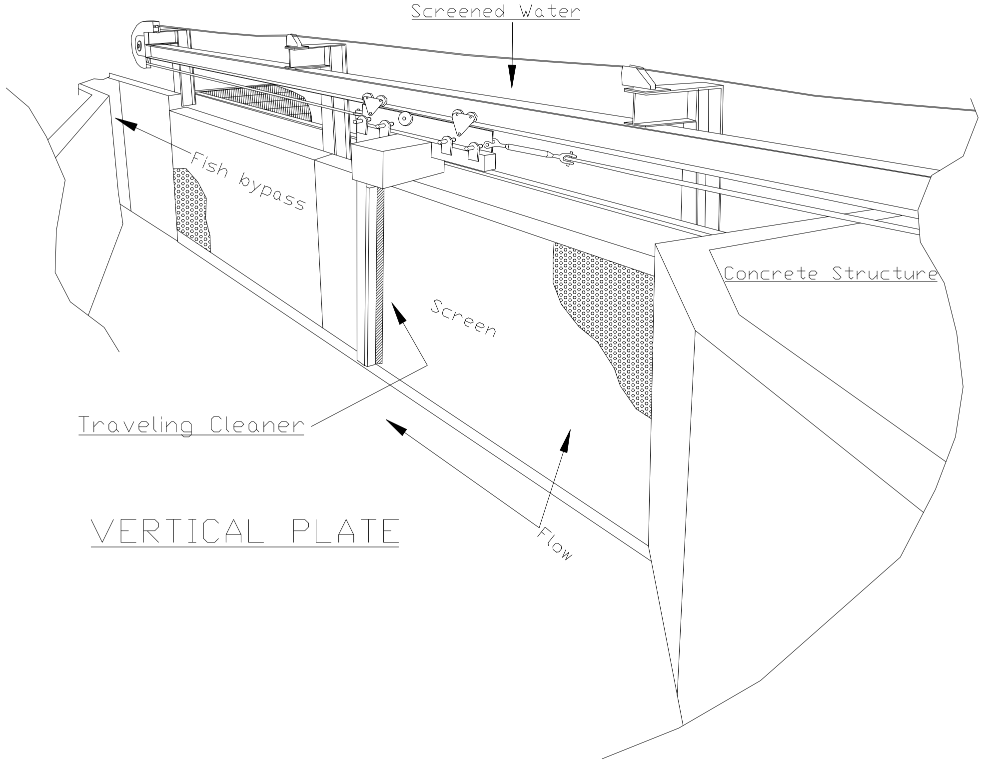
single rotary drum screen

double rotary drum screens

rotary drum screen in water

rotary drum screen out of water

Figure 8.5. Photo examples of rotary drum screens.



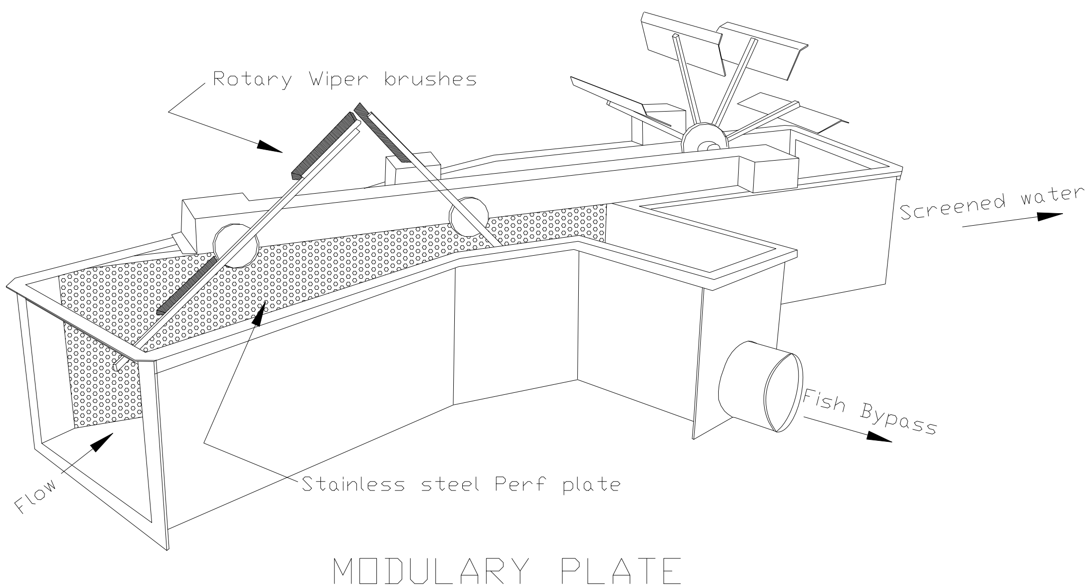


Figure 8.6 Vertical fixed plate screen.

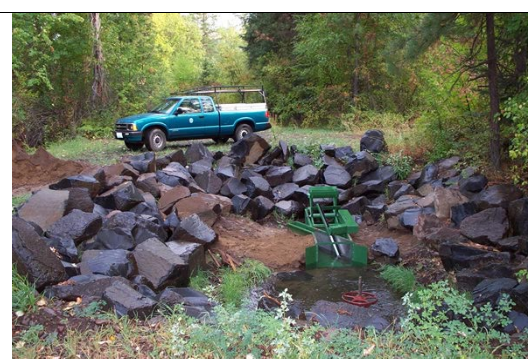
 vertical plate screen (‘air burst’ active cleaning system)	 vertical plate screen (‘passive’; no cleaning system)
 vertical plate screen	 vertical plate dewatered
 brush sweeping the plate screen (‘sweeping brush’ active cleaning system)	 brush used to clean plate screen
 vertical plate screen (‘rotary wiper’ cleaning)	 vertical plate screen

Figure 8.7. Photo examples of vertical plate screens.

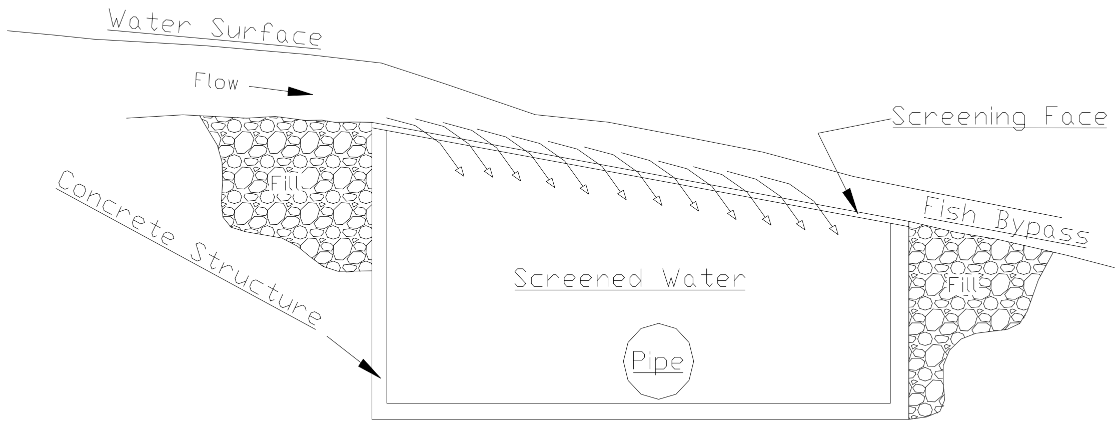


Figure 8.8 Non-vertical plate screen.

non-vertical fixed plate screen

Figure 8.9. Photo example of non-vertical plate screen.

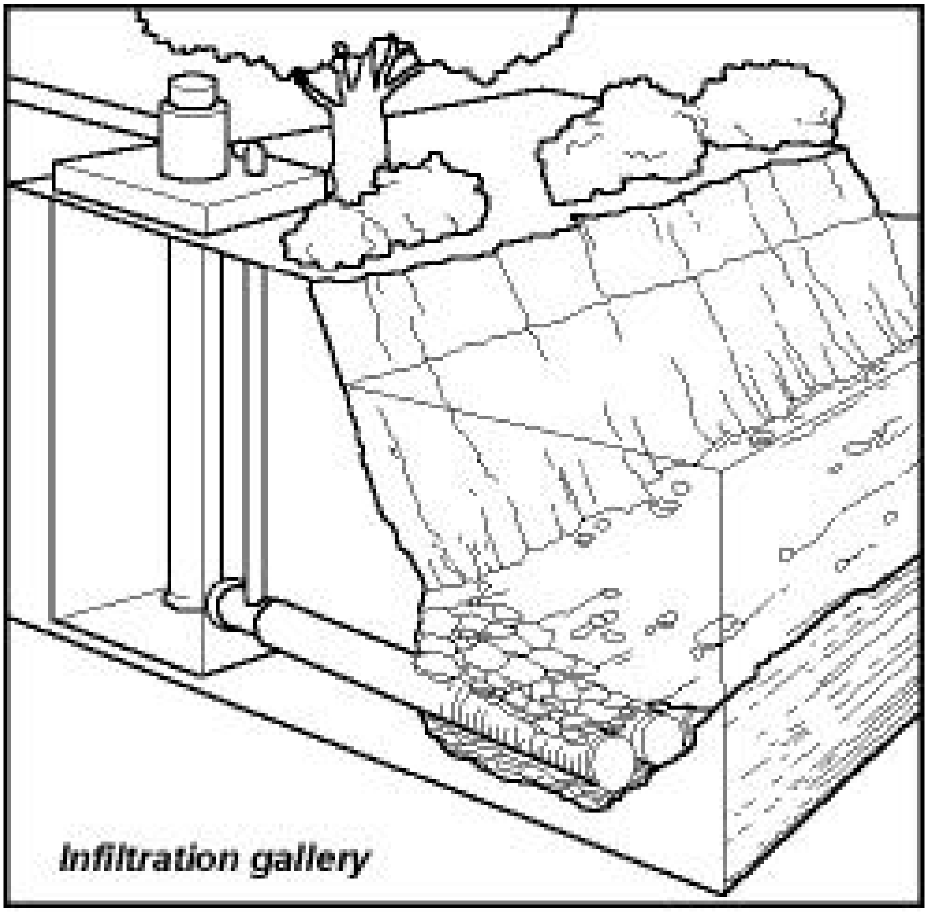


Figure 8.10 Infiltration gallery screen.

passive infiltration gallery

Figure 8.11. Photo example of passive infiltration gallery

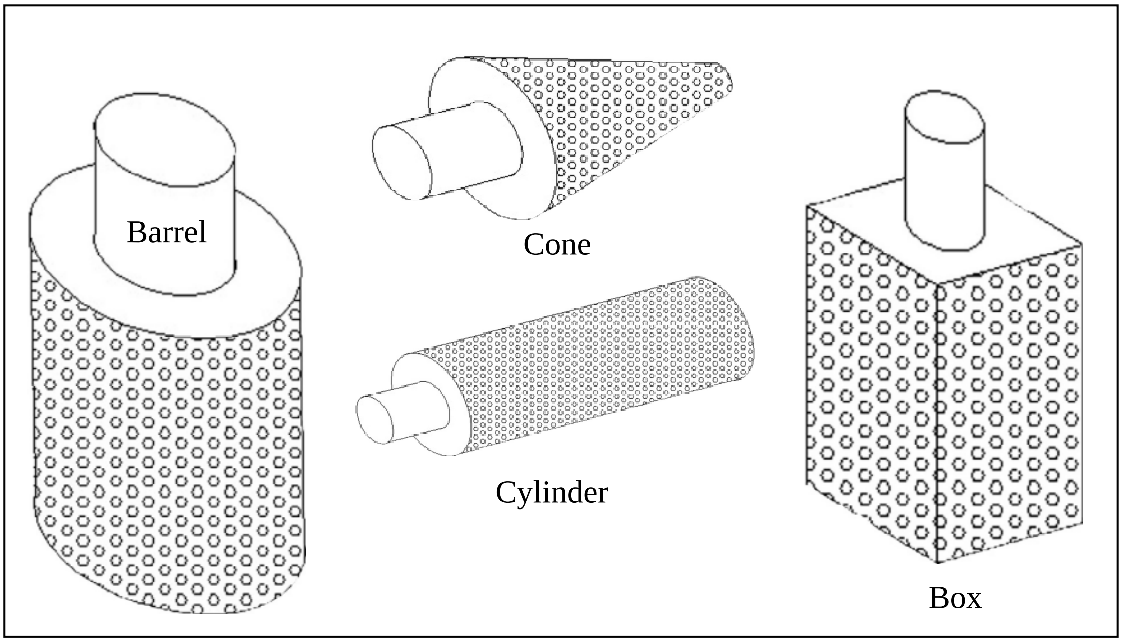


Figure 8.12. Common types of end of pump screens.

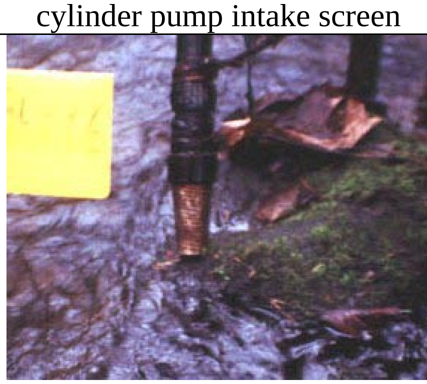
 cylinder pump intake screen	 box pump intake screen
 cone pump intake screen	 barrel pump intake screen

Figure 8.13. Photo examples of common pump intake screens.

Screen Material
Screen material refers to the porous part of the diversion screen. Common materials are woven wire mesh, plastic mesh, perforated plate (stainless steel, aluminum or brass with round or slotted holes), stainless steel profile bar (also called wedge wire or well screen), and slotted polyvinyl chloride pipe (PVC). Figure 8.14 illustrates these common screen material types**.** Materials not meeting these descriptions are designated as “Other”.

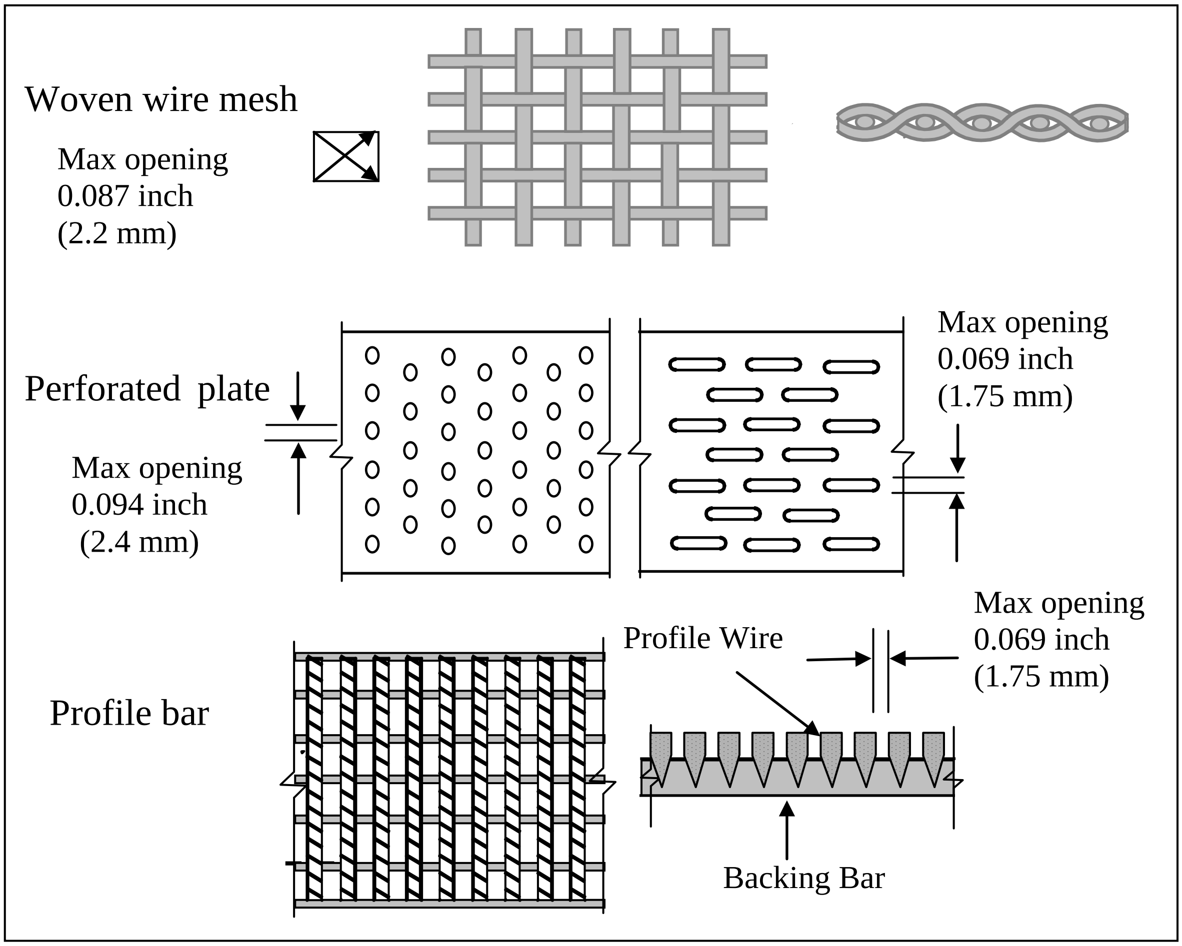


Figure 8.14. Common fish screening materials.

Mesh Size
Mesh size refers to the opening in the screen material. Screen mesh diameter can easily be measured using a set of calipers. How mesh size is measured is dependent on the type of screen material (Figure 8.14). For wire or plastic mesh, measure the largest diagonal dimension. For perforated plate measure the diameter of the hole or the narrowest dimension of the slot. For profile bar and slotted PVC measure the narrowest dimension of the slot. On damaged screens, measure the undamaged mesh opening and note the screen damages in the comments section. Mesh size is reported in inches to the nearest to the nearest ten thousands (10000's).

Fish Bypass
Gravity diversions with fish screens installed downstream of a headgate and pump diversions withdrawing water from a lagoon, usually require a "fish bypass system" to collect fish from in front of the screen and safely transport them back to the stream. Gravity diversion bypass systems consist of an entrance/flow control section and a fish conveyance channel or pipeline. Lagoons must be configured with an outlet channel (or pipe) having sufficient flow away from the pump intake to carry fish back to the parent water body. The intake channel or pipe to a lagoon does not constitute a bypass channel, since it requires fish to swim upstream to get back to the parent water body. This data element is a flag indicating the presence or absence of a bypass system at the diversion.

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

- Is the bypass entrance or return pipe blocked with debris?
- Is there sufficient flow to allow fish to find and enter the bypass and return to the river?
- Do the flows in front of screens allow fish bypass without delay or impingement?
- Does the bypass return have an outfall drop? What is the height and condition of the outfall?

Note: there are cases during low river flow when the bypasses are shut off to enable the diverter to obtain the water right.

Screen Dimensions
The following general measurements are taken to help characterize the screen. Not all dimensions apply to all screen types. Measurements are reported in English units.

- Screen mesh/slot opening diameter (to the nearest 0.0001 inch)
- Screen width (to the nearest 0.01 feet)
- Screen height (to the nearest 0.01 feet)
- Screen area (to the nearest 0.01 square feet)
- Diameter (to the nearest 0.01 feet)

Screen Condition

Screen condition reflects whether a screen is clean and intact or if it is in need of maintenance. *It is not an evaluation of compliance with federal and/or state screening requirements.* Inadequately maintained screens can result in entrainment (passage through, around or under the screen) or impingement (involuntary contact and immobilization on the screen surface) of fish.

The following items should be considered when evaluating screen condition:

- Holes or dents in the screen surface or frame that would allow small fish to pass through the screen or be injured by contact with the surface. Screens should be adequately sealed to prevent fish injury or entrainment.
- Screen mesh openings that exceed the maximum allowable opening diameter for type of screen (see Table 8.14)
- Gaps and spaces greater than 0.094 inches (2.4 mm) between the screens, structural frames, and/or civil works (wood, metal or concrete section in the channel that the screen fits into).
- Side and bottom rubber seals **not** intact and in continuous contact with the screen.
- Screens or trash racks plugged with debris.

If any of these situations exist the screen condition should be indicated as “maintenance needed”.

Screen Comments

The comments section is used to briefly describe important aspects of the screen not captured by the standard data elements. It is also a space for explanations when “Other” or “Unknown” are selected for items on the field forms.

Screen Compliance

Survey crews may not always be able to determine whether a screen is compliant and meets WDFW screening criteria. Advanced expertise is needed for determining whether the approach velocity, sweeping velocity, and minimum screen area criteria are met. However, if the screen mesh size exceeds the WDFW criteria (see maximum openings in Figure 8.14 and Appendix I), then screening is not compliant. Likewise, if the diversion is unscreened, then the screening is non-compliant. When the screening criteria cannot be adequately evaluated, then compliance is ‘unknown’.

Table 8.2. Table 8.2 Field descriptions for the Surface Water Diversion data collection form for screens (Appendix C). Items in bold text represent predefined choices on the form.

Field Form Name	Description
Site ID	Unique identifier for each diversion. Must be identical to the Site ID for the site.
Screen Type	Specify the type of screen. For Gravity Diversions: **RD** = rotary drum, **VFP** = vertical fixed plate, **NVFP** = non-vertical fixed plate, **TB** = traveling belt, **IG** = infiltration gallery, **OT** = other. For Pump Diversions: **BX** = box, **BR** = barrel, **CY** = cylinder, **CN** = cone, **IG** = infiltration gallery, **OT** = other.
Screen Material	Material screen is constructed of: **WM** = woven wire mesh, **PM** = plastic mesh, **PP** = perforated plate, **PB** = profile bar, **EM** = expanded metal, **SP** = slotted PVC, **OT** = other.
Mesh Size	Largest dimension of the screen material opening, measured in inches (0.0001).
Screen Height	Height of screen, measured in feet (0.01).
Screen Width	Width of screen, measured in feet (0.01).
Screen Condition	Indicate screen condition: **OK**= screen clean and intact, **MN** = maintenance needed.
Fish Bypass	Presence of fish bypass. **Yes** = present, **No** = not present, or **Unknown** = unable to determine presence or absence.
Bypass Condition	Indicate whether fish bypass is in operation and comment on the condition of the bypass.
Screen Comments	Screen specific comments.
Screen Compliant	Is the screen compliant with WDFW criteria? Indicate **Yes**, **No**, or **Unknown**.

8.3 Diversion Flow

Determining maximum diverted flow is a critical piece of information used by WDFW to prioritize the diversion for screening, establish the size and type of screen needed, and to estimate construction costs. Table 8.3 summarizes the data elements collected or recorded for diversion flow calculations. Key elements are described in detail below.

Flow is the volume of water moving through the diversion for a specified unit of time (e.g. cubic feet per second, gallon per minute). Some of the methods described in this section yield flow in cubic feet per second (cfs), however, the Screen Priority Index (Chapter 10) requires flow in gallons per minute (gpm). To convert cfs to gpm, multiply by 449 (1.0 cfs = 449 gpm).

The preferred value for flow is that allowed by the diverters water right permit or certificate. Most surface water diversions require authorization from the Washington State Department of Ecology (WDOE). The water right permit or certificate defines the legal, maximum instantaneous flow allowed for the diversion. Water right information can be requested from WDOE's public disclosure office at (360) 407-6040, or obtained from the agency's Water Right Tracking System (WRTS), available online at: http://www.ecy.wa.gov/PROGRAMS/wr/rights/tracking-apps.html. If flow cannot be obtained from water rights then it can be measured or calculated by the techniques described below.

Pump Diversions
For diversions equipped with an in-line flow meter, the instantaneous flow in gpm can be read directly from the meter if the diversion is in operation. Unfortunately, most diversions are not equipped with flow meters. Pump flow may also be estimated based on the outside diameter or circumference of the intake pipe. Table 8.4 provides estimated flow in gpm based on these dimensions.

Gravity Diversions
Some gravity diversions are equipped with calibrated staff gages from which flow can be read directly when the diversions are in use. Figure 8.15 shows photo examples of staff gages. Otherwise, flow is calculated by multiplying water velocity (ft/sec) times the cross-sectional area (ft^2) of the diversion channel. The result is flow in cubic feet per second (cfs). Velocity can be measured with a portable flow meter or by the three-chip method (described below) when the diversion is in use. If the diversion is not in operation, an average velocity (described below) can be used as a surrogate. The cross-sectional area of the channel is calculated based on simple measurements.

Cross-Sectional Area
The bank full, cross-sectional area of the channel should be calculated from measurements taken approximately 100-300 feet downstream of the point of diversion where the normal waterline is readily apparent on the bank. Measure the width of the channel at the waterline elevation. Then measure the vertical distance (depth) from the horizontal waterline elevation to the channel bottom. Multiply the width times the depth to generate the bank full cross-sectional area. The area must be expressed in square feet to the nearest tenth of a foot (0.1 ft^2). If the ditch cross-section is not rectangular, calculate area as accurately as possible by using the formula for a trapezoid (Area = ½ ($\text{width}_{\text{waterline}}$ + $\text{width}_{\text{bottom}}$) x depth).

Three Chip Method
With the three chip method, velocity is estimated by measuring the time it takes a floating object to travel a set distance, then dividing the distance traveled by the time. For example, if the object travels ten feet in twenty seconds, the velocity is 0.5 feet per second (10 ft / 20 sec = 0.5 ft/sec). This is repeated three times with the results used to compute an average velocity. Multiply the average velocity by the diversion channel cross-sectional area to generate flow in cfs. Multiply the result by 449 to obtain gpm.

Average Velocity
An average velocity of 0.75 ft/sec, based on velocities measured by WDFW crews in a number of diversion channels, may be used. To calculate flow, multiply the diversion channel cross-sectional area by 0.75 ft/sec. The result will be flow in cfs. Multiply the result by 449 to obtain gpm. The flow generated by this method is not as accurate as the other methods described above.

Table 8.3. Flow calculation data elements, collected on the Surface Water Diversion Data Form (Appendix C). Items in bold text represent predefined choices on the form.

Field Form Name	Description
Cross-Sectional Area	Bank full, cross-sectional area of the diversion ditch, canal, flume, or pipe, in square feet (0.1). *For Gravity Diversions only.*
Intake Pipe Outside Diameter	Measured outside diameter of the intake pipe in inches (0.001). *For Pump Diversions only*.
Diversion Flow	Volume of water diverted in gallons per minute (gpm).
Flow Derivation	How flow was determined: **Staff Gauge, Flow Meter, Three-Chip Method, Water Right, WDFW Average Velocity, Pipe Capacity, Other.** Non-standard ("Other") flow derivation methods require explanation in diversion comments section (e.g. landowner provided information; from a report; from an HPA; etc).
Water Right Number	Water Right number issued by the Washington Department of Ecology, if known.
Power Meter Number	Number issued to Power Meter servicing the diversion, if known.

Table 8.4. Pump diversion pipe flow estimation table.

Standard PVC & Steel Pipe Sizes (inches)		Outside Diameter (inches)		Outside Circumference (inches)		Estimated Flow
Fraction	Decimal	Fraction	Decimal	Fraction	Decimal	GPM
1	1	1 5/16	1.313	4 1/8	4.125	14
1 1/4	1.25	1 11/16	1.688	5 3/16	5.188	25
1 1/2	1.50	1 7/8	1.875	6	6	35
2	2	2 3/8	2.375	7 7/16	7.438	40
2 1/2	2.50	2 7/8	2.875	9 1/16	9.063	65
3	3	3 1/2	3.500	11	11	90
4	4	4 1/2	4.500	12 3/4	12.750	160
5	5	5 9/16	5.563	20	20	180
6	6	6 5/8	6.625	28 7/8	28.875	280
8	8	8 5/8	8.625	27 1/8	27.125	460
10	10	10 3/4	10.750	33 3/4	33.750	750
12	12	12 3/4	12.750	40 1/16	40.063	1100

Figure 8.15. Examples of staff gages.

8.4 Field Considerations

If screening facilities are fenced, locked, or otherwise inaccessible, there may be an existing record of the facility at WDFW; please check with WDFW/TAPPS screening experts in Yakima or contact the WDFW Habitat Program.

Fish screening facilities at gravity diversions are usually present near the point of diversion, but in some cases they are a significant distance downstream. At a minimum, the inventory crew should walk a 200-meter reach of the diversion channel to search for a screening facility. If the entire diversion channel cannot be walked, and a screening facility is not found within 200-meters, then select 'Unknown' on the data collection form for "Screen Presence" and report in the comments section the distance (meters) walked.

Pump diversions are usually screened at the intake. 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 field.

8.5 Additional Reading

NMFS (National Marine Fisheries Service). 2008. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon. http://www.nwr.noaa.gov/Salmon-Hydropower/FERC/upload/Fish_Passage_Design.pdf

Nordlund, B. and K. Bates. 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

CHAPTER 9

Revised 12/21/09

HABITAT ASSESSMENT

Habitat assessments are conducted when the goal or objective of the fish passage inventory is to prioritize barriers for correction. When conducting a watershed-based inventory where all fish bearing water is walked, the habitat assessment begins once the first human-made barrier is encountered; habitat data is collected simultaneously while walking the stream for the inventory.

Contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov, to arrange for training or for technical assistance with the habitat assessment methods presented in this manual.

Field Considerations

To facilitate the efficient collection of data and for safety reasons it is recommended that a two-person crew be used to conduct habitat assessments. Typically, one person takes measurements while the other person records data in a weather-resistant field notebook. A list of recommended survey equipment is presented in Appendix B. Crews should follow safety precautions, such as carrying a first aid kit, having a communication plan, and using a mobile phone. Field crews should receive training in first aid.

Try to obtain landowner permission to access private property before conducting fish passage and screening inventories and/or habitat assessment. Contact all landowners along the stream, explain the project, and ask for permission to walk the stream. This form of outreach is essential in creating a rapport with landowners. Landowners generally have a keen interest in salmon recovery and can provide first hand observations of fish use in the stream, problem barriers, and often a history of the site.

Habitat Assessment Options

Two habitat assessment options are available. The most reliable is the full survey (FS) since it has a higher sampling frequency than the reduced sampling full survey (RSFS). Other than sampling frequency, the two methods are identical and are discussed in Section 9.1. Both methods allow for the identification of natural and human-made barriers as well as evaluation of the habitat quality throughout the survey.

If the inventory is not watershed-based (streams are not being walked), and there is no plan to prioritize the barriers, a simple threshold determination (TD) is recommended. This involves walking at least 200 meters downstream and 200 meters upstream of each human-made fish passage barrier to verify that a significant reach of fish habitat exists upstream and downstream of the barrier. A significant reach is defined as a section of stream having at least 200 linear meters of useable habitat without a gradient or natural point barrier. In the case where a culvert falls within the 200 meters, do not count the length of the culvert as part of the significant reach since the culverted section of stream is not considered useable habitat.

If the inventory is not watershed-based and the plan is to conduct habitat assessments and prioritize barriers, a fish access check (FAC) needs to be conducted. The FAC verifies whether anadromous salmonids have access to the barrier and involves walking downstream to a point where there is known anadromous access. If a natural barrier is encountered during the fish access check, then the habitat upstream of the natural barrier would be considered to be inhabited by resident species only and would be prioritized using only resident species. Figure 9.1 is a flow chart showing the habitat assessment options.

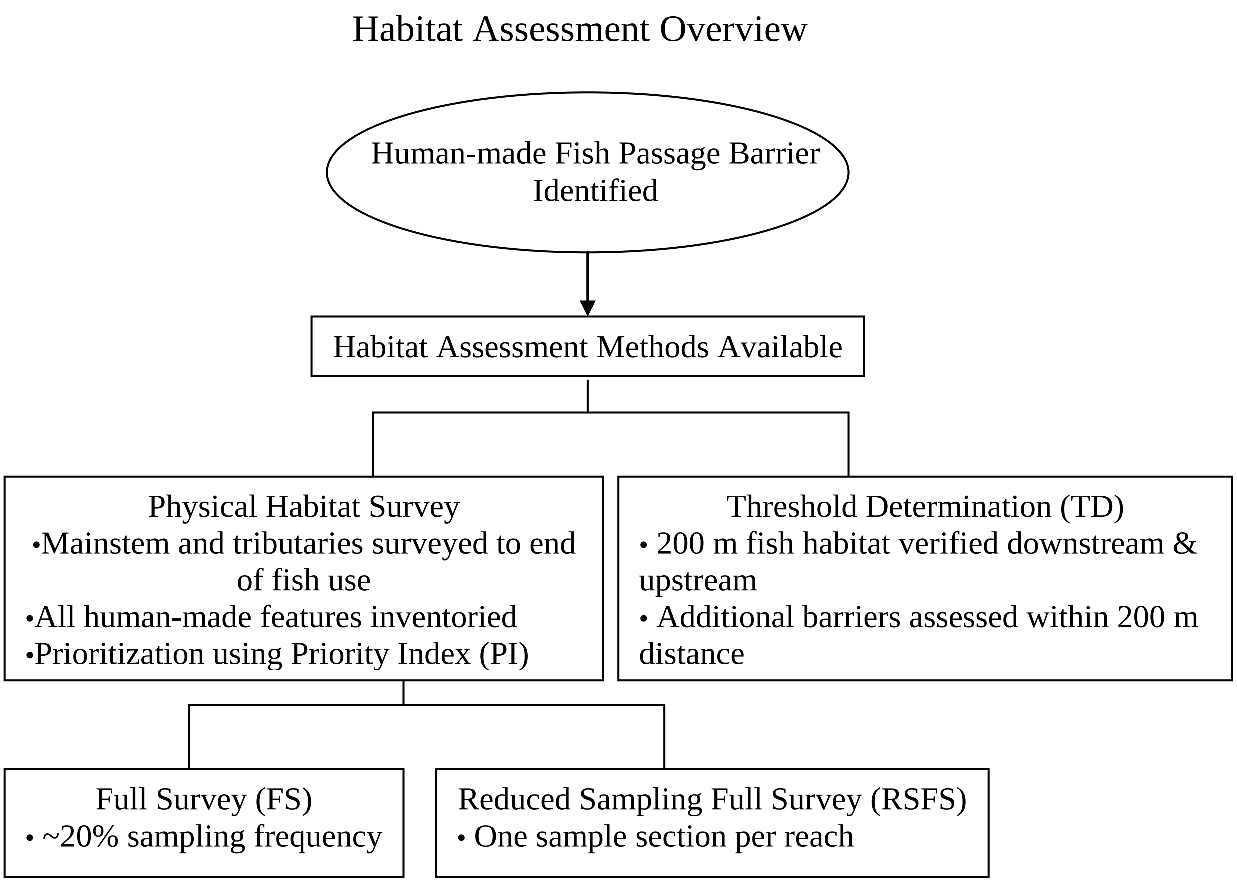


Figure 9.1. Overview of habitat assessment options.

9.1 Physical Habitat Survey

The stream length is measured using a belt chain from the barrier to be prioritized proceeding upstream to the first natural barrier or until the stream is no longer fish bearing.

While conducting the survey:

- Break the stream into reaches with similar gradient, bed form and channel size. In addition, a reach break is established at every human-made fish passage barrier. Ponds are treated as an independent reach.
- Take habitat measurements in the first 60 meters representative of each 320 meter section walked on streams longer than one mile and the first 30 meters representative of each 160 meters on streams less than one mile. For a RSFS, one representative 60-meter sample is taken for each stream reach.
- Document and evaluate all human-made features encountered for fish passage.
- Take detailed notes and photos for each reach.

For each sample section collect the following information:

- The length of each pool, riffle and rapid within the sample section.
- Measure the wetted and scour line widths at the first two pools, riffles and rapids found within the sample section that are representative of conditions within the sample section.
- Measure the average depth at the location of each wetted width measurement.
- Visually estimate the substrate composition of each pool, riffle and rapid sampled.
- At a minimum, measure the gradient at each sample section.

For each reach record the following information:

- Assign a habitat quality modifier independently to spawning and rearing habitat.
- If a habitat quality modifier other than 1 is assigned to a reach, indicate what is reducing habitat quality.
- Estimate the magnitude of spring influence to the stream flow.
- Record the water temperature.
- Visually estimate the percent of stream area shaded by the riparian canopy assuming full leaf out condition.
- Instream cover density such as large woody debris (LWD), undercut banks, large boulders, close overhanging vegetation (etc) is visually estimated as high, medium or low.
- Make a visual estimate (high, medium or low) of juvenile abundance by species if possible.

When back in the office, measure the basin area either using a planimeter or GIS software.

The following definitions, habitat measurements, and habitat descriptions apply to both the FS and RSFS methodologies. An example of a habitat survey field form that can be used for both methodologies can be found in Appendix J and an example for data entry is in Appendix K. Table 9.1 includes the field descriptions for the Physical Habitat Survey data collection form.

Stream Length

Measure stream length to the nearest meter using a belt chain with a 3 strand, biodegradable thread. Begin measuring at the human-made barrier and continue upstream (if the stream is utilized by resident salmonids only, then the habitat gain may be downstream as discussed in Section 9.2) until a natural barrier is encountered or the stream is no longer fish bearing. *Note: even if biodegradable thread is used, it is best to collect used hip chain (whenever feasible) and pack it out, as a courtesy to landowners and others and for wildlife safety.*

Reach

A reach is defined as a section of stream with a similar gradient, bed form, channel size, streamflow, land use characteristics, and having a length of at least 160 meters (except for pond reaches which can be less than 160 meters in length).

Reach Breaks

A stream reach break is established at each tributary contributing ≥20% or more of the parent stream flow above the confluence. Reach breaks are also created at 1%, 3%, 5%, 7%, 12%, and 16% gradient. Table 9.2 shows the expected species utilization in each gradient stratum and the gradient strata that each species may ascend, even though they may not reside in that stratum. For instance, coho salmon are generally found in stream reaches having gradients of 7% or less, however, they may ascend stream reaches up to16% and reproduce and rear in lower gradient reaches upstream. In this case, you would include coho salmon in all reaches having a gradient of 7% or less even if there are intermediate reaches up to 16%. Table 9.2 should be used to assign species utilization to reaches unless additional information is available for the stream. The reach breaks do not necessarily correspond with changes in species utilization because some reach breaks are established to account for habitat differences at different stream gradients.

Gradient strata must be sustained for at least 160 meters. The survey is terminated at a natural point barrier (waterfall >3.7 meters vertical height) or when a sustained gradient >20% is encountered for a distance of 160 meters (>16% for a channel width <0.6 meters in Western Washington and <0.9 meters in Eastern Washington, measured at the scour line width).
Since it will not always be known how long the stream continues at a particular gradient, it is necessary to measure the first 160 meters by belt chain to verify the need to create a new reach when a new gradient reach stratum is encountered. Sample frequency should continue uninterrupted across gradient reaches, to avoid unnecessary sampling should the gradient change occur in less than 160 meters. This is an exception to the way other types of reach breaks (bed form change, land-use change, secondary human-made barriers, *etc.*) are handled, where a new sampling frequency will begin at the reach break.

Table 9.1. Field descriptions for the Physical Habitat Survey data collection form (Appendix J). Predefined field values are indicated in **bold** text.

Field Form Name	Description
Survey ID	Unique identifier, must be identical to the Site ID for the site.
Date	Date of the field review. **MM/DD/YYYY** format.
Observers	Last names of the field crew that conducted the upstream survey, separate names with a semicolon.
Stream Name	Name of the stream where the feature is located. If the stream is unnamed, enter unnamed.
Tributary To	Name of the water body to which stream (above) is connected. If unnamed, enter unnamed. May include WRIA & stream number (e.g., unnamed 04.0373).
WRIA	Water Resource Inventory Area number for stream (above), 8-character maximum consisting of 6 digits, 1 decimal point, and 1 upper case letter (e.g., 00.0000A), where applicable. The first two digits are the WRIA number (1-62), the remaining 4 digits and alpha character are the stream number. If the stream has no number enter at least the WRIA number. Do not use X's as place holders.
Position	Location of the beginning of the reach (*e.g.*, at barrier culvert Site 370054 on Jones Road; or; at left bank tributary entering at 1543 meters upstream Site 370054).
Survey Type (Habitat Assessment Method)	Habitat assessment method used to determine Significant Reach and/or Priority Index. **FS** = full survey, **RSFS** = reduced sampling full survey, **TD** = Threshold Determination.
Reach #	Number or reach being sampled. For example, the first reach sampled would be Reach 1, the second Reach 2, the third Reach 3, and so on.
Begin CR	Beginning Chain Reading (CR). The hip chain reading at the beginning of the reach, in meters.
End CR	Ending CR. Hip chain reading at the end of the reach, in meters.
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 <u>No</u> Habitat Value = 0.
Rearing HQM	HQM assigned to rearing habitat for the reach. Appropriate values: Good = 1; Fair = 0.67; Poor = 0.33; Very Poor with <u>No</u> Habitat Value = 0.
Limiting Factors	If an HQM less than 1 was assigned, explain why.
Spring Influence	Estimate of the spring contribution to the flow of the stream. Absent = 0; Slight = 1; Moderate = 2; Pronounced = 3.
Instream Cover	Characterize the amount of instream cover as low, medium, or high.
Juvenile Abundance	A visual estimate of salmonid fry abundance as low, medium, or high.

Table 9.1. (continued) Field descriptions for the Physical Habitat Survey form (Appendix J).

Field Form Name	Description
Temperature	Temperature measured in degrees Celsius.
Canopy	Percent canopy cover assuming full leaf-out conditions. Note dominant tree species.
Additional Features	The number of features encountered within the reach, including human-made and natural.
Culverted Length	Total length of all culverts within the reach, in meters.
Sampling Frequency	Sample frequency; 30 meters every 160 meters, 60 meters every 320 meters, or 60 meters per reach.

Table 9.2. Expected species utilization (shaded) and passability (horizontal lines) for each gradient stratum.

	Gradient Strata (%)						
Species	0-1	1-3	3-5	5-7	7-12	12-16	16-20
Chum Salmon	■	■	☰				
Pink Salmon	■	■	■	■	☰		
Coho Salmon	■	■	■	■	☰	☰	
Sockeye Salmon	■	■	■	■	☰	☰	
Chinook Salmon	■	■	■	■	☰	☰	
Steelhead Trout	■	■	■	■	■	☰	☰
Searun Cutthroat	■	■	■	■	■	☰	☰
Bull Trout[1]	■	■	■	■	■	■	■
Trout[2]	■	■	■	■	■	■	■

[1]Includes resident and anadromous bull trout/Dolly Varden
[2]Includes resident rainbow and cutthroat trout

As a rule of thumb a reach break is made wherever a change in stream characteristic will affect one of the measured parameters used to calculate species-specific production potential (gradient, channel width, riffle area, pool area, bed composition, or habitat quality modifier). In addition, a reach break is made at each human-made barrier feature encountered during the survey.

Changes in bed form that requires a reach break are any change that significantly affects pool:riffle:rapid ratio, substrate composition, or channel width. Bed form strata need not be 160 meters long to qualify as a reach. An example is a stream that has a significant gravel source (feeder bluff), which provides good spawning gravel in riffle areas downstream but has boulder and bedrock (gravel poor) upstream from this point. In this case a reach break at the feeder bluff is necessary to keep from biasing the gravel composition assessments regardless of the length of riffle and bedrock areas above and below the feeder bluff. For another example, if a sediment source is a sand bluff that changes bed composition to a high percentage sand (low percentage spawning gravel) downstream and low sand (high percentage spawning gravel) upstream a reach break is also required.

Other bed form changes that require a reach break are a change from a forested high quality channel (high level of LWD) that emerges into a highly impacted dairy or cattle grazing reach of lower productivity (cattle waste, low LWD, or lack of stream bank vegetation and hiding cover).

Natural Barriers

A waterfall greater than 3.7 meters in vertical height is considered a natural barrier to most fish**.** A gradient barrier is a sustained gradient >20% for a distance of 160 meters, or when the channel has a sustained gradient >16% for a distance of 160 meters and has a channel width <0.6 meters in Western Washington or <0.9 meters in Eastern Washington as measured at the scour line width (SLW). These criteria for natural barriers are used when conducting habitat assessment for prioritizing correction of human-made barriers. Refer to Chapter 6 for evaluation and data collection requirements for documenting natural barriers.

Additional Barriers

Frequently, additional human-made barriers and water diversions exist which may need to be corrected to realize the potential habitat gain above or below the primary barrier. When encountered, record the Site Identification number for the barrier or diversion into the "additional barrier" space in the field data notebook. Record the distance in meters above or below the target barrier. Identify the method of distance measurement (belt chain, stream catalog, aerial photo, USGS quadrangle) used to locate the barrier within the reach. Record the type of structure (*e.g.*, water diversion, lake outlet screen, culvert, dam, fishway, or other) and record the location (preferably the GPS position). Collect the site information and complete the appropriate field form(s) for the type of feature encountered. Each secondary human-made barrier will appear as an additional record in the FPDSI database. A reach break is made at each human-made barrier encountered.

Comments

Note principal stream features, tributaries entering, seeps and springs, road crossings and other human-made features, etc. as they are encountered. Note natural features such as beaver dams, log jams, cascades, falls, etc. Record the end of the survey and the reason for ending the survey. Record the GPS coordinates and survey location (in meters from the beginning of the survey) relating to comments made. Also, it is a good practice to record brief comments and GPS coordinates for all habitat photos taken.

Sample Section

When conducting a full survey, the length of the stream is estimated from USGS quadrangle maps (1:24,000), to determine the appropriate sampling frequency. For streams less than 1.6 kilometers in length, 30 meters of habitat is sampled for every 160 meters of stream length. For streams greater than 1.6 kilometers in length, sample the first 60 meters of every 320 meters of stream. This method results in approximately a 20% sampling level. Habitat surveys proceed from the human-made barrier and continue upstream or downstream until a gradient or natural point barrier is reached. All of the information described in Section 9.1 is collected.

If a RSFS is being conducted, the only departure from the FS is that only one 60 meter sample is collected for each stream reach rather than collecting a sample every 160 or 320 meters. Everything else is identical between the two methodologies.

Pool, Riffle, Pond, and Rapid Physical Measurements

The stream is divided into four habitat types - pool, riffle, pond, and rapid. Pool habitat is characterized by relatively deep, low velocity water and smooth water surface. A riffle is a stream segment in which the water flow is rapid and usually shallower than the stream segments above and below. Rapids are high gradient (>5%) riffles with larger substrate and generally contain "white water". Runs and glides must be broken into riffles or pools. Surface flow characteristics and depth should be used to distinguish whether a run or glide is characterized as a riffle or pool.

Pond habitat is defined as a zero gradient reach having an average width at least five times that of the average pool width and five times the average pool length in the downstream reach. Ponds are treated as separate reaches and do not need to be 160 meters in length. In the event short, high quality riffles exist between a series of high quality rearing ponds, exceptions to the reach length can be made (<160 meters) to capture these high quality areas in the survey. Larger freshwater bodies, such as perennial wetlands and lakes, are also classified as pond habitat for purposes of data analysis.

For each habitat type, record the length, to the nearest 0.1 meter, within the sample section. Record, to the nearest 0.1 meter, the stream wetted width and the scour line width (SLW) at the first two pools, riffles, and rapids found within the sample section that are representative of the conditions within the section. The width measurements should be taken in an area representative of the average width of the habitat type, not in an area where the stream is wider or narrower. Use either a staff marked for metric lengths or meter tape to measure width. Pond average widths may be measured in the field using a hip-chain or range-finder laser or measured off an aerial photo in the office if taking measurements in the field is not possible.

Record the average water depth to the nearest 0.01 meter at the cross section where each of the wetted width measurements were taken. Take a minimum of three measurements that are representative of the range of depths found in the cross section and average.

Scour Line Width

Measure the scour line width (SLW) perpendicular to the flow, from the line along a stream channel created by scour and kept primarily unvegetated by running water. Includes everything within the active channel where stream flow would be expected during the time of salmonid spawning activity. Look for distinct marks, such as a line left by debris, pollen or silt, or a mark made by erosion, destruction of terrestrial vegetation, or other easily recognized characteristic. See Figure 3.3 in Chapter 3 for an example of where to take channel width measurements.

Substrate Composition

Substrate composition for pools, riffles, and rapids are visually estimated in each habitat type measured. The method estimates the percent of total area of each sample pool, riffle, and rapid measured that is occupied by each substrate category listed in Table 9.3. Both observers should complete the process independently and then average their estimates into one sample estimate. Be sure to consider all of the substrate within the active channel (SLW area).

For example, to estimate substrate composition for a sample pool, each surveyor would visually observe the most abundant substrate type and estimate the percent of the total pool area it occupies. Repeat the process for estimates of the second most abundant substrate type then the third and finally the fourth or least abundant. Substrate particles are sorted by hydraulic forces that tend to group substrate particles of similar size categories. Once all four substrate categories have been estimated they should be totaled and equal 100%.

Substrate composition estimates are very important because the production estimates for spawning-limited species such as chum, pink, and sockeye salmon are calculated using the estimated percent gravel by pool/riffle/rapid area.

Table 9.3. Substrate size classes used to characterize substrate composition.

MEAN PARTICLE DIAMETER SIZE CLASS RANGES		
CATEGORY	SIZE CLASS RANGE (mm)	SIZE CLASS RANGE (in)
Boulder	>305 mm	>12 in
Rubble/Cobble	76 to 305 mm	3 to 12 in
Gravel	5 to 76 mm	0.20 to 3 in
Sand/Fines	< 5 mm	<0.20 in

Gradient

Take at least one gradient measurement per sample section. Gradient may be measured using a clinometer or hand or tripod mounted level and stadia rod. Take the gradient over as long of a stream section as visibility allows, being careful to not shoot across meanders. Take back sights when possible as a double check.

Habitat Quality Modifiers

Two Habitat Quality Modifiers (HQM) are assigned to each survey reach to identify the productive capability of the habitat as described in Table 9.4. The HQM rating is used as a multiplier of the habitat area to obtain H in the Priority Index (PI) model (H= habitat quality modifier x habitat in square meters). Since a separate production rate is used for each species present in the PI model and the production rate is calculated using square meters of spawning habitat for species that normally do not rear in streams (chum, sockeye/kokanee and pink salmon), and square meters of rearing habitat for species dependent upon stream rearing habitat (coho, chinook, sea-run cutthroat, steelhead, resident trout, and Dolly Varden/bull trout*)*, the habitat quality modifier must be applied independently to spawning and rearing habitat. Often the habitat quality modifier will be the same for both. However, in some situations, such as silt bottom creeks, rearing habitat may be excellent (rearing HQM = 1) but spawning habitat is reduced due to a high percentage of fines (grain size <0.85 mm) mixed in with spawning size gravel.

The spawning habitat quality modifier is determined visually by estimating the percent fine particle (<0.85mm) composition within areas/patches that are classified as “gravel” (5 to 76 mm diameter particles) substrate. The estimating procedure combines subjective evaluations of the surface composition, silt plume characteristics as a boot heel is dug 20-25 centimeters (8-10 inches) into a “gravel” patch substrate, and the composition of several handfuls of the underlying substrate. The procedure should be repeated several times at each site to estimate the percent fines (<0.85 mm) in the “gravel” for each reach. Refer to the criteria in Table 9.4, for evaluating spawning habitat quality.

The habitat components or functions to be considered when assigning a rearing habitat quality modifier are riparian vegetation (shade, cover), channel morphology (pool/riffle ratio), undercut banks, instream cover (LWD, boulder matrix), seasonal flow, and temperature. Components are to be evaluated within the context of expected normal density, occurrence and function given the stream gradient, elevation, and geographical location. Refer to the criteria in Table 9.4, for evaluating rearing habitat quality.

Without formal training it may be difficult to assign the habitat quality modifiers. If training has not been received, use a habitat quality modifier of 0.66 as a default.

Table 9.4. Criteria used to assign Habitat Quality Modifiers to rearing and spawning habitat.

HABITAT QUALITY MODIFIER (HQM)			
HABITAT CONDITION	HQM VALUE	REARING HABITAT CRITERIA	SPAWNING HABITAT CRITERIA
GOOD TO EXCELLENT	1	Rearing habitat is stable and in a normal productive state with all components functional	Spawning gravel patches have ≤16% fine particle sizes that are <0.85mm in diameter
FAIR	0.67	Rearing habitat shows moderate/widespread signs of instability and/or disturbance known to reduce productive capability (one or more habitat components missing or significantly reduced presence)	Spawning gravel patches/riffles show moderate/widespread signs of instability (scour/filling) and/or >16% to 21% fine particle sizes <0.85mm in diameter
POOR	0.33	Rearing habitat shows signs of major/widespread disturbance likely to cause major reductions in its production capabilities (two or more habitat components missing or severely reduced presence)	Spawning gravel patches/riffles show major/widespread signs of instability (scour/filling) and/or heavy amount of fines (>21% to 26% fine particle sizes <0.85mm in diameter) and/or embedded gravels
NO VALUE	0	Rearing habitat severely disturbed so that production capabilities are without value to salmonids at this time	Spawning gravel patches with >26% fine particle sizes <0.85mm in diameter

Limiting Factors

If a habitat quality modifier other than 1 is assigned to a reach, indicate why. A simple note will suffice (dairy waste, unstable channel, >16% fines, heavily embedded gravels, lacking riparian vegetation, lacking instream cover, irrigation return water, high summer water temperatures, stormwater, urban development, *etc*.).

Spring Influence

Calculation of the 60-day low flow requires identification of the degree of "spring influence" as described in the 60-day low flow methodology (Appendix L). The spring influence factor (Table 9.5) is used to minimize the reduction of measured wetted area in streams that have springs contributing a substantial part of the flow during the low flow period.

The influence the spring factor has on the 60-day low flow calculated area ranges from no influence (spring factor = 0), to completely canceling the reduction of measured wetted area for the summer flow period and effectively saying that the stream runs at a constant flow perpetually with no summer low flow area reduction (spring influence = 3). Few streams are unaffected by summer drought, so it is important to use good judgment when applying the spring factor. Use the guidelines found in Table 9.5 to assign the spring factor to each reach surveyed.

Table 9.5. Criteria used to assign a spring influence factor.

SPRING INFLUENCE FACTOR (SPRING FACTOR)		
SPRING INFLUENCE	SPRING FACTOR	CRITERIA
ABSENT	0	normal channel morphology with evidence of a range of flows (scoured pool riffle sequence)
SLIGHT	1	rectangular cross section with minor variations in depth (less evidence of scour and bed transport than above) ***(low flow width = 1/3 scour line width)***
MODERATE	2	as above but even less sediment transport and scour with low flat flood plains and little evidence of freshet activity ***(low flow width = 2/3 scour line width)***
PRONOUNCED	3	bank vegetation established with a distinct line a small distance above the water surface during summer flow period, heavy moss growth on the exposed stream rocks can indicate freshet activity is very weak. *Must flow at nearly constant flow level year around* ***(low flow width = scour line width)***

Water Temperature

Water temperature is taken for each stream reach using a hand-held thermometer calibrated for Celsius readings. Temperature is recorded to the nearest degree. *Note: WDFW recommends using mercury-free thermometers, which are readily available. Mercury thermometers should not be used, since they are prone to break. Mercury is a toxic element, a known neurotoxin and suspected carcinogen, and is harmful when it builds up in the environment.*

Canopy Composition

Visually estimate the percent of the wetted stream area shaded by the riparian vegetation while assuming a full leaf out condition. Note the dominant tree and shrub species within the stream corridor. One canopy composition estimate should be made for each reach. Periodic use of a densiometer is advised to calibrate survey observations and to train new survey teams.

Instream Cover

Instream cover includes large woody debris (LWD), undercut banks, large boulders, and close overhanging vegetation located within 0.91 vertical meters (3 feet) from the water (WDFW and Ecology 2004). Instream cover is visually estimated as high, medium, or low. The instream cover rating should be reflected in the rearing habitat modifier. One estimate of instream cover density should be made for each reach.

Juvenile Abundance

A subjective visual estimate (none, low, medium, or high) of juvenile densities is noted by species (if possible) for each stream reach.

Basin Area

The basin area (also known as ‘watershed’ or ‘drainage’ area) includes all water bodies (rivers and streams) that convey water, as well as the land surfaces from which water drains into the conveying stream channels. Each drainage basin is separated topographically from adjacent basins by a ridge, hill or mountain, which is known as a watershed boundary. When measuring the basin area, consider all upstream area that would contribute water to the point of the beginning of the reach, or inventory feature. The basin area for each reach surveyed is measured off a USGS quadrangle map, using a planimeter or GIS software. See Figure 9.2, for an example of delineating basin areas by reach.

9.2 Habitat Gain: Anadromous and Resident-only Fish Habitat

In watersheds accessible to anadromous salmonids, the potential habitat gain is always calculated from the human-made barrier upstream to the first natural barrier or end of fish bearing habitat, whichever comes first. The net gain is represented by the connection of the smaller (upstream) piece of habitat with the larger (ocean access downstream). Therefore the habitat gain will always be upstream of the inventoried human-made barrier in anadromous waters.

In those portions of a watershed that only support resident salmonids, barrier removal may not result in a net gain of habitat upstream because resident fish populations can exist both up and downstream of a human-made barrier. Resident fish populations become fragmented and isolated by human-made barriers. This reduces genetic interchange and makes fish populations susceptible to extinction within isolated reaches. Overall fish habitat quality is diminished when some habitat components are isolated from segments of the population. Some reaches may not have all habitat components necessary to sustain an independent population. Barrier removal reconnects isolated fish populations and restores habitat connectivity.

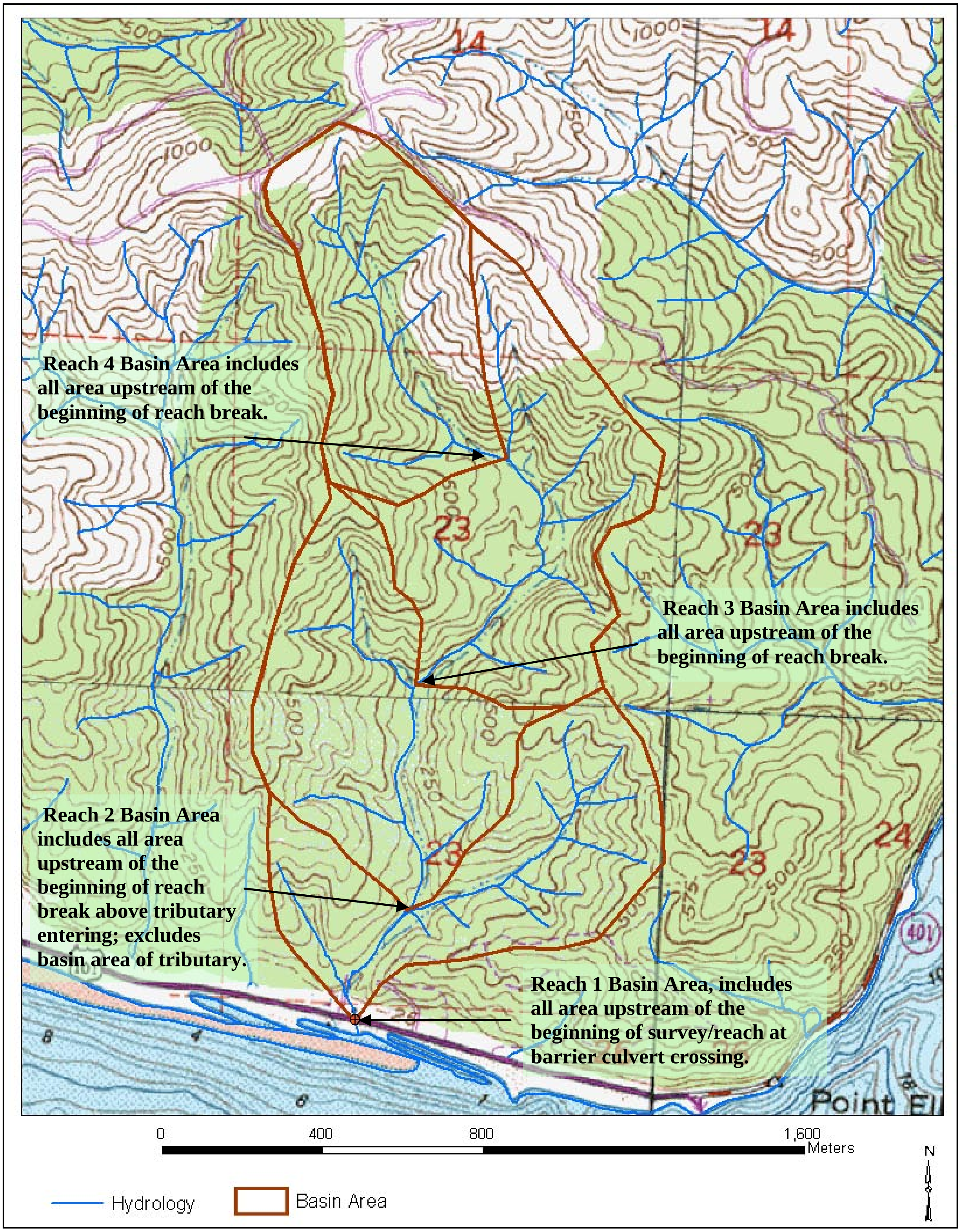


Figure 9.2. Example of how to measure basin area.

For the purposes of calculating a PI value, the benefit to the resident fish population is represented by the shortest habitat segment between the human-made barrier and the nearest upstream and downstream natural barrier.

9.3 Habitat Survey Data Entry

A customized spreadsheet is used to process field data collected using the FS or the RSFS methods described earlier. The primary output from the spreadsheet is species-specific adjusted production area values that represent the H variable in the PI equation. The spreadsheet is named SurveyV4.xls (This spreadsheet can be downloaded from the Internet at http://wdfw.wa.gov/hab/engineer/fishbarr.htm.). Once it has been completed it must be saved under a different file name in order to maintain the template. A separate file is created for each stream surveyed. Multiple surveys and thus files may be necessary for some human-made barriers. Combining the output from multiple files is described below in the summary section. The spreadsheet consists of four sheets, an input sheet where all the physical habitat measurements are entered, an output sheet, which contains the results of the analysis, and two comments sheets, which contain field observations associated with the fish access check and the habitat survey.

Sample field data can be found in Appendix K. These sample data are used in the examples for data input and output in the following sections.

Input

The input sheet has a header section containing the following fields: Survey Method, Stream Name, Tributary To, WRIA #, Sample Frequency, Date, Observer(s), Section Surveyed, and File (electronic file name). This information is automatically inserted into the Output and Comments sheets. The header is followed by ten reach sections, each containing information on location, habitat quality, species presence, 60-day low-flow parameters, and habitat measurements (samples). Each reach can accommodate 79 samples. Between the sample input area and the next reach are a series of fields containing formulas for calculating sample averages. Data entry is restricted to the gray shaded cells on the spreadsheet. White cells contain either labels or display results of underlying formulas. An example of the input sheet (single reach), with the sample data, is presented in Appendix K and each data field and its appropriate inputs are described in Table 9.6.

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 of the second file, and so on. Actual reach numbers should be explained in the comments section. Combining the output from the two files is described below in the summary section.

Table 9.6. Instructions for data entry into the Input spreadsheet. Required data entry fields and values are in **bold**.

Field Name	Field Type	Instructions for Data Entry
HEADER INFORMATION		
Survey Method:	Character	Habitat survey methodology used. Valid entries include: **FS** for full survey, and **RSFS** for reduced sampling full survey.
Stream Name:	Character	Name of the stream being surveyed. If the stream is an unnamed tributary, then enter unnamed stream.
Tributary To:	Character	Name of the water body the surveyed stream is tributary to.
WRIA # :	Character	Water Resource Inventory Area (WRIA) and stream number assigned to the surveyed stream. In cases where unnamed tributaries do not have an assigned stream number, or the stream number is unknown, then include only the WRIA. Refer to the following publications to find WRIAs and stream numbers*:* Williams *et al.* (1975), Phinney and Bucknell (1975), and WDOE (1972). WDOE's Internet website <http://www.wa.gov/ecology/wr/wrias.html> contains a map of all WRIAs. For streams having no assigned stream number, briefly describe the location of the stream where at the confluence with a known water body (for example, "unnamed LB trib to Shinando Cr at Lat/Long", or "Prospectors Cr RB trib Gold R entering at RM 4.7").
Sample Frequency:	Character	Survey sample frequency. 60 meters/322 meters, 30 meters/161 meters, or 60 meters per reach.
Date:	Date	Date of FS or RSFS. If the stream survey took more than one day to complete, then enter the date when survey began. Format **MM/DD/YYYY**.
Observer(s):	Character	Last names of the stream surveyors.
Section surveyed:	Character	Enter text describing the stream section surveyed, from beginning to ending point. (e.g. -mouth to 1000 m upstream, or, highway 101 milepost 10.90 to 1000 m upstream or Site 991745 to 1000 m upstream)
File:	Character	Filename the stream survey is saved as. (e.g. 991745.wb1)
LOCATION INFORMATION *Note: All of the following fields are repeated for each reach within the survey.*		
Begin (m):	Numeric	Hip-chain reading at the beginning of the reach (e.g. Reach 1 should begin at zero, Reach 2 should begin where Reach 1 ends, Reach 3 begins where Reach 2 ends, and so on). Units in meters.
End (m):	Numeric	Hip-chain reading at the end of each reach. Units in meters.
Reach Length (m):	Numeric	Total length of the surveyed reach, in meters, based on beginning and ending positions. *Calculated field, do not edit.*
Position:	Character	Describe the beginning position of the survey reach (e.g. 250 m upstream Site 991745 Highway 101 Milepost 10.90; or; immediately upstream of confluence with main stem; or; immediately upstream of culvert under 223rd St).

Table 9.6. (continued). Instructions for data entry into the Input spreadsheet.

Field Name	Field Type	Instructions for Data Entry
HABITAT QUALITY		
Instream Cover:	Character	Describe the amount and type of instream cover. Instream cover density is visually estimated as high, medium, or low. Types include large woody debris (LWD), undercut banks, large boulders, close overhanging vegetation, etc (e.g. high, mostly large woody debris; or; medium, primarily boulder; or; low, tall grasses and other rooted macrophytes). *A low instream cover rating should be reflected in the rearing habitat quality modifier.*
Juv. Abundance:	Character	A subjective visual estimate of fry densities, by species if possible, within the reach. Valid entries include: low, moderate, high, or none observed.
Canopy:	Character	Canopy composition, in percent, noting major tree and shrub species within stream corridor (e.g. 85% canopy, primarily second growth alder and other deciduous species; or; 100% second growth, primarily cedar and Douglas fir; or; 10% very sparse canopy, some deciduous shrubs present).
Limiting Factors:	Character	If a habitat quality modifier other than 1 was assigned, explain why (e.g. dairy waste, unstable bed, lacking riparian vegetation, lacking instream cover, irrigation return water, stream dries in summer, high summer water temperatures, gravels heavily silted, etc.).
Barrier SiteID:	Character	Site identification number for any additional barrier upstream of the initial barrier, both human-made and natural, including partial and total fish barriers. If there is no additional barrier within the reach, then leave blank.
Total culverted length:	Numeric	Total length of all culverts located within the reach.
Spawning:	Numeric	Habitat quality modifier for spawning habitat. Valid entries include: Good to Excellent = **1**; Fair = **0.67**; Poor = **0.33**; No Value = **0**.
Rearing:	Numeric	Habitat quality modifier for rearing habitat. Valid entries include: Good to Excellent = **1**; Fair = **0.67**; Poor = **0.33**; No Value = **0**.
T (C):	Numeric	Stream temperature, measured in degrees Celsius.
T @ trib:	Numeric	Stream temperature measured at the confluence with a tributary entering the survey reach. Leave blank if there are no tributaries.
REACH SPECIES USE		
Species Presence	Character	Enter an ‘x’ under each species that is expected to utilize the habitat. If species utilization is unknown, contact area fish biologists, habitat biologists, or consult publications including the *Stream Catalog* (Williams *et al.* 1975 and Phinney and Bucknell 1975), SaSI (WDFW 2003), or Salmonscape (http://wdfw.wa.gov/mapping/salmonscape/). 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 barriers are removed) and do not exceed the normal upper gradient limits for the species.

Table 9.6. (continued). Instructions for data entry into the Input spreadsheet.

Field Name	Field Type	Instructions for Data Entry
60-DAY LOW FLOW		
Est. Basin Area:	Numeric	Estimated basin area for the reach, measured off a USGS quadrangle map, using a planimeter or GIS software. Units in square miles, measured to the nearest hundredth.
Spring influences are (see below):	Numeric	Spring influences (absent - **0**, slight - **1**, moderate - **2**, pronounced - **3**).
Reg. Constant (for 60-d low flow calc.):	Numeric	Regional constant (Figure 9.3) 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 MEASUREMENTS		
Type	Character	Under the heading 'Type', enter the habitat type measured for each sample. Valid entries include: **'pl'** for pool, '**rf**' for riffle, '**rp**' for rapid, and 'pd' for pond. Pond habitat should be broken out as a separate reach that does not contain pool, riffle or rapid data. Ponds, wetlands and lakes will be considered "pond" habitat for data entry purposes.
L	Numeric	Under the heading 'L', enter the length (in meters) of the habitat type measured for each sample. For pond habitat, enter the length (in meters) walked in the field or measured from an aerial photo.
W	Numeric	Under the heading 'W', enter the wetted width (in meters) of the habitat type measured for each sample.
SLW	Numeric	Under the heading 'SLW', enter the scour line width (in meters) of the habitat type measured for each sample.
D	Numeric	Under the heading 'D', enter the depth (in meters) of the habitat type measured for each sample.
Grad.	Numeric	Under the heading 'Grad.', enter the percent stream gradient for each sample section, expressed as a decimal. (e.g. a 5% stream gradient would be entered as 0.05).
B	Numeric	Under the heading 'B', enter the percentage of boulder that is present within each habitat type measured, expressed as an integer.
R	Numeric	Under the heading 'R', enter the percentage of rubble that is present within each habitat type measured, expressed as an integer.
G	Numeric	Under the heading 'G', enter the percentage of gravel that is present within each habitat type measured, expressed as an integer.
S	Numeric	Under the heading 'S', enter the percentage of sand/silt that is present within each habitat type measured, expressed as an integer.

Output

The output sheet displays the results and summaries of the survey. It contains most of the formulas used to process the data. As such, it is a 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 K with the sample data.

The survey summary page contains the header information, total lengths for the survey, samples, additional human-made barriers, area totals and ratios for pool, riffle, rapid, and pond habitats, total stream area measured, and total spawning and rearing area. Two ‘production area’ tables are presented, one with areas adjusted for species interaction, the other not. The total adjusted production area for a given species is the value for the H variable in the Priority Index equation for that species.

The reach pages summarize survey information on a reach-by-reach basis. This includes the locational, habitat quality, species presence, temperature, and substrate composition information from the input sheet. Lengths, average widths and depths, areas, ratios, and gravel percentages are calculated for pools, riffles, rapids, and ponds. Pool, riffle, rapid, and pond areas are calculated for wetted measures, scour line width (SLW) measures, and 60-day low flow equations. Wetted areas represent conditions at the time of the survey, SLW areas represent conditions expected during the spawning season, and 60-day low flow areas represent low flow conditions. Spawning area is based on SLW area and rearing area is based on 60-day low flow area as described above.

Habitat Survey Comments

Upstream survey and fish access check comments are recorded on the appropriate comments sheet. Each sheet contains the heading information from the input sheet. Do not change the heading. If there are any errors in the heading correct them on the input sheet. Below the heading there is a column (A) for the hip-chain reading and a column (B) for the comments associated with that reading. When text reaches column J, continue entering comments on the line below. Upstream comments should be divided by reaches. Highlighting additional barriers or instream activities (e.g., bank stabilization, stream dredging, etc.) with bold text is recommended. The comments may be printed after proofing, see Printing instructions. An example is presented in Appendix K using the sample data.

Habitat Survey Summary

The summary spreadsheet (Summary.xls) is used to calculate the total survey length, rearing area, spawning area, and adjusted production areas from multiple stream surveys associated with a single fish passage barrier. The output represents the total potential habitat gain upstream of the target barrier. The spreadsheet will accommodate 10 surveys and individual species.

The survey length, rearing area, spawning area, and adjusted production areas from each stream survey (output sheet-survey summary page) are entered into the appropriate cells in the Summary spreadsheet where they are summed and totals presented. Table 9.7 describes the cells and the data entry protocol. A sample is provided in Appendix K.

Table 9.7. Data entry instructions for the Summary spreadsheet.

Field Name	Field Type	Instructions for Data Entry
Stream Name:	Character	Name of the primary stream surveyed, which flows through the target fish passage barrier.
WRIA:	Character	WRIA and stream number for primary stream surveyed.
Tributary To:	Character	Water body for which the primary stream is a tributary to.
Site ID:	Character	Site ID number assigned to the target fish passage barrier during the inventory process.
Filenames:	Character	Enter the filenames of all stream surveys associated with the barrier. Accommodates up to ten stream surveys, the primary stream and nine tributaries.
Species Present:	Character	Species names for all salmonids present in the streams surveyed. Include all species that were selected during data entry into the habitat survey spreadsheet. These species names will automatically be inserted into the appropriate cells for the Adjusted Production Area headings.
Length Surveyed (m):	Numeric	Length (in meters) of each survey (for primary stream, 1st tributary, 2nd tributary, 3rd tributary, and so on), taken from the survey summary report, use the "Total Length Surveyed:" cell on the first page of the Output sheet.
Total Length Surveyed (m):	Numeric	Total length (in meters) surveyed, upstream or downstream of the target fish passage barrier. *Calculated field, do not edit.*
Rearing Area (m^2):	Numeric	Amount of rearing area (in square meters) for each survey, from the survey summary report, use the "Total Rearing Area:" cell found on the first page of the Output sheet.
Total Rearing Area (m^2):	Numeric	Total rearing area (in square meters) available above the target fish passage barrier. *Calculated field, do not edit.*
Spawning Area (m^2):	Numeric	Amount of spawning area (in square meters) for each survey, from the survey summary report, use the "Total Spawning Area:" cell found on the first page of the Output sheet.
Total Spawning Area (m^2):	Numeric	Total spawning area (in square meters) available above the target fish passage barrier. *Calculated field, do not edit.*
Adjusted Production Area:	Numeric	Next to each species listed, enter the adjusted production area for that species for each survey, taken from the survey summary report, found at the bottom of the first page of the Output sheet in the Adjusted Production Areas table.
Total Adjusted Production Area:	Numeric	Total adjusted production area, for each species. These values will be used in the PI formula. *Calculated fields, do not edit.*

Saving/File Naming

To maintain template integrity both the SurveyV4 and Summary spreadsheets are distributed as read-only files. Once data are entered the files must be saved under new names. The unique site identification (SITE ID) number assigned to the target barrier is used in naming all associated survey files. For the primary stream surveyed the name consists of the SITE ID and the file extension (e.g., 991754.xls). For tributaries to the primary stream, the name consists of the SITE ID plus a lower case letter (‘a’ for the first tributary encountered, ‘b’ for the second, and so on) and the file extension (e.g., 991754a.xls). For tributaries to the secondary streams, the name consists of the SITE ID, the lower case letter for the secondary tributary, a number (‘1’ for the first tertiary stream, ‘2’ for the second, and so on), and the file extension (e.g., 991754a1.xls). For Summary spreadsheets, the name consists of the SITE ID number plus the characters ‘su’ and the file extension (e.g., 991754su.xls).

Printing

The SurveyV4 output and comments sheets are printable. The input sheet is solely for entering data. The output sheet is formatted into 11 printable pages: one survey summary page and ten reach summary pages. In the print dialog box, select “current sheet” and specify the range of pages to print based on one survey summary page and the number of reaches (*e.g.,* for a survey with 5 reaches, pages 1 through 6 must be specified). To print the comment sheets, select the desired sheet, initiate the print function, and select “current sheet” in the print dialog box. To confirm that all the text will be printed, view the comments with “print preview” prior to printing. To print the Summary spreadsheet, block select all of the text to print, then initiate the print function.

9.4 Habitat Survey Data Analysis

Physical habitat survey data are used to estimate habitat gains in terms of fish production potential. Habitat gain is expressed in square meters (m^2) of either spawning or summer rearing habitat. These values are a key variable (H) in the Priority Index (PI) Model that is used to prioritize barrier correction. Spawning area is used for those species (chum, pink, and sockeye salmon) whose production is limited by spawning habitat. Rearing area is used for those species (coho and chinook salmon, steelhead, cutthroat, rainbow, bull, brook, and brown trout) whose production is limited by rearing habitat.

Physical habitat survey data are processed in the customized Excel spreadsheet. The spreadsheet generates a detailed report for each stream surveyed which contains the total habitat gain per species, habitat measurements for each stream reach and the total survey, habitat quality information, and other fundamental survey data.

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. Widths measured at the scour line are determined during the survey using the bank vegetation line and other hydrologic evidence.

Rearing area is calculated using a projected 60-day low flow that is calculated using basin area, spring influence, and a regional constant (Figure 9.3). Sixty-day low flow is defined as the lowest average flow occurring over any period of 60 consecutive days during the year. The entire stream area calculated using the 60-day low flow is considered rearing area. This methodology allows comparison of rearing areas regardless of the season in which the stream was surveyed.

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:

$$(((\text{Area} – 2{,}000)/2{,}000)^{½}\ 2{,}000)+2{,}000.$$

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 Modifier (HQM) can adjust both the spawning and rearing areas, which is a subjective estimate of habitat quality. The HQM has a value that ranges in one-third increments from zero to one.

A separate modifier is assigned to rearing and spawning habitat within each stream reach. This modifier serves to decrease the habitat areas in degraded streams to reflect the lower production potential.

Gains in spawning or rearing area are calculated for each species (potential presence) for each sample reach within a survey. Reach values are then subjected to an analysis of species interaction. Competition between species with similar freshwater life histories[1] tends to reduce the production rate below single species production values. For example, optimum single species productivity for two species within the same complex (coho and steelhead) is estimated at 0.05 and 0.0021 adults/m^2 respectively. If the single species values are added, a total production value of 0.0521 is the result. To adjust for competition within species complexes, the species complex factor was developed to reduce multiple species production values below the simple total of individual values.

If there are 3 species in the species complex then:

Species Complex Factor (CF) = production value species 1 + 0.67 (production value species 2) + 0.33 (production value species 3) / production value species 1 + production value species 2 + production value species 3

If there are 4 species in the species complex then:

[1] Species complexes are determined by similarities in life history and are as follows (with the production values in parentheses): sockeye (3.0), chum (1.25), and pink (1.25) salmon; coho (0.05) salmon, searun cutthroat trout (0.037), chinook salmon (0.016), and steelhead (0.0021); resident cutthroat/rainbow trout (0.04) and bull trout/Dolly Varden (0.0007).

Species Complex Factor (CF) = production value species 1 + 0.75 (production value species 2) + 0.5 (production value species 3) + 0.25 (production value species 4)/ production value species 1 + production value species 2 + production value species 3 + production value species 4

In the case of coho and steelhead the species complex production value would be reduced from 0.0521 to 0.0516 or [*0.0521 x (0.05+0.75(0.0021)/0.05+0.0021)*].

It is important that species 1 is the species within the complex that has the highest production value followed by the species with the next highest production value and so on. To ensure consistent results we recommend using the SurveyV4 spreadsheet.

In practice, the species complex factor is used to reduce the habitat area (H) used in the Priority Index formula. The habitat area value is adjusted on a reach-by-reach basis for each species present. In the case where coho and steelhead utilize the same stream reach the total rearing area available would be multiplied by the species complex factor [H = habitat gain (m^2) x *(0.05+0.75(0.0021)/0.05+0.0021*)].

The adjusted habitat values for each reach are summed and used to calculate single species PI values using the full single species adult production value. The result is the same as adjusting the adult production value.

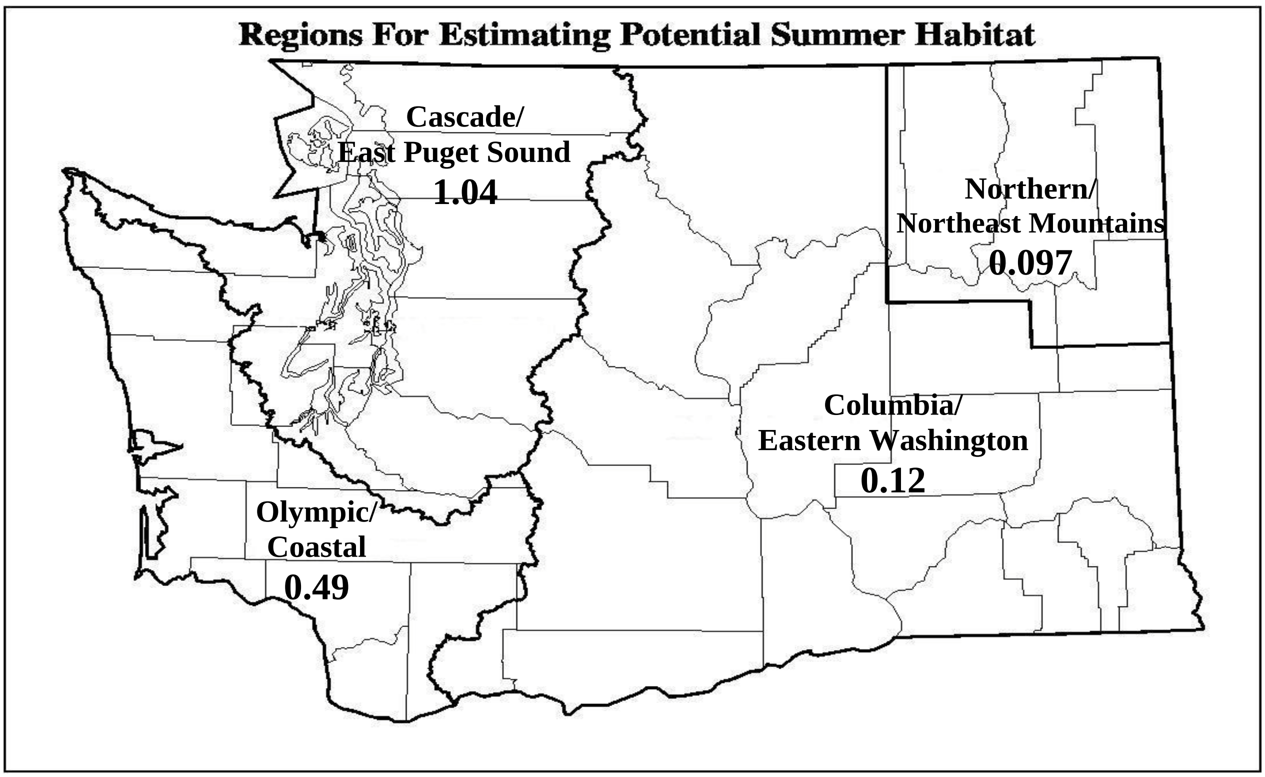


Figure 9.3. Regions and their associated constants for estimating the 60-day low flow.

9.5 Additional Reading

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CHAPTER 10

Revised 12/21/09

PRIORITIZATION

This manual chapter deals with prioritizing fish passage barriers and unscreened/insufficiently screened diversions for correction. For technical assistance with prioritization, contact the WDFW Habitat Program at (360) 902-2534, or TAPPS@dfw.wa.gov.

Why Prioritize?

Prioritization helps ensure projects that have the greatest benefits to fish are constructed first. It provides the ability to compare similar projects in different watersheds. It takes into account the benefits to fish as well as other pertinent factors like project cost and stock status. Prioritization may be advantageous if competing for grant funding.

10.1 Fish Passage Priority Index

The variability in costs, amounts of habitat gain, and species utilizing potential project sites throughout Washington State can make the characterization and prioritization of corrections to fish passage barriers complex. The WDFW Fish Passage Inventory process uses a Priority Index model to consolidate several factors that affect a fish passage project's feasibility (expected passage improvement, production potential of the blocked stream, fish stock health, *etc*.) into a manageable framework for developing prioritized lists of projects. The result is a numeric indicator giving each project's relative priority that includes production benefits to both anadromous and resident salmonid species adjusted for sympatric species interactions (species complexes). The Priority Index (PI) for each barrier is calculated as follows:

$$PI = \sum_{\text{all species}} \sqrt[4]{[(BPH) \times MDC]}$$

Where:

PI = Fish Passage Priority Index

- Relative project benefit considering cost.

- The PI is actually the sum ($\Sigma_{\text{all species}}$) of individual PI values, one of which is calculated for each species present in a stream (*e.g.*, PI_{coho} is added to PI_{chum} to obtain $PI_{\text{all species}}$).

- The quadratic root in the equation is used because it provides a more manageable number and represents a geometric mean of factors used.

B = Proportion of passage improvement

- Proportion of fish run expected to gain access due to the project; gives greater weight to projects providing a greater margin of improvement in passage.

- Derived from passability estimate:
  - 0% passable = 1.00
  - 33% passable = 0.67
  - 67% passable = 0.33

- Refer to Table 3.3 in Chapter 3 for a discussion of judging percent passability.

P = Annual adult equivalent production potential per m^2

- Estimated number of adult salmonids that can potentially be produced by each m^2 of habitat annually.

- The values (adults/m^2) 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, searun cutthroat trout = 0.037, resident cutthroat/rainbow trout = 0.04.

H = Habitat gain in m^2

- Measured/calculated from a habitat survey (described in Chapter 8); gives greater weight to projects that will make greater amounts of habitat available.

- Spawning area values used for species complexes normally limited by spawning habitat (sockeye, chum, and pink salmon) and rearing area values used for species complexes normally limited by rearing habitat (coho salmon, searun cutthroat, chinook salmon, and steelhead), (resident cutthroat/rainbow trout and bull trout/Dolly Varden).

- When more than one species within a species complex is present, H is modified to reflect sympatric interactions among species with similar freshwater life histories. The result is a reduction of single species' habitat area values when competing species coexist.

M = Mobility Modifier

- Accounts for benefits to each fish stock for increased mobility (access to habitat being evaluated); gives greater weight to projects that increase productivity of species that are highly mobile and subject to geographically diverse recreational and commercial fisheries by providing access to habitat currently limiting productivity.

  2 = Highly mobile stock subject to geographically diverse recreational and commercial fisheries (anadromous species).

  1 = Moderately mobile stock subject to local recreational fisheries (resident species).

D = Species Condition Modifier

- Representation of status of species present; gives greater weight to less healthy species as listed in the *Washington State Salmonid Stock Inventory (SaSI)* report (WDFW 2003). In the absence of a SaSI assignment, stock condition should be estimated using the best available information.

  3 = Condition of species considered critical.

  2 = Condition of species considered depressed or stock of concern.

  1 = species not meeting the conditions for 2 or 3.

C = Cost Modifier

- Representation of projected cost of project; gives greater weight to less costly projects.

  3 = incremental funds needed $100,000.

  2 = incremental funds needed between >$100,000 and $500,000.

  1 = incremental funds needed >$500,000.

- All barriers receive a cost modifier value of 2 until engineering evaluations are completed.

10.2 Screening Priority Index

The Screening Priority Index Model is a hybrid of the quadratic formula used in prioritizing fish passage barriers. The SPI was created to consolidate the many variables relevant to water diversions into a manageable framework for developing prioritized lists of screening projects.

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

$$\text{SPI} = \sum_{\text{all species}} \sqrt[4]{[(\text{QP}) \times \text{MDC}]}$$

Where:

SPI = Screening Priority Index

- Relative project benefit considering cost.
- The SPI is actually the sum ($_{\text{all species}}$) of individual SPI values, one of which is calculated for each species present in a stream (*e.g.*, SPI_{coho} is added to SPI_{chum} to obtain $\text{SPI}_{\text{all species}}$).

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 determined from the water right, directly measured, or is estimated from the diversion ditch area multiplied by 0.75.
- For pump diversions, flow is determined from the water right, flow meter, or gauge.

P = Annual adult equivalent production potential per m^2

- Estimated number of adult salmonids that can potentially be produced by each m^2 of habitat annually. Used as a surrogate for the probability of an individual fish of a given species encountering a diversion.
- The values (adults/m^2) 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, searun cutthroat trout = 0.037, resident cutthroat/rainbow trout = 0.04.

M = Mobility Modifier

- Gives greater weight to projects that increase productivity of species that are highly mobile and subject to geographically diverse recreational and commercial fisheries by providing increased survival through screening.

  2 = Highly mobile stock subject to geographically diverse recreational and commercial fisheries (anadromous species)

  1 = Moderately mobile stock subject to local recreational fisheries (resident species)

  0 = Increased survival of stock would have negative or undesirable impacts on productivity of native species or would be contrary to fish management policy.

D = Species Condition Modifier

- Representation of status of species present; gives greater weight to less healthy species as listed in the Washington State Salmonid Stock Inventory (SaSI) report (WDFW 2003). In the absence of SaSI assignment, stock condition should be estimated using the best available information.

  3 = Condition of species considered critical

  2 = Condition of species considered depressed or stock of concern

  1 = Species not meeting the conditions for 2 or 3

C = Cost Modifier

- Representation of projected cost of project; gives greater weight to less costly projects.

  3 = incremental funds needed ≤$1,000

  2 = incremental funds needed between > $1,000 and $5,000

  1 = incremental funds needed > $5,000

10.3 Additional Considerations

In addition to using the PI and SPI models, some other considerations to make when prioritizing projects include:

- Species Listings – Are federally listed stocks present?

- Coordination – Does the project compliment or is it complimented by other work in the watershed?

- Benefits – Does the project have other benefits to fish above and beyond fish passage or screening?

- Community Support – Does the project have the potential to involve multiple partners or have educational value?

10.4 References Cited

Washington Department of Fish and Wildlife. 2003. Salmonid Stock Inventory (SaSI). Olympia, WA. Available at: http://wdfw.wa.gov/fish/sasi/.

APPENDIX A

Glossary of Terms

a**ctive screen cleaning:** Screens equipped with a mechanical cleaning system that automatically clean the screens.

abandoned crossing: 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 to enhance habitat quality and prevent erosion. These roads are usually blocked 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 freshwaters to spawn. Examples include salmon and steelhead.

approach velocity: Mean flow velocity, measured a short distance upstream of a hydraulic structure. The calculated component of approaching water velocity passing through the fish screen perpendicular (90^o) to the screen surface (usually expressed in feet/sec).

apron: A pad or slab of non-erosive material designed to prevent scour holes developing at the outlet ends of culverts, outlet pipes, grade stabilization structures, and other water control devices. Erosion protection replacing or reinforcing streambed in an area of high velocity flow such as downstream of a culvert.

average stream width: See definition for "channel-bed width".

backwater: Water backed up in its course by an obstruction, an opposing current, or the tide. A condition whereby a water surface control reduces, eliminates, or controls a water surface drop located upstream of the control.

backwatered culvert: Condition within a culvert where a pool with little or no 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 to increase boundary roughness, thereby reducing the average water velocity and increasing water depth within the culvert.

bankfull width: The width of a stream channel at the point where over-bank flow begins during a flood event. Determining bankfull width requires the presence of a floodplain or a bench; however, many channels have neither. In those cases, bankfull channel must be determined by using features that do not depend on a floodplain, such as those used in the description of active channel and ordinary high water.

bed: The land below the ordinary high water lines of the waters of the state of Washington. This definition does not include irrigation ditches, canals, storm water run-off devices, or artificial watercourses, except where they exist in a natural watercourse that has been altered by man.

bedload: Portion of the 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 Manning's roughness coefficient.

benchmark: A marked point of known elevation from which other elevations may be established.

cascade: A series of small, vertical drops within a channel.

channel bed slope: Vertical change with respect to horizontal distance within the channel. 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 dam: A small temporary barrier, grade control structure, or dam constructed of rock, gravel bags, sandbags, fiber rolls, or other materials placed across a waterway.

countersunk: The downstream culvert bottom is embedded (countersunk) below the channel bed by a minimum of 20% of the culvert diameter or rise, and streambed material is present throughout the length of the culvert.

cove: A small sheltered bay in the shoreline of a river or lake. An indentation in the shoreline out of the main flow.

culvert: A conduit or passageway under a road, trail, dike, or other obstruction. A culvert differs from a bridge in that it is usually placed entirely below the elevation of the road surface. It usually consists of structural material around its entire perimeter.

culvert invert: The lowest internal point of any cross section within the bottom of a culvert. The inside bottom of a culvert or other conduit.

culvert span to stream width ratio: The ratio of the culvert width to the channel-bed width.

dam: An instream structure built to impound or divert water.

differential correction: Refers to a technique for improving the accuracy of the Global Positioning System (GPS) in which error corrections are transmitted to users based on measurements of GPS signals by one or more reference receivers situated at known locations.

dike: An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee.

diversion entrainment: The voluntary or involuntary movement of fish from the parent water body into the surface water diversion. Entrainment occurs when a fish is drawn into a water intake and cannot escape.

diversion headgate: A gated structure that controls the flow of water from the surface water source into a gravity conveyance facility (canal, ditch, pipeline, etc.)

durable and efficient fishway: A "durable and efficient fishway" is a fishway that does not exhibit any structural deficiency that would compromise fish passage during 90% of the time the species present require passage.

entrainment: Occurs when a fish is drawn into a water intake and cannot escape. *See definition for diversion entrainment.*

ephemeral stream: An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year. Ephemeral stream beds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from rainfall is the primary source of water for stream flow.

fish screen (or fish guard): A fish protection device installed at or near a surface water diversion headgate to prevent entrainment, injury or death of targeted aquatic species. 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* but also known as *fish passes*, are human-made structures built to facilitate passage of fish through, over, or around an instream barrier. Most fishways enable fish to pass around the barriers by swimming and leaping up a series of relatively low steps (hence the term *ladder*) into the waters on the other side.

ford: A shallow area in a stream that can be crossed by a vehicle without the presence of a bridge, culvert, or other formal water crossing structure.

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 used for assessing the habitat above or below a human-made fish passage barrier. The Full Survey (FS) method is described in the *Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual*. The main difference between a Full Survey (FS) and a Reduced Sampling Full Survey (RSFS) is the sampling rate. The FS approximately 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 30-meter sample length is generally used on streams expected to be less than 1.6 kilometers (1 mile) long, while the 60-meter sample length is used for streams greater than 1.6 kilometers. One 60-meter sample is taken within each reach using the RSFS method.

grade stabilization or 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 that holds a set elevation.

fish bypass system: Gravity fish screens installed downstream of the diversion headgate usually require a "fish bypass system" to collect fish from in front of the 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.

fish bypass water: A portion of the diverted flow used to transport fish from in front of the fish screen back to the stream through the fish bypass system. Fish bypass flow requires positive hydraulic head differential between the water surface at the screen and the water surface at the bypass outfall to the stream.

flap gate: The flap gate consists of a flat 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 against the rim of the culvert to seal it. The gate is forced open when the water pressure at the upstream end is greater than the water pressure at the downstream end.

flashboard riser: A weir made with removable boards that can be used to adjust the level of water held up behind the weir. Boards 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.

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.

gradient: The slope of a stream-channel bed or water surface, expressed as a percentage of the drop in elevation divided by the distance in which the drop is measured.

Habitat Quality Modifier: The Habitat Quality Modifier (HQM) is 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 culvert attached to a horizontally placed culvert, used to impound water. Half of the culvert may be removed over all or a portion of its length and it may or may not have slots to accommodate flashboards. This structure is sometimes placed in regulated wetlands to enhance wetland hydrology.

impingement: The involuntary contact and entrapment of fish on the screen surface due to the approach velocity exceeding swimming capability.

intermittent stream: A stream which ceases to flow during dry periods.

invert: The lowest point of the internal cross section of culvert or pipe arch.

lake: a large inland body of fresh water with a surface area greater than 10 acres (40,000 m^2).

LE: Lead Entity. Lead entities are local, watershed-based organizations that function to guide salmon recovery efforts within their geographic scope and watershed boundaries.

levee: An embankment constructed to prevent a river from overflowing (flooding); a dike.

littoral: Shallow water habitats (potentially having aquatic vegetation) of lakes and ponds. Part of the shore zone of a large body of water.

mainstem: The main channel of a river or stream.

Manning's Equation: An equation for determining the quantity of flow whose factors are the hydraulic radius, cross section area of flow, and a coefficient of roughness (Manning's n).

Manning's n: An empirical coefficient used in Manning's Equation to describe the resistance to flow due to the surface roughness of a culvert or stream channel.

ordinary high water (OHW) mark: Generally, the lowest limit of perennial vegetation. There are also legal definitions of ordinary high water mark that include characteristics of erosion and sediment. The ordinary high water mark can usually be identified by physical scarring along the bank or shore, or by other distinctive signs. This scarring is the mark along the bank where the action of water is so common as to leave a natural line impressed on the bank. That line may be indicated by erosion, shelving, change in soil characteristics, destruction of terrestrial vegetation, the presence of litter or debris or other distinctive physical characteristics.

The legal definition of ordinary high water mark per WAC 220-110-020(31) is:

"Ordinary high water line means the mark on the shores of all waters that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual and so long continued in ordinary years, as to mark upon the soil or vegetation a character distinct from that of the abutting upland:
Provided, That in any area where the ordinary high water line cannot be found the ordinary high water line adjoining saltwater shall be the line of mean higher high water and the ordinary high water line adjoining freshwater shall be the elevation of the mean annual flood."

orphaned road: An orphaned road is a road or railroad grade that is unused and neglected. While many of these roads are overgrown, blocked, or closed off, they are not fully abandoned, stream crossings may still exist and the road may be usable in the future. *See definition for abandoned crossing.*

passive screen cleaning: Screens that are designed to be self-cleaning without a 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/or 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 vertical drop at the outfall of a culvert usually due to erosion of the stream channel downstream of the drainage structure.

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.

PI: Priority Index; a tool used for prioritizing fish passage barrier correction projects.

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 mechanical parts.

pond: a body of water larger than a pool, that is five times the width and length of representative pools located within the downstream reach, yet smaller than a lake, with a surface area of less than 10 acres (40,000 m^2).

pool: A reach of stream that is characterized by relatively deep, low velocity water and a smooth surface.

Priority Index: The Priority Index (PI) is an objective prioritization tool that consolidates several factors that affect a fish passage project's feasibility (including expected passage improvement, production potential and amount of habitat available for the blocked stream, species mobility, fish stock health, and project cost estimate) into a manageable framework for developing prioritized lists of projects. The result is a numeric indicator giving each project's relative priority that includes production benefits to both anadromous and resident salmonid species adjusted for sympatric species interactions (species complexes).

pump intake screens: Screening devices attached directly to a pressurized diversion intake pipe.

puncheon: A low-lying wooden trail tread that is used to cross wet, boggy ground or small creeks. Puncheon is a type of boardwalk that is built on sills so that contact with the terrain is intermittent. A puncheon looks like a collapsed pile of woody debris and dirt at a road crossing with no culvert installed.

Ranney well: A well that has a center chamber with horizontal perforated pipes extending radially into an aquifer. A depression dug off-channel (in a stream or river) with a pump and/or pipe present for water diversion purposes.

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: Habitat survey method used for assessing the habitat above or below a human-made barrier. The Reduced Sampling Full Survey (RSFS) method is described in the *Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual*. (*see Full Survey*)

resident fish: Fish that do not migrate to the ocean and complete their entire life cycle in fresh water.

riffle: A reach of stream in which the water flow is rapid and usually more shallow than the reaches above and below. Natural streams often consist of a succession of pools and riffles.

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 a stream bank or shoreline from erosion.

rise: The maximum, vertical, open dimension of a culvert; equal to the diameter in a round culvert and the height in a rectangular culvert.

salmonid: any fish of the taxonomic family Salmonidae, including salmon, trout, char, whitefish, and grayling.

scour: The process of removing material from the bed or banks of a channel through the erosive action of flowing water.

scour line: The line along a stream channel created by scour and kept primarily unvegetated by running water. Includes everything within the active channel where stream flow would be expected during the time of salmonid spawning activity.

scour line width: The distance measured from the scour line of one bank to the scour line of the opposite bank. Includes everything within the active channel where stream flow would be expected during the time of salmonid spawning activity.

screen entrainment: The voluntary or involuntary movement of fish through, under, or around the fish screen resulting in loss of fish from the population.

screen mesh opening: The narrowest opening in screen mesh.

Screening Priority Index: The Screening Priority Index (SPI) is a hybrid of the quadratic formula used in prioritizing fish passage projects. The SPI was created to consolidate the many variables relevant to water diversions (including diversion flow, fish production potential, species mobility, fish stock status and project cost estimate) into a manageable framework for developing prioritized lists of screening projects.

significant reach: A significant reach is defined as a section of stream having at least 200 linear meters of useable habitat without a gradient or natural point barrier.

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 the water control needs.

slope: Vertical change with respect to horizontal distance within the channel *(see gradient)*.

span: The horizontal dimension of the culvert; the width of the culvert spanning the channel.

staff gage: a device for measuring the water level of a stream at the time of inspection.

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 a beneficial purpose (municipal, industrial, agricultural, hydroelectric generation, etc.). Surface water diversions fall into two general categories: **"gravity"** and **"pump"**.

surface water flow: Water flowing above the ground surface, overland.

sweeping velocity: The component of approaching water velocity which moves **parallel** to the screen surface as a function of screen orientation and the amount of fish bypass flow. High sweeping velocity reduces the chance of impingement or screen entrainment.

swing gate: A swing gate (barn-door style) 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 immediately upstream of a riffle.

thalweg: The longitudinal line of deepest water within a stream.

tide gate: An opening through which water may flow freely when the tide sets in one direction (outgoing tide), but which closes automatically and prevents the water from flowing in the other direction (incoming tide).

toe: The base area of a streambank; the point where the bed and the bank intersect.
velocity: The distance traveled divided by the time required to travel that distance.

Water Resource Inventory Area: 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). They were formalized under WAC 173-500-040 and authorized under the Water Resources Act of 1971, RCW 90.54.

Water Type: The interim water typing system is defined in WAC 222-16-031 and has been adopted by the Washington Department of Natural Resources (DNR) Forest Practices Board. For stream features, the system is based on a computer model and qualifying field observations.

Water Type Classifications:
Type "**S**" = Shorelines
Type "**F**" = Fish
Type "**Np**" = Non-Fish Perennial
Type "**Ns**" = Non-Fish Seasonal
Letter "**U**" = Unknown

watershed: The specific land area that drains into a river system or other body of water.

washed-out road crossing: 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.

WRIA: Water Resource Inventory Area.

Source of Definitions:
Some of the definitions used in this glossary were derived from the following sources:

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APPENDIX B

Recommended Survey Equipment

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 Level*	Determining culvert length and slope	$2500.00
Monopod	Stabilizes Impulse 200 laser unit	$80.00
Yolk Assembly	Connecting laser unit to monopod	$100.00
GPS Receiver	Determining features geographic location	Prices vary
Surveyors Tape (30m)	Level B hydraulic analysis.	$25.00
Retro-reflective safety vest	Improved safety	Varies
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)	Locating culvert bottom through bed material	$36.00
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, while the auto-level and total station are more suitable for road-based inventories, 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	Measuring Distance	$110.00
Biodegradable string for hip chain	Used with hip chain box	$5.00 per roll
Clinometer	Obtaining stream gradients	$130.50
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
Water resistant field notebook	Note taking	$10.00
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

Additional Recommended Equipment		
Equipment	**Used For**	**Approximate Cost**
Geographical Information Systems (GIS) mapping software	Creating field and report maps, displaying feature data and other corporate data, and measuring lengths and areas.	Prices vary depending on type of software
Field guides	For identification of juvenile and adult salmonids and other inland fishes, trees, shrubs, terrestrial and wetland plants, amphibians, insects, and other organisms that may be encountered in an aquatic environment that may be observed during field surveys.	Varies
Books on aquatic habitat assessment and habitat restoration	For 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.	varies

APPENDIX C

Field Forms for Fish Passage and Surface Water Diversion Features

SITE IDENTIFICATION FIELD FORM (1/15/09)

[1]Site ID:______________________ GPS Position Taken: □Yes □No
[2]Latitude:____________________ [3]Longitude:__________________
[4]Identifying Group:_____________ [5]Road Name:________________
[6]Milepost:_____________________ [7]County:____________________
[8]Location/Directions:____
____
____
[9]Stream Name:_______________________ [10]WRIA #:_____________
[11]Tributary To:_______________________ [12]River Mile:___________
[13]Fish Use Potential: □Yes □No □Unknown
[14]Fish Use Criteria: □Mapped □Physical □Biological □Other
[15]Species: □Chinook □Chum □Sockeye □Coho □Pink □Steelhead
□Resident Cutthroat/Rainbow Trout □Searun Cutthroat
□Bull/Dolly Varden Trout
[16]Feature Type: □Culvert □Fishway □Dam □Gravity Diversion
□Pump Diversion □Other □Non Culvert Crossing □Natural Barrier
[17]Site Comments:____
____
____

[18]OWNER INFORMATION

Type: □Federal □State □County □City □Tribal □Private □Other
Name:____
Street Address:____
Mailing Address:____
City:________________________ State:______ Zip:______________
Phone #:____________________
Contact Name & Phone#:____________________________________
____

SITE FORM INSTRUCTIONS

1) Site ID number (unique site identifier).
2) Northerly geographic position of the feature expressed in decimal degrees (WGS 84).
3) Westerly geographic position of the feature expressed in decimal degrees (WGS 84).
4) Group or agency making the report.
5) Name of the road (if any) on which the feature resides.
6) Highway milepost (to .01 mile) where the feature is located.
7) County Name.
8) Location of feature relative to landmarks or driving directions.
9) Name of the stream where the feature is located.
10) Water Resource Inventory Area (WRIA) number.
11) Name of the water body to which the stream is connected to (tributary to).
12) Distance (to .01 mile) from mouth of stream to the feature location.
13) Indicate whether or not the stream has the potential to support fish life.
14) How was the potential fish use determination made.
15) Fish species that are either known to inhabit the stream or that would potentially utilize the available habitat were the barrier to be corrected.
16) Type of instream feature encountered.
17) Concise comments pertinent to the operation or characteristics of the site being evaluated.
18) Owner information.

CULVERT EVALUATION FIELD FORM (Level A) (1/15/09)

[1]Site ID:______________________
[2]Culvert Number:_______________

[3]Field Review Crew
Crew:___________________
Date:___________________

CULVERT DESCRIPTION

[4]Shape: □RND □BOX □ARCH □SQSH □ELL □OTH

[5]Material: □PCC □CPC □CST □SST □CAL □SPS □SPA □PVC □TMB □MRY □OTH

[6]Span/Dia:______ [7]Rise:________ [8]Water Depth in Culvert:___________

[9]Hydraulic Drop:_________ [10]Drop Location:_________

[11]Length:________ [12]Culvert Slope:_______ [13]Road Fill Depth:_________

[14]Countersunk: □Yes □No

[15]Apron: □None □US □DS □Both [16]Tidegate: □Yes □No

[17]Number of Baffles:_______ [18]Baffle Type: □Concrete □Metal □Wood □Rock □Plastic □Other

PLUNGE POOL DESCRIPTION

[19]Length:_________________ [20]Maximum Depth:_________________

[21]Scour Line Width (SLW):_________________

CHANNEL DESCRIPTION

[22]Average Channel Width:_________________

[23]Culvert Span / Channel Width Ratio:_____________________________

SUMMARY INFORMATION

[24]Barrier: □Yes □No □Unk [25] %Passability: □0 □33 □67 □100

[26]Method: □Level A □Level B □Oth □FW □Professional Judgment

[27]Reason: □WS Drop □Slope □Velocity □Depth □Tidegate □Obstruction □Other

[28]Significant Reach: □Yes □No □Unknown

[29]Comments:____
____

LEVEL A FORM INSTRUCTIONS

1) Site ID number (Unique site identifier)
2) Culvert Number - If 1 culvert at site then 1.1, if 2 then 1.2 or 2.2
3) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
4) Cross-sectional shape of the culvert. RND - round, BOX - square or rectangular, ARCH - bottomless, SQSH - squash (pipe arch), ELL - elliptical, OTH - other
5) Material Pipe is composed of. 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 - polyvinylchloride, TMB - timber, MRY - masonry, OTH - other
6) Maximum width of the culvert to the nearest 0.01 meter.
7) Height of the culvert to the nearest 0.01 meter.
8) Water depth in culvert to the nearest 0.01 meter.
9) The difference between any abrupt change in water surface elevation at the inlet, outlet or anywhere within the culvert.
10) Location of the water surface drop.
11) Length of the culvert to the nearest 0.1 meter.
12) Slope of the culvert reported in %. (USIE – DSIE/Length)*100. May be a positive or negative number.
13) Estimated height of the road fill.
14) Is the DS culvert invert countersunk below the channel bed at least 20% of the culverts rise?
15) Is there an apron attached to either or both ends of the culvert?
16) Is there a tidegate associated with the culvert?
17) Number of baffles (if any) within the culvert.
18) Material that the baffles are constructed of.
19) Length of the plunge pool from the culvert outlet to the DS control.
20) Maximum depth of the plunge pool.
21) Maximum width of the plunge pool measured at the scour line width (SLW).
22) The average stream channel width measured outside of the culvert influence.
23) The ratio of the width of the culvert to the width of the stream channel.
24) Results of the Level A or B fish passage assessment.
25) Estimated percent passability of the culvert.
26) Assessment method used to determine the barrier status of the culvert.
27) Why did the culvert fail the Level A or B assessment?
28) Is there a Significant Reach (200 linear meters) of useable habitat available US and DS of the feature?
29) Concise comments related to the culvert feature and an explanation of any attribute where “Other” was selected. **Include photos with the form**.

Level B Analysis Field (1/15/09)

[1]Site ID ______________________
[3]Datum Elevation ______________________
[4]Datum Location ______________________

[2]Field Review Crew
Crew:__________________
Date:___________________

	HI	RH	VD - /+	ELEV
[5]US Invert Elevation				
[6]DS Invert Elevation				
[7]US Culvert Bed Elev.				
[8]DS Culvert Bed Elev.				
[9]Water Surf. Elev. 15m DS				

(HI = Height of Instrument; RH = Rod Height; VD = Vertical Distance)

[10]DOWNSTREAM CONTROL CROSS-SECTION

	STA	HI	RH	VD - /+	ELEV	Depth	WSE
Top LB STA 0	0					add	
Toe LB STA 1							
Bed 1 STA 2							
Bed 2 STA 3							
Bed 3 STA 4							
Toe RB STA 5							
Top RB STA 6						Avg WSE	
	[11] SLW						

[12]**Corrugation** ☐ smooth ☐ 0.5 x 2.67 ☐ 1 x 3 ☐ 2 x 6
☐ steel ☐ concrete ☐ paved invert

[13]**Channel Substrate** ☐ mud/sand ☐ gravel/rubble/riprap/bedrock ☐ boulder

Formulas for Determining Height of Instrument (HI)

If using a Laser Level: **HI = ELEV + RH + VD** (IF VD is negative)
HI = ELEV + RH - VD (IF VD is positive)

If Using a Standard Level: **HI = ELEV + Rod Reading** (Backsight)

Formulas for Calculating Elevations Using a Laser Level

Laser reading (VD) + : Subtract the VD from the RH then subtract the remainder from the HI. **ELEV = HI - (RH - VD)**

Laser Reading (VD) - : Subtract both the VD and the RH from the HI.
ELEV = HI - RH - VD.

Remember that a VD with a - sign in front of it is only indicating a VD shot that is below level. A VD with no sign in front of it indicates a VD shot that is above level. Think of the level plane as "0".

Formula for Calculating Elevations Using a Standard Level

ELEV = HI - Rod Reading (Foresight)

LEVEL B FORM INSTRUCTIONS

1) Site ID number (Unique site identifier)
2) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
3) What is the datum (benchmark) elevation? May be an established datum or a local assumed datum (e.g. 100).
4) Location of the datum.
5) US Invert Elevation of the invert (bottom) of the culvert at the upstream end to the nearest 0.01 meter.
6) DS Invert Elevation of the invert (bottom) of the culvert at the downstream end to the nearest 0.01 meter.
7) The elevation of the streambed, if any, at the upstream end of the culvert.
8) The elevation of the streambed, if any, at the downstream end of the culvert.
9) Water surface elevation 15 meters downstream of the downstream control to the nearest 0.01 meter.
10) Downstream Control Cross-Section. The downstream control is the normally the head of the first riffle downstream of the culvert. Start at the top of left bank (station 0, facing downstream) and proceed to the right taking 7 elevations, to the nearest 0.01 meters, to describe the cross-sectional profile of the stream. The station is the distance, to the nearest 0.01 meters, from station 0 to the location the bed elevation was taken.
11) The elevation of the Scour Line Width (SLW) at the downstream control.
12) Corrugation dimensions in inches, measured valley to peak and peak to peak. If the corrugations at the culvert invert are completely covered with asphalt or concrete, enter paved.
13) Dominant channel substrate between the downstream end of the culvert and the point 15 meters downstream of the downstream control.

DAM FIELD FORM (1/15/09)

[1]Site ID:______________________

[3]Dam Name: _________________

[4]Reservoir Name:

[5]Type: □CN □RE □MS □MT □ER □TB □OT

[6]Span: □Full □Partial

[2]Field Review Team
Crew:_________________
Date:_________________

[7]Length:_______________________ [8]Height: _____________________

[9]Water Surface Difference:____________ [10]Plunge Pool Depth:________

[11]Description:____

[12]Primary Purpose: □D □C □H □I □N □P □Q □R □S □T □O □F □W

[13]Recheck: □No □GPS □Photo □Pass HF □Pass LF

[14]Barrier: □Yes □No □Unk □FW □NFB

[15]%Passability: □0 □33 □67 □100

[16]Significant Reach: □Yes □No □Unk

[17]Comments:____

____

____

DAM FORM INSTRUCTIONS

1) Site ID number (Unique site identifier).
2) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
3) Legal or local name of the dam.
4) Legal or local name of the reservoir.
5) Type of dam, referring to the material from which the dam is constructed. CN - concrete, RE - earthfill, MS - masonry, MT - metal, ER - rockfill, TB - timber, and OT - other.
6) Does the dam completely or partially span the stream channel?
7) Length of the dam in meters (0.01).
8) The height of the dam from the front base to the crest to the nearest 0.01 meters.
9) If water is flowing over the crest of the dam, give the difference between the water surface elevations above and below the dam in meters (0.01). If the dam is equipped with a standpipe, leave blank.
10) Maximum depth of the plunge pool to the nearest 0.01 meters.
11) Description of the dam and any problems associated with it.
12) The purpose of the dam. D - debris control, C - flood control, H - hydroelectric, I - irrigation, N - navigation, P - stock or farm pond, Q - water quality, R - recreation, S - water supply, T - tailings, O – other, F = fish propagatioin, W = wildlife habitat.
13) Is there a need to recheck the dam in the future? No - no need, GPS - GPS position needed, Photo - photo needed, Pass HF - evaluate passage at high flow, Pass LF - evaluate passage at low flow.
14) Barrier status of the dam. Values; Yes = dam is a barrier; No = dam is not a barrier; Unk = unknown barrier status; FW = fishway present; NFB = stream does not have fish potential.
15) Estimated percent passability of the dam.
16) Indicates the presence of 200 meters of habitat upstream and downstream of the feature.
17) Comments regarding the dam. **Include photos with the form**.

'OTHER' EVALUATION FORM (1/15/09)

[1]Site ID:_____________________

[3]Type: □Flume □Dike/Levee
□Roughened Channel □Hatchery
□Streambed Control □Stormwater
□Tide/Floodgate □Erosion Control
□Artificial Waterfall □Footbridge
□Fill/Debris □Pipeline Crossing
□Lake Screen □Trash Rack
□Other Miscellaneous Obstruction

[2]Field Review Crew

Crew:__________________

Date:__________________

[4]Barrier: □Yes □No □Unk □FW

[5]%Passability: □0 □33 □67 □100

[6]Significant Reach: □Yes □No □Unk

[7]Comments:____

____

____

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____

OTHER FORM INSTRUCTIONS

1) Site ID number (Unique site identifier).
2) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
3) Type of feature being assessed. May add additional feature type.
4) Barrier status of the feature.
5) Estimated percent passability of the feature.
6) Is there a Significant Reach (200 linear meters) of useable habitat available US and DS of the feature?
7) Concise comments related to the feature. **Include photos with the form**.

NON-CULVERT CROSSING EVALUATION FORM (1/15/09)

[1]Site ID:_____________________

[3] Crossing Type: □Bridge □Ford
□Fill / Puncheon □Abandoned
□Washout □Undefined

[2]Field Review Crew
Crew:__________________
Date:__________________

[4]Barrier: □Yes □No □Unknown □FW

[5] %Passability: □0 □33 □67 □100

[6]Significant Reach: □Yes □No □Unknown

[7]Comments:____

____

____

____

____

____

____

____

____

____

NON-CULVERT CROSSING FORM INSTRUCTIONS

1) Site ID number (Unique site identifier).
2) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
3) Type of crossing being assessed.
4) Barrier status of the feature.
5) Estimated percent passability of the feature.
6) Is there a Significant Reach (200 linear meters) of useable habitat available US and DS of the feature?
7) Concise comments related to the feature. **Include photos with the form**.

NATURAL BARRIER EVALUATION FORM (1/15/09)

[1]Site ID:____________________

[3]Site Name:_________________

[4]Barrier Type: □Waterfall □Gradient

□Subsurface Flow

[5] Waterfall Height.:____________

[6] Plunge Pool Depth:__________

[7]Length:______________ [8]Channel Width:_______________

[9] Slope(%):__________________

[10]Fishway Present: □Yes □No

[11]Barrier Criteria: □Physical □Biological

[12]Blockage: □Total □Partial □None

[13]Comments:____

[2]Field Review Crew
Crew:_________________
Date:_________________

NATURAL BARRIER FORM INSTRUCTIONS

1) Site ID number (Unique site identifier).
2) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
3) Common or popular name of the site.
4) Type of natural barrier being assessed.
5) The height of the waterfall being assessed.
6) The maximum depth of the pool at the base of the waterfall.
7) Length of stream defining barrier reach, applies to gradient and subsurface flow barrier types.
8) Average width of the stream channel; applies to all barrier types.
9) Degree of slope defining the barrier reach, applies to gradient barrier type.
10) Indicates the presence of a fishway
11) Identifies the criteria on which the barrier is based.
13) Specifies whether the barrier is a total or partial blockage.
14) Concise comments relating to the feature. **Include photos with the form**.

FISHWAY DESCRIPTION FORM (1/15/09)

[1]Site ID: ____________________

[2]Field Review Crew
Crew:_________________
Date:_________________

[3]Barrier: □Yes □No □Unknown

[4]%Passability: □0 □33 □67 □100

[5]Construction Year: _________

[6]Attached to: □Culvert □Dam

□Falls □Habitat

[7]Fishway Type: □BC □BF □PC □SBC □WP

[8]Number of Pools: _________ [9]Entrance Pool Depth: _________

[10]Maximum Water Surface Drop: _________

[11]Number of Weirs: ________

[10]Weir Type: □Concrete □Rock □Metal □Plastic □Wood □Other

[13]Grade Control Location: □None □Upstream □Downstream □Both

[14]Control Type: □CC □GC □LC □PLC □SCC

[15]Number of Controls: _________

[16]Culvert Shape: □RND □BOX □ARCH □SQSH □ELL □OTH

[17] Culvert Material: □PCC □CPC □CST □SST □CAL □SPS □SPA □PVC

□TMB □MRY □OTH

[18]Culvert Span: _________ [19]Culvert Rise: _________

[20]Culvert Length: _________ [21]Culvert Slope: _________

[22]Number or Baffles: _________

[23]Baffle Type: □Concrete □Rock □Metal □Plastic □Wood □Other

[24]Fishway description/comments:

FISHWAY FORM INSTRUCTIONS

1) Site ID number (unique site identifier).
2) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
3) Is the fishway a barrier to fish passage?
4) Estimated percent passability of the fishway.
5) Year of fishway construction.
6) The feature the fishway is attached to and modified for fish passage.
7) Fishway type: BC – baffled culvert, BF – baffled flume, PC – pool chute, SBC – streambed control, WP – weir pool.
8) Number of pools in the fishway (include last pool below the last downstream control).
9) Depth of the fishway entrance pool (nearest 0.01 meter).
10) Maximum water surface drop from drops measured at each weir or baffle from water surface to water surface.
11) Number of weirs present in the fishway.
12) Material from which the weirs are constructed.
13) Position of bed controls relative to other fixed structures.
14) Grade control type: CC - concrete, GC – gabion, LC – log, PLC – plank, SCC – saccrete.
15) Number of streambed controls.
16) Cross-sectional shape of the culvert. RND – round, BOX – square or rectangular, ARCH – bottomless, SQSH – squash pipe arch), ELL – elliptical, OTH – other.
17) Material culvert is made of: 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 – polyvinylchloride , TMB – timber, MRY – masonry, OTH – other.
18) Maximum width of the culvert to the nearest 0.01 meter.
19) Height of the culvert to the nearest 0.01 meter.
20) Length of the culvert to the nearest 0.1 meter.
21) % slope of the culvert (USIE-DSIE/Length)*100
22) Number of baffles in a baffled culvert or flume.
23) Material from which baffles are constructed.
24) Description of the fishway and additional comments. **Include photos with the form**.

FISHWAY INSPECTION FORM (1/15/09)

[2]Field Review Crew
Crew:_________________
Date:_________________
Time:_________________

[1]Site ID: ___________________

[3]Fishway Condition:

- OK= durable & efficient
- MN = maintenance needed
- MNFP = maintenance needed for fish passage
- MNR = major repair or replacement needed
- NLE = no longer exists
- UNK = unknown

[4]Maintenance Needed: ___________________________________

____

[5]Fishway Inspection Comments:

FISHWAY FORM INSTRUCTIONS

1) Site ID number (unique site identifier).
2) Field crew information. Last name(s) of the field review team responsible or the data. Field review date. MM/DD/YYYY format.
3) Fishway condition. OK = durable & efficient, MN = maintenance needed, MNFP = maintenance needed for fish passage, MNR = major repair or replacement needed, NLE = fishway no longer exists, Unk = unknown.
4) Describe the type of maintenance needed to make the fishway durable, functional, and/or passable for fish; photos may help illustrate this. If no maintenance needed, indicate 'none'.
5) Additional comments about the fishway conditions, fish observations, etc.

SURFACE WATER DIVERSION DATA FORM (1/15/09)

[1]Site ID: _______________

[3]Diversion Type: □Gravity □Pump

[4]Access: □Boat □Vehicle □ORV □Foot

[5]Point of Diversion: □LB □RB

[6]Pump Intake Location: □RB □OS □LN □CV

[7]Diversion Dam: □Yes □No

[8]Headgate: □Yes □No

[9]Cross-sectional Area (ft^2): _______

[10]Intake Pipe Outside Diameter (inches): _________

[11]Diversion Flow (gpm): ______

[12]Flow Derivation: □Measured □Water Right □Calculated □Other

[13]Water Right Number: _________

[14]Power Meter Number: _________

[15]Presence of a fish bypass: □Yes □No

[16]Fish bypass condition: _____________________________________

[17]Screen Presence: □Yes □No □Unknown

[18]Screen Type: Gravity: □IG □NVFP □PMP □PTS □RD □TB □VFP □OT

Pump: □BR □BX □CN □CY □ST □OT

[19]Screen Material: □EM □PB □PM □PP □SP □WM □OT

[20]Mesh Size (inches): _________

[21]Screen Height (feet): _________

[22]Screen Width (feet): _________

[23]Screen Compliant: □Yes □No □Unknown

[24]Screen Condition: □OK □MN □UNK

[25]Problems/Comments: _____________________________________

____

[2]Field Review Crew
Crew:________________
Date:________________

SURFACE WATER DIVERSION DATA FORM INSTRUCTIONS

1) Site ID number (Unique site identifier).
2) Field crew information. Last name(s) of the field review team responsible for the data. Field review date. MM/DD/YYYY format.
3) Indicate type of surface water diversion: Gravity or Pump diversion.
4) Access. Type of transportation capable of accessing site. Indicate: boat, on-road vehicle, off-road vehicle (ORV), or foot.
5) Point of diversion, referenced looking downstream: LB = left bank, RB = right bank.
6) If pump is present, the location of the pump intake: RB = riverbank (or streambank), OS = off shore, LN = lagoon, CV = cove.
7) Presence of an instream diversion dam: yes or no.
8) Presence of a headgate: yes or no.
9) Bankfull, cross-sectional area of the diversion ditch, canal, flume, or pipe, in square feet to the nearest 0.1.
10) Measured outside diameter of the pump intake pipe in inches (0.1).
11) Flow of diversion in gallons per minute (gpm).
12) How flow was determined: measured (staff gauge, flow meter or "three-chip method"), water right, calculated (ditch area multiplied by 0.75), or other (describe in comments)
13) Water Right number issued by Washington Department of Ecology.
14) Power Meter number.
15) Presence of a fish bypass: yes or no.
16) Fish bypass condition: Indicate whether bypass is in operation and comment on the condition of the bypass (debris blockage, amount of flow, hydraulic drops present, etc.)
17) Screen presence: yes, no, or unknown.
18) Gravity Diversion Types: IG = infiltration galleries, NVFP = non-vertical fixed plate, PMP = pump screen, PTS = portable screen, RD = rotary drum, TB = vertical traveling screen (panel and belt types), VFP = vertical fixed plate, OT = other. Pump Diversion Types: BX = box, BR = barrel, CN = cone, CY = cylinder, ST = strainer, OT = other.
19) Material screen is constructed of: EM = expanded metal, PB = profile bar, PM = plastic mesh, PP = perforated plate, SP = slotted PVC, WM = wire mesh, OT = other
20) Largest dimension of the screen mesh opening, measured in inches.
21) Height of screen, measured in feet.
22) Screen width measured in feet.
23) Is the screen compliant with WDFW criteria? Indicate: yes, no, or unknown.
24) Screen condition: OK = ok, MN = maintenance needed, UNK = unknown. Indicate whether the screen is operating: yes, no, or unknown.
25) Description of problems or comments regarding the diversion facility.

Include photos with the form.

APPENDIX D

Measuring Channel Width

(Appendix ‘H’ from the *Design of Road Culverts for Fish Passage)*

Bates, K; Barnard, R.; Heiner, B; Klavas, P.; Powers, P. 2003. Design of Road Culverts for Fish Passage. Washington Department of Fish and Wildlife. Olympia, Washington. http://wdfw.wa.gov/hab/engineer/cm/

Appendix H – Measuring Channel-Bed Width

Channel-bed width is a design parameter for the No-Slope and Stream-Simulation design options. Correctly identifying and measuring the channel width is fundamental to good culvert design.

Channel geometry represents current hydrologic and geologic conditions. Prolonged dry periods with low peak flows tend to narrow channels as vegetation progressively stabilizes the bed and banks. Measuring a channel width under these conditions tends to indicate a much narrower width than would be found under a wetter regime. Catastrophic floods and debris flows rip out equilibrium channels and completely obscure historical geometry.[1]

The climatic and geological cycles of an area create a history in the channel that is typically not well accounted for in measured channel geometry.[1] The life of a culvert is considered short when compared to these larger processes, but culvert sizing should take them into account nonetheless, at least in a conservative way that acknowledges uncertainty regarding the types of cycles that may take place within the culvert's lifespan.

Definition of Channel Width

At least three parameters are commonly used to describe channel width:

- active channel width,
- ordinary high water width, and
- bankfull width.

In western Washington, the actual, measured, channel width may not vary significantly among these parameters; in eastern Washington, variations can sometimes be found. The language used to describe them is often identical. These descriptions were developed for and apply primarily to alluvial channels, not bedrock or debris-controlled channels. If applied to the latter, be mindful that the outcomes regarding fish-passage and other ecological goals may not be successfully met.

The term "active channel" is a geomorphic expression describing a stream's recent and current discharges. Beyond the boundaries of the active channel, stream features are typically permanent and vegetated.[1] The upper limit of the active channel is defined by a break in the relatively steep bank slope of the active channel to a more gently slopping surface beyond the edge. This normally corresponds to the lower limit of perennial vegetation. Features inside the active channel are partially if not totally sculpted by the normal process of water and sediment discharge.[2]

The term, "ordinary high water line" is defined several places in state law (WAC 220-110-020) as:

> *"the mark on the shores of all waters that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual and so long continued in ordinary years, as to mark upon the soil or vegetation a character distinct from that of the abutting upland; Provided, That in any area where the ordinary high water line cannot be found the ordinary high water line adjoining saltwater shall be the line of mean higher high water and the ordinary high water line adjoining freshwater shall be the elevation of the mean annual flood."*

Of course, this is the legal definition, which does not always serve design needs well. A more useful and thorough definition for design purposes can be found in Appendix A, *Glossary* (however, the legal definition prevails). The distance between ordinary high water marks on the bank is considered the ordinary high water width. It is very similar to active channel and the width used in the past for culvert design.

The "bankfull channel" is defined as the stage when water just begins to overflow into the active floodplain. In order for this definition to apply, of course, a floodplain or a bench is required – features often not found along western Washington tributary streams (though more frequently found east of the Cascade mountains).[3] Incised channels, for instance, do not have bank heights that relate to "bankfull" discharges and may never be overtopped.[4] C. C. Harrelson, et. al.,[5] use features to determine channel width that do not depend on a floodplain; features that are similar to those used in the description of active channel and ordinary high water:

- a change in vegetation (especially the lower limit of perennial species);
- a change in slope or topographic breaks along the bank;
- a change in the particle size of bank material, such as the boundary between coarse cobble or gravel with fine-grained sand or silt;
- undercuts in the bank, which usually reach an interior elevation slightly below the bankfull stage;
- the height of depositional features, especially the top of the point bar, which defines the lowest possible level for bankfull stage; and/or
- stain lines or the lower extent of lichens on boulders.

Using a combination of indicators at a variety of locations improves the estimation of the channel width, since stream anomalies may mask or accentuate a given mark on the bank. As an example, perennial vegetation may grow lower on the bank during the dry period, not only lowering that indicator but forcing the channel into a more constricted reach. A short distance downstream from this location, the upper-story canopy may be denser, limiting understory growth on the streambanks and negating the effect.

For culvert design, the designer should use these indicators to determine channel width, unless there are legitimate reasons not to use these methods. One such case is alluvial channels in lower-gradient reaches. These channels have more traditionally defined bankfull-width indicators[6] and should be used instead. The floodplain is the relatively flat area adjoining the channel, and the bankfull width is the horizontal distance from the break between channel and floodplain on one side of the channel to the other side of the channel. Floodplains may be discontinuous, or may occur on only one side, so measurements must be taken at appropriate locations. The indicators listed above also apply to alluvial channels and provide additional indicators for identifying bankfull width in alluvial channels.[3,7]

Where to Measure Channel Width

Theoretically, the average of a large enough number of random width measurements will yield an average stream width. This is particularly true in alluvial streams where the bed and banks are freely modified by stream flow. Many streams in eastern Washington are like this, but very few tributaries in western Washington are. The correct location to measure channel width in the profile and planform is a matter of judgment. Some of the concerns to be address are as follows:[2,8]

- Where the channel has been realigned or modified by construction activity or in reaches lined with riprap, channel width will not be indicative of natural conditions. Usually these cross sections will be substantially narrower.
- Avoid reaches with cemented sediments, hard clay or bedrock.
- Large pools downstream of culverts or confined steep sections will be wider than channel width.
- Braided sections will indicate a wider width than single-thread reaches on the same stream (although, if the culvert is located in a naturally braided section, culvert sizing should reflect conditions).
- Avoid unusually shaped cross sections and sharp bends.
- Areas of active bank cutting, degradation or deposition may indicate that width is in the process of changing, in which case, conservative culvert sizing is recommended.
- Areas with natural or man-made log sills or channel-modifying logjams will affect width. These can be very common in forested, western Washington streams. Width measurements should be taken between such structures, but be sure to avoid backwater effects.
- Side channels, especially those that go undetected and act only at high flow, narrow the measured channel width.
- Active and remnant beaver dams obscure flow-generated channel processes.
- Dense vegetation and small woody debris in the channel increase the channel width and fragment the flow.
- Know the recent flood or drought history of the area to avoid misleading indicators.

Incised channels are problematic. Incised channels in cohesive materials may have a measured width only a fraction of what it would be if it was connected to a floodplain. In order to make sure that the culvert fill is stable and passage conditions in the culvert are good, culvert width must be greater than the width of this type of incised channel. On the other hand, streams incised into granular soils – Rosgen's type F[8] – may be wider than the equivalent type C. It is not recommended that culvert sizes be reduced in this instance, except with appropriate site analysis, since it is rarely clear what the appropriate measured width should be.

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[6] Rosgen, D. L. 1994. A classification of natural rivers. Catena 22, pp. 169-199.

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Appendix E

Basic Culvert Surveying Techniques
(Excerpts from the Family Forest Fish Passage Program's
Fish Passage Barrier Evaluation Guide)

Basic Culvert Surveying Techniques

Training guide written by
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Washington Department of Fish and Wildlife
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June 2005

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Measuring Culvert Slope and Length with an Auto Level

Set up and level the auto level on the tripod directly over the culvert where visibility is good to each end of the culvert. Place the stadia rod at each culvert invert, extend it up and read the stadia rod height through the auto level. The vertical distance is the difference between a horizontal line extending from the auto level to the stadia rod and the culvert invert. The difference between the vertical distances of each culvert invert gives us the relative difference in elevations. *Refer to the illustration in Figure 1.*

It's simple as long as you don't need to move the auto level and tripod and 95% of the time with forest road culverts this will be the case. It's only when there is very deep fill, a very wide road, and/or dense vegetation that moving the auto level may be required. If this is the case the instrument height changes and that change must be taken into account.

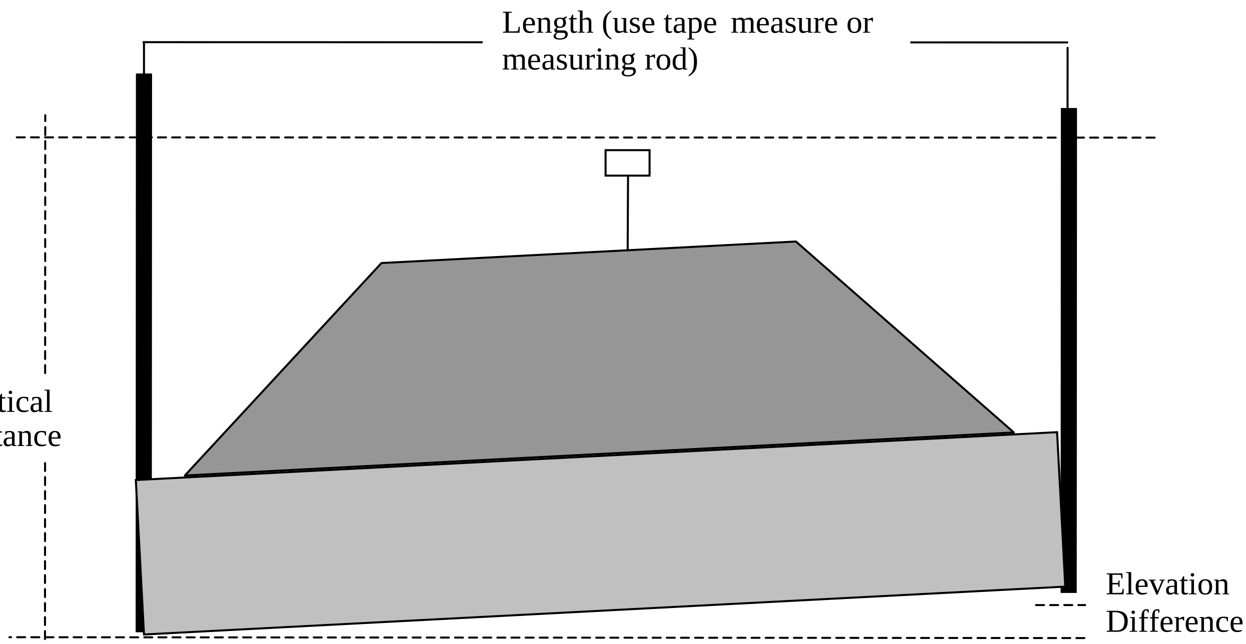

Figure 1. Auto level slope measurement.

An auto level is simpler to use under simple conditions. The advantage of a laser level is that it measures length at the same time it measures slope, sets up quick and with it's ability to tilt, handles more difficult conditions than the auto level without having to move the instrument which makes the math more complicated.

It's critical that the height of the instrument, whether laser or auto level, remains consistent throughout the process. You must pivot on the monopod when turning to measure the other end of the culvert. Make a mark in the dirt with the monopod foot or place a coin under the foot. Make sure the telescoping connections are tight and do not change the length of the monopod.

If the laser level cannot read the reflector at both ends of the culvert try adding the larger adjustable reflector to the top of the rod. If you must move the laser level there are instructions in Multi-shot Length and Slope Measurements section at the end of this guide that explains this process. With the laser level's ability to tilt this is not likely for forest road culverts.

Measuring Culvert Slope and Length with a Laser Level

A laser level measures horizontal distances, slope distances, slopes or gradients, vertical differences and heights. While the laser level can measure slopes or gradients directly, the conditions associated with culverts often prevent direct measurement (i.e. the culverts are usually smaller than the laser level mounted to the monopod). Sometimes the plunge pool is too deep to stand in or the body contortions required to read the laser just aren't worth it. It's easier and safer to measure the vertical differences and calculate the slope.

The vertical difference is the difference between an invisible line extending horizontally from the laser level and the reflector that the laser level is aimed at. *See Figure 2.*

This horizontal line provides a line of reference from which we can measure differences in elevation. These are not actual elevations like 230 feet above sea level but elevations relative to other elevations or an assumed datum. A datum or temporary benchmark is a starting point from which all other elevations are compared to. A datum is described in more detail in the section on Level B assessment.

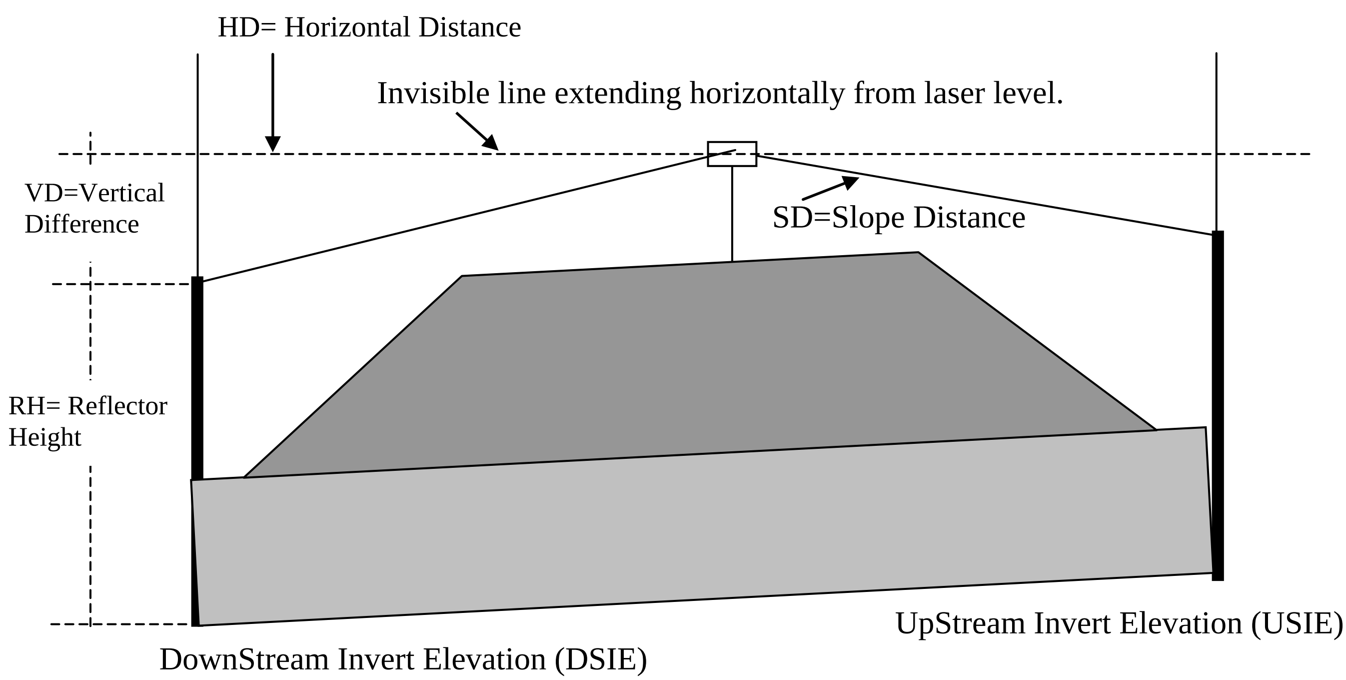

Figure 2: Measure Length and Slope with Laser Level

As you can see from the Figure 2. drawing, the distance from the invisible horizontal line to the downstream invert (culvert bottom) is greater than the distance from the invisible horizontal line to the upstream invert. The difference between those two distances gives us the difference in elevation described in the formula for calculating slope:

((USIE – DSIE) / culvert length) x 100 = % slope

Meter Rods
Practice reading your meter rod until you are comfortable with what all the little hash marks mean. There are many different styles of meter rods, some measure in feet, some in meters and some have feet on one side and meters on the other. Some have an ability to display the rod height down where you can see it and can measure inside diameters of culverts by extending the topmost sections first (the Sokkia 3JB-108702 is recommended).

Reflectors
You should attach reflective material to the top of your meter rod and have an adjustable reflector that can be positioned anywhere on the meter rod. The adjustable reflector cannot be purchased but is easy to make. You need a piece of sticky-backed reflective material about 2 inches by 8 inches preferably red or yellow (not grey), a piece of solid Plexiglas-like material the same size, a piece of elastic cord and a cord lock. Stick the reflective material to the Plexiglas, trim off the excess and drill two holes through it about 1.5 inches apart or a little less than the width of the narrowest part of the meter rod. Thread the elastic through the holes and attach the cord lock. Make several, as they tend to disappear.

Most culverts can be measured with just the reflective material on the meter rod. Long culverts require a bigger reflector. Shooting through a culvert with a rise less than the height of the meter rod requires a moveable reflector.

Laser Level
You will see 3 buttons on each side. The ones closest to you on each side are called the **FIRE** buttons, the middle buttons are the **FORWARD** buttons and the buttons furthest away from you are the **BACK** buttons. **FIRE** **FORWARD** **BACK**

Turn on your laser level with button closest to you on the right or the left side. The display should read "**Right HT HD (blinking) M"** with a dashed line through the middle.

- **Right** means it is set up for a right-handed person. Is anyone left-handed?
- **HT** stands for Height and the level is ready to make a height measurement.
- **M** stands for Meters

The Laser Level automatically starts up in the Height measurement mode. We do not want to make a height measurement so you need to tap the **Back** button 5 times to get to **VD** which means **Vertical Difference**. Tap the **FIRE** button to turn on the red dot.
We are now ready to take a measurement. Hold the FIRE button down and you will hear a grinding noise. The laser is seeking the reflector target, when it finds it you will hear a double beep.

To measure the length and slope of a culvert we use the Vertical Difference (VD) and Horizontal Distance (HD) settings. Attach your laser level to the monopod and extend the monopod to a comfortable height. **It is very important that you do not change the Height of the Instrument (monopod) at any time during the process.**

Position the laser level in the line of the culvert to get the most accurate length. Grind the monopod foot into the dirt to mark the location or place a coin on the concrete to mark your monopod position if you think you may have to move for cars or set the instrument down for any reason.

Position the meter rod with reflector at one culvert invert and extend the rod as little as possible to minimize error from the tilt of the rod. If you start with the downstream invert you are likely to have sufficient reflector height at the upstream end as well without having to change the reflector height. It's ideal to keep the reflector height the same throughout the process. Pay close attention to raising the top section first if you have a meter rod that measures from the top down. If not, you will need an adjustable reflector that you can place anywhere on the rod.

Level the laser level using the bubble level on the bracket. Hold steady and aim the red dot slightly above the reflector. Press and hold the fire button, you should hear the grinding noise. Tilt the laser down slowly until you hear the double beep. Record the HD and VD in separate columns under the heading of US invert in your rite-n-rain notebook. Repeat HD and VD measurements two more times and record. The readings should all be within 0.02 meters (2 hundredths of a meter) of each other. If not continue taking measurements until you have a group of three that are within 0.02 meters of each other. Average the three measurements for both VD and HD.

Repeat this process for the other culvert invert. Make sure the instrument height and the reflector height are consistent for both ends. Your notes should look like this:

US invert		DS invert	
HD	VD	HD	VD
5.60	+0.03	4.31	+0.12
5.62	+0.05	4.31	+0.11
5.61	+0.04	4.30	+0.11
5.61	+0.04	4.307	+0.113

Add the averaged HDs together to get the length of the culvert. 5.61 + 4.307 = 9.917.
When the signs of the upstream and downstream invert VDs are the same (either both positive or both negative), subtract the smaller averaged VD from the larger averaged VD.
0.113 – 0.04 = 0.073

Then divide the result by the culvert length and multiply that result by 100.
0.073 / 9.917 = 0.00736 x 100 = 0.7361. Round up and enter the slope as 0.74%

Slope = The difference between the US and DS inverts divided by culvert length multiplied by 100:

Slope = USIE – DSIE / length x 100

See examples of measuring slopes using a level laser in Figure 3 and Figure 4.

Figure 4 shows measuring slope when reflector height (RH) is the same at both ends of the culvert. If the Vertical Differences (VD) are both negative or positive subtract the smaller from the larger.

VD Sum = 0.32 – 0.20 = 0.12 Slope = 0.12 / 5.5 x 100 = 2.18%

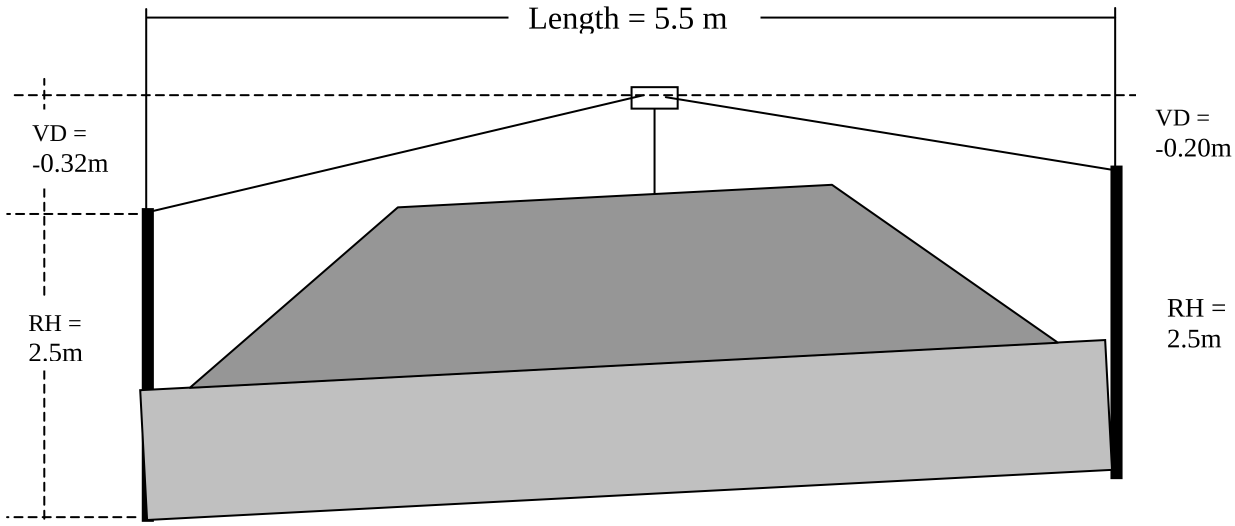

Figure 3: Same Reflector Height, both VDs Negative or Positive

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Figure 4 shows measuring slope when reflector height (RH) is the same at both ends of the culvert and the VD signs are opposite (one is positive and the other is negative). If they have opposite signs ADD the two VDs together ignoring the signs.

VD Sum = 0.12 + 0.11 = 0.22 Slope = 0.22 / 10.5 x 100 = 2.10%

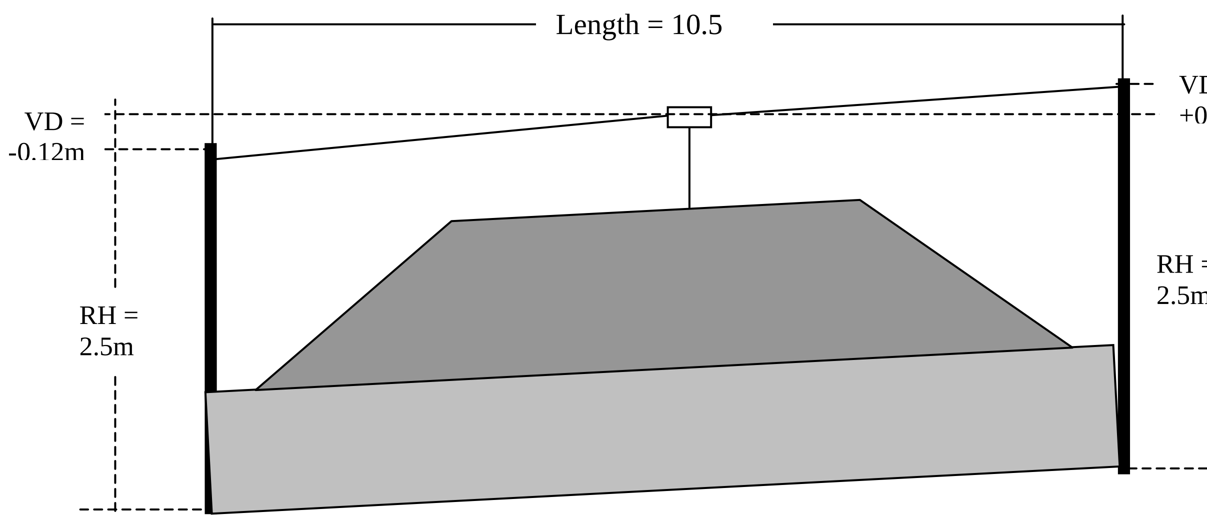


Figure 4: Same Reflector Height, Negative and Positive VDs

Figure 5 illustrates having different reflector heights at each end of the culvert; you must subtract the VDs from the RHs to get the overall VD for each invert. Use the following formula to calculate slope.

Slope = (DSRH - VD) - (USRH - VD) / length x 100
VD Diff. = (2.5 - 0.59) - (2.1 - 0.26) VD Diff. = 1.91 – 1.84 = 0.07 Slope = 0.07/ 15.3 x 100 = 0.46%

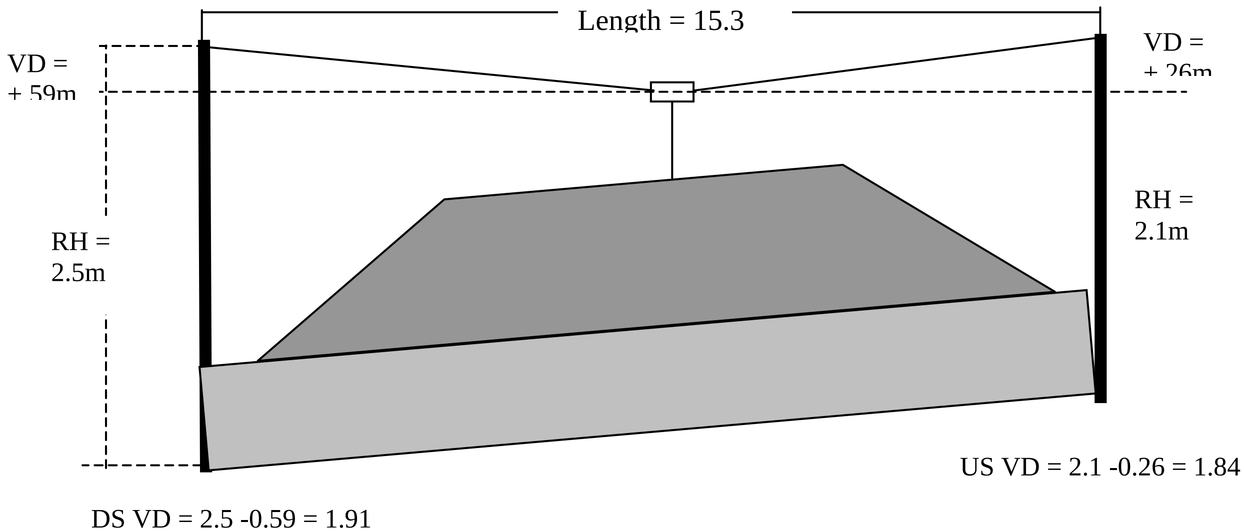


Figure 5: Different Reflector Heights, both VDs Positive or Negative

Figure 6 is an example of having different reflector heights at each end of the culvert, and the VD signs are opposite (one is positive and the other is negative). Use the same formula to calculate slope.

Slope = (DS RH - VD) - (US RH - VD) / length x 100
VD Diff. = (1.5 - -0.31) - (1.7 - +0.07) VD Diff. = 1.81 – 1.63 = 0.18 Slope = 0.18/ 15.3 x 100 = 1.18%

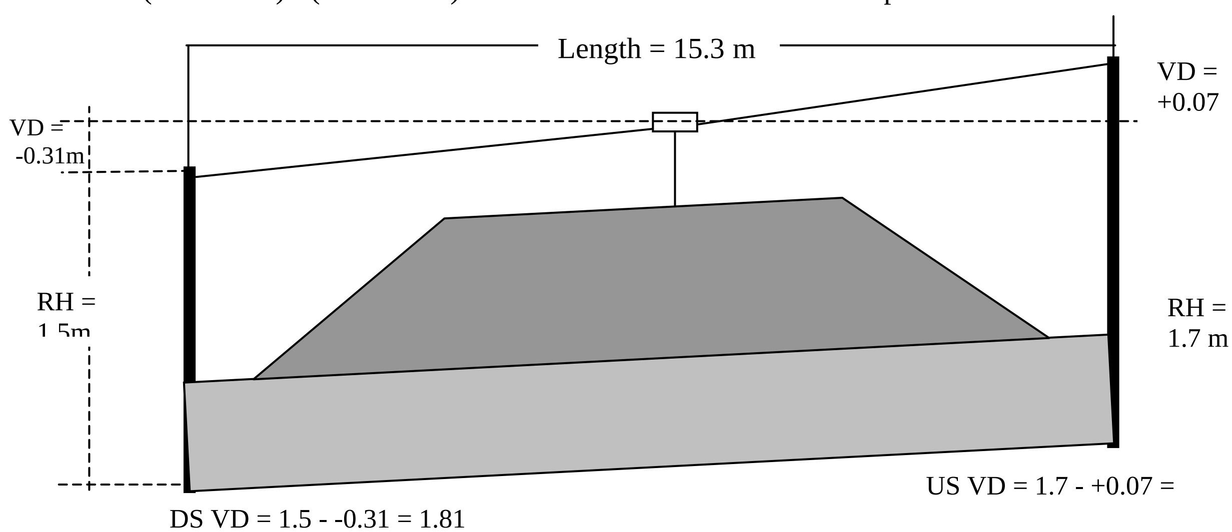


Figure 6: Different Reflector Heights, Positive and Negative VDs

Level B Measurements

Elevations are measured from the upstream culvert invert downstream to 15m below control to provide a longitudinal profile of the stream. Measurements are also taken across the downstream control to provide a cross sectional profile of the stream.

Use the US culvert invert as the datum or temporary benchmark. All other elevations will be relative to this point. There is no need to record horizontal distances when shooting any of the elevations, only VDs. Take the average of three readings for each elevation. Record all VDs, RHs, water depths and station distances, culvert corrugation frequency, and dominate channel substrate between the culvert and the point 15 meters downstream of the downstream control. Then get in the warm, dry truck, get out your calculator and figure out the height of the instrument and all the elevations.

Do NOT change the height of the Instrument during the process of taking elevations. You can adjust the reflector height as needed, since it is figured into the calculations and be sure to record it on the form for every elevation.

See Figure 7 for where to measure the culvert and channel elevations. Measure elevations at the:

- UpStream Invert Elevation (USIE)
- DownStream Invert Elevation (DSIE)
- DownStream Control (DS Control)
- DownStream Water Surface Elevation (DSWSE) - 15 meters DS of the control

The first thing I do is locate the downstream control, set-up the cross section tape measure and clear away any brush. It pays to look over the location of your shots in relation to the position of the laser level to make sure everything will be visible without having to move the laser level.

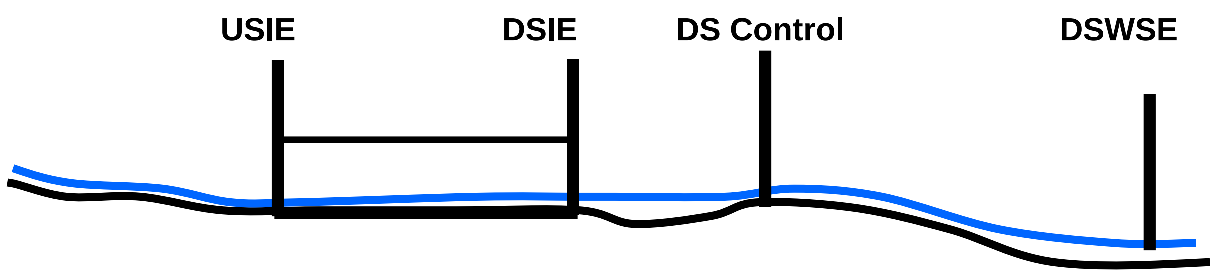


Figure 7: Longitudinal Profile of Stream

Laying out the control elevation measurements.
Stake your 15 meter tape measure across the stream starting at the left bank top of bank and record the distance to each elevation from the top left bank starting point. *See Figure 8 for an example of a channel cross section.* For water surface elevations at the downstream control, record the water depth at each station where you measured elevation and distance from top left bank.

For the water surface elevation 15 meters downstream of the control, remove the top right bank end of the tape measure and walk 15 meters downstream using the tape measure with the top left bank end still attached. Position the bottom of the meter rod at the water surface.

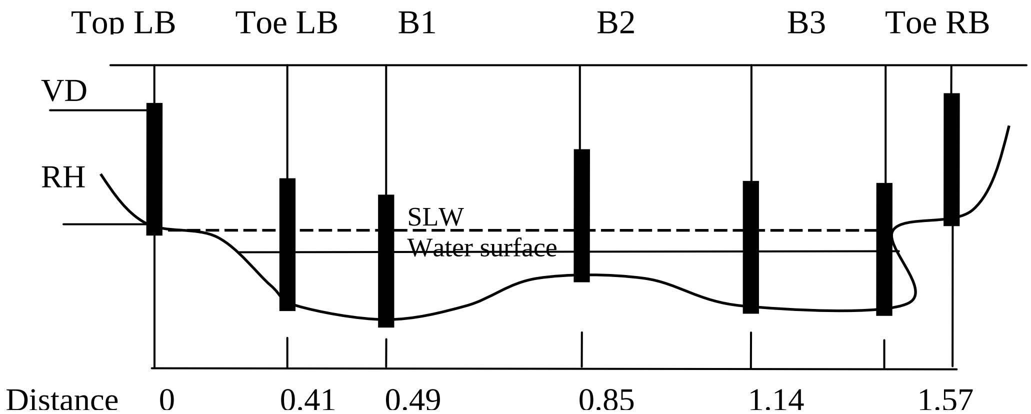


Figure 8: Cross Sectional Profile of the Stream

Multi-Shot Length and Slope Measurements

3 - Shot Length and Slope Measurement

When deep fill, obstructions or very long culverts make it impossible to measure length and slope with just two shots, we need to use a survey technique called differential leveling. This allows us to move the instrument one or more times to get the upstream and downstream invert elevations. With a simple 2 shot setup we measure the elevation differences simply by figuring the vertical differences, taking into account the rod height if it is different, for each shot. With multiple shots we need to think in terms of elevations and we need to calculate the elevations of the rod and the laser level as we make our traverse from one end of the culvert to the other.

Refer to the handout on Differential Leveling for a good description of this method particularly if you are using some other kind of level than the Impulse 200 by Laser Technology.

See example in Figure 10, Measuring Length and Slope in 3 Shots. First make your upstream invert elevation 100m to eliminate having to deal with negative elevation numbers. With the laser set up on the road edge, shoot the vertical difference (VD) to the rod stationed at the upstream invert and record the rod height (RH). Record the horizontal distance (HD) as well.

Calculate the height of the instrument (HI_1) using the following formula:

$$HI = RH - VD + ELEV$$

This gives you the elevation of the laser level about where the thumb screw on the laser bracket attaches to the laser level. Its important to maintain the same monopod height throughout.

Bring the rod up to the other side of the road from the laser (TP_1, turning point 1) and set the rod height at 2.0m to simplify the math. Shoot and record the VD and HD. Calculate the ELEV at the base of the rod using the following formula:

$$ELEV = HI - (RH - VD)$$

This gives you the elevation of TP_1, the point where the rod touches the road surface. Now measure the instrument height (IH) with the meter rod by placing both the monopod/laser and the rod side by side on a flat surface and reading the height at the middle of the thumb screw on the laser level bracket. Add the IH to the TP_1 elevation to get HI_2. Move the laser level to the location of TP_1 where the rod was positioned and move the rod to the downstream culvert invert.

Shoot the VD and HD, record the rod height and calculate the downstream culvert invert elevation using the ELEV formula above. Subtract the downstream culvert invert elevation from 100, (upstream culvert invert elevation) to get the difference in culvert invert elevations. Divide the difference by the culvert length (total of 3 HD measurements) and multiply by 100 to get the culvert slope.

US culvert invert elevation (100) - DS culvert invert elevation = Elevation Difference
Elevation Difference / culvert length x 100 = Slope

Remember to hold the rod as straight and steady as possible and extend it no further than necessary to get the shot. Raise rod sections from the top and be careful not to miss any sections. The 3 VD and HD (horizontal distance) readings that you average should be close, within a few 1/100s of each other. Start shooting above the target and slowly tilt the laser down till you hear a pause in the grinding noise and stop and hold while it makes its reading. Be sure to level the laser before each shot.

3 – SHOT EXAMPLE

HI = RH – VD + ELEV **ELEV = HI – (RH – VD)**

Station	RH	VD	HI	ELEV	EXAMPLE	HD
US invert				**100**		
HI_1	**4.5**	**-5.7**	**110.20**		**4.5 - - 5.7+100**	**7.38**
TP_1	**2.0**	**+1.1**		**109.30**	**110.2 -(2.0 - +1.1)**	**14.53**
HI_2	IH=1.67+109.3=		**110.97**	**Measure IH with meter rod, add to TP1 elev.**		
DS Invert	**3.3**	**-8.5**		**99.17**	**110.97 –(3.3 - - 8.5)**	**4.79**
					Total length =	**26.70**

USIE - DSIE / length x 100 = slope
100 – 99.17 = 0.83
0.83 / 26.70 x 100 = 3.11%

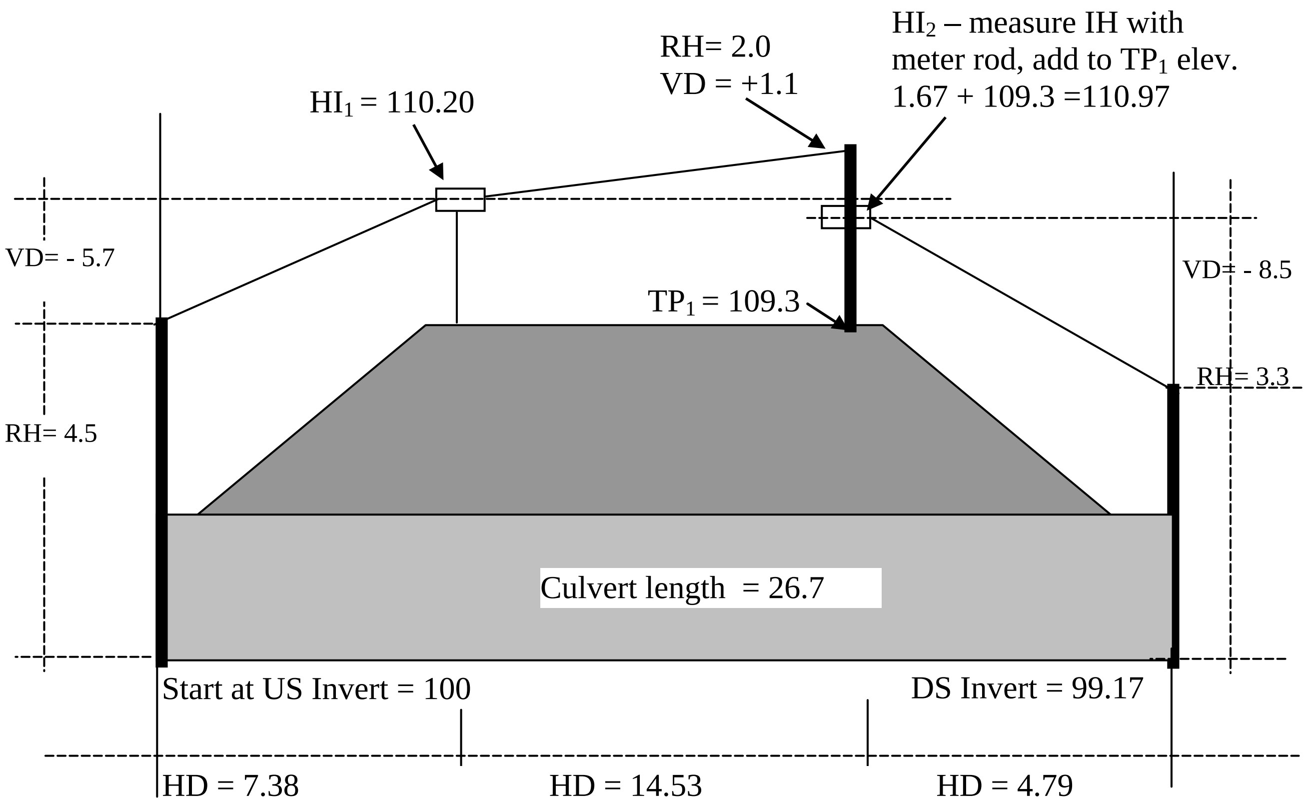


Figure 9. Measuring length and slope in 3 shots.

4 - Shot Length and Slope Measurement

This is very similar to the 3 shot method and doing the 3 shot method as described above will make it much easier when the occasional 4 shot method becomes necessary to do because you will understand the concept. This example applies when you can shoot from the road edge down to one culvert invert in a single shot but shooting from the road edge down to the other culvert invert requires 2 shots. Start with the upstream end regardless of whether it requires one shot or 2 shots from the road edge to the culvert invert. The following example has the upstream end requiring 2 shots to get from the road edge to the culvert invert, but if it's the downstream end that requires 2 shots from the road edge to the invert still start at the upstream invert. Only the locations of the laser and the rod turning points will change, the method is basically the same. If a level B analysis is required you'll be a little further ahead as long as you marked your last HI location and kept the monopod extension the same.

See example in Figure 10, Measuring Length and Slope in 4 Shots.
Again make your upstream invert elevation 100m. Set up the laser where you can see the rod when placed at the upstream culvert invert and when it is positioned on the shoulder of the road.
Get the vertical difference (VD) to the rod stationed at the upstream invert and note the rod height (RH). Calculate the height of the instrument (HI_1) using the following formula:

$$HI = RH - VD + ELEV$$

This gives you the elevation of the laser level about where the thumb screw on the laser bracket attaches to the laser level. Its important to maintain the same monopod height throughout. The rod height can vary for each shot.

Bring the rod up to the side of the road and set the rod height at whatever height is needed for the laser to get the shot. Calculate the ELEV at the base of the rod (TP_1) using the following formula:

$$ELEV = HI - (RH - VD)$$

This gives you the elevation of TP_1, the point where the rod touches the road shoulder surface. Relocate the laser level to the other side of the road and shoot back to the rod still positioned at TP_1 and note the RH.

Calculate the HI at this new location, (HI_2), using the HI = RH - VD + ELEV formula. Turn and shoot the downstream invert VD, note the rod height and calculate the downstream culvert invert elevation using the ELEV formula above.

Subtract the downstream culvert invert elevation from 100, (upstream culvert invert elevation) to get the elevation difference in culvert invert elevations. Divide the elevation difference by the culvert length and multiply by 100 to get the culvert slope.

> US culvert invert elevation (100) - DS culvert invert elevation = Elevation Difference
> Elevation Difference / culvert length x 100 = Slope

If more shots are needed, add in another turning point (TP) and instrument setup (HI). Make sure the last shot has the rod at the culvert invert.

4 – SHOT EXAMPLE

HI = RH – VD + ELEV **ELEV = HI – (RH – VD)**

Station	RH	VD	HI	ELEV	EQUATION	HD
US invert				100		
HI_1	6.0	-5.5	111.50		6.0 - - 5.5+100	5.45
TP_1	2.0	+1.5		111	111.5-(2.0 - +1.5)	3.88
HI_2	2.0	+0.5	112.5		2.0 - +0.5 + 111	30.05
DS Invert	5.0	-10.2		97.3	112.5 – (5 - -10.2)	6.12
					Total length =	45.50

USIE - DSIE / length x 100 = slope
100 – 97.30 = 2.7
2.7 / 45.50 x 100 = 5.93%

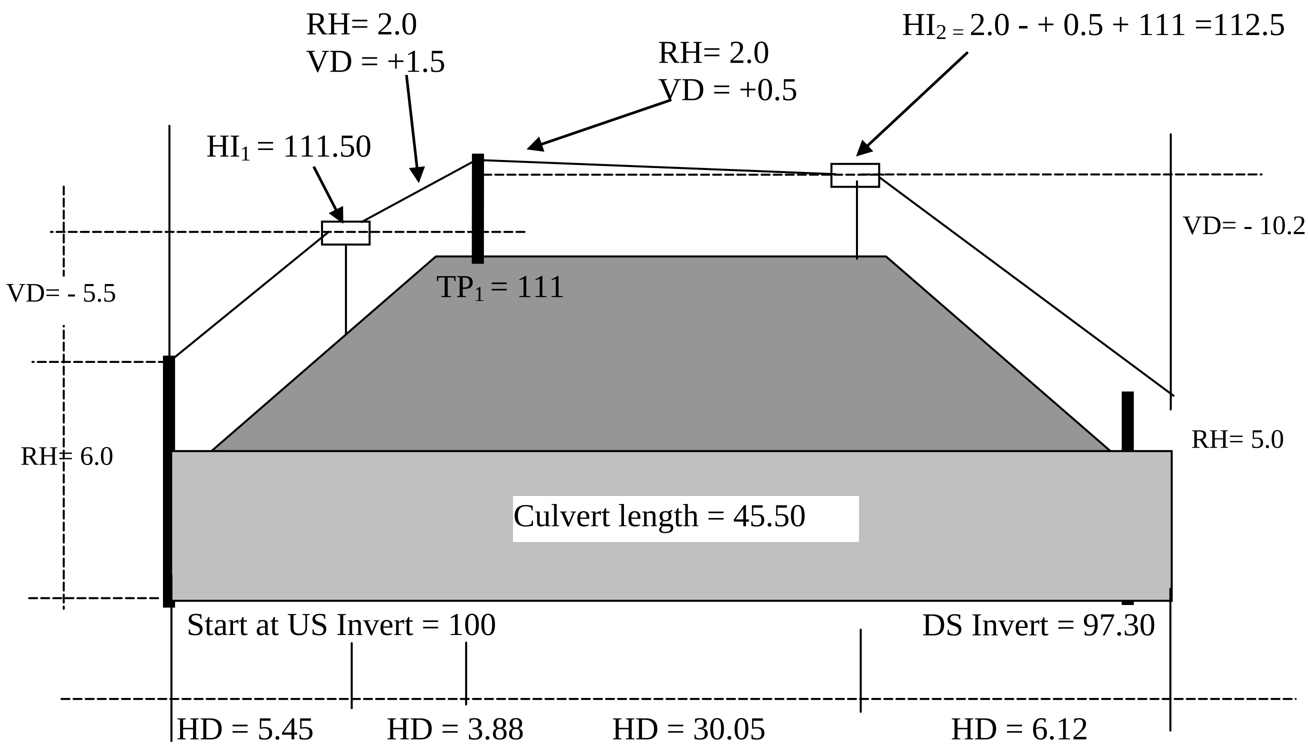


Figure 10. Measuring length and slope in 4 shots.

APPENDIX F

WAC 220-110-070 Water Crossing Structures

WAC 220-110-070 Water crossing structures.

In fish bearing waters, bridges are preferred as water crossing structures by the department in order to ensure free and unimpeded fish passage for adult and juvenile fishes and preserve spawning and rearing habitat. Pier placement waterward of the ordinary high water line shall be avoided, where practicable. Other structures which may be approved, in descending order of preference, include: Temporary culverts, bottomless arch culverts, arch culverts, and round culverts. Corrugated metal culverts are generally preferred over smooth surfaced culverts. Culvert baffles and downstream control weirs are discouraged except to correct fish passage problems at existing structures.

An HPA is required for construction or structural work associated with any bridge structure waterward of or across the ordinary high water line of state waters. An HPA is also required for bridge painting and other maintenance where there is potential for wastage of paint, sandblasting material, sediments, or bridge parts into the water, or where the work, including equipment operation, occurs waterward of the ordinary high water line. Exemptions/5-year permits will be considered if an applicant submits a plan to adhere to practices that meet or exceed the provisions otherwise required by the department.

Water crossing structure projects shall incorporate mitigation measures as necessary to achieve no-net-loss of productive capacity of fish and shellfish habitat. The following technical provisions shall apply to water crossing structures:

(1) Bridge construction.

(a) Excavation for and placement of the foundation and superstructure shall be outside the ordinary high water line unless the construction site is separated from waters of the state by use of an approved dike, cofferdam, or similar structure.
(b) The bridge structure or stringers shall be placed in a manner to minimize damage to the bed.
(c) Alteration or disturbance of bank or bank vegetation shall be limited to that necessary to construct the project. All disturbed areas shall be protected from erosion, within seven calendar days of completion of the project, using vegetation or other means. The banks shall be revegetated within one year with native or other approved woody species. Vegetative cuttings shall be planted at a maximum interval of three feet (on center), and maintained as necessary for three years to ensure eighty percent survival. Where proposed, planting densities and maintenance requirements for rooted stock will be determined on a site-specific basis. The requirement to plant woody vegetation may be waived for areas where the potential for natural revegetation is adequate, or where other engineering or safety factors preclude them.
(d) Removal of existing or temporary structures shall be accomplished so that the structure and associated material does not enter the watercourse.
(e) The bridge shall be constructed, according to the approved design, to pass the 100-year peak flow with consideration of debris likely to be encountered. Exception shall be granted if applicant provides hydrologic or other information that supports alternative design criteria.

(f) Wastewater from project activities and water removed from within the work area shall be routed to an area landward of the ordinary high water line to allow removal of fine sediment and other contaminants prior to being discharged to state waters.
(g) Structures containing concrete shall be sufficiently cured prior to contact with water to avoid leaching.
(h) Abutments, piers, piling, sills, approach fills, etc., shall not constrict the flow so as to cause any appreciable increase (not to exceed .2 feet) in backwater elevation (calculated at the 100-year flood) or channel wide scour and shall be aligned to cause the least effect on the hydraulics of the watercourse.
(i) Riprap materials used for structure protection shall be angular rock and the placement shall be installed according to an approved design to withstand the 100-year peak flow.

(2) Temporary culvert installation.

The allowable placement of temporary culverts and time limitations shall be determined by the department, based on the specific fish resources of concern at the proposed location of the culvert.
(a) Where fish passage is a concern, temporary culverts shall be installed according to an approved design to provide adequate fish passage. In these cases, the temporary culvert installation shall meet the fish passage design criteria in Table 1 in subsection (3) of this section.
(b) Where culverts are left in place during the period of September 30 to June 15, the culvert shall be designed to maintain structural integrity to the 100-year peak flow with consideration of the debris loading likely to be encountered.
(c) Where culverts are left in place during the period June 16 to September 30, the culvert shall be designed to maintain structural integrity at a peak flow expected to occur once in 100 years during the season of installation.
(d) Disturbance of the bed and banks shall be limited to that necessary to place the culvert and any required channel modification associated with it. Affected bed and bank areas outside the culvert shall be restored to preproject condition following installation of the culvert.
(e) The culvert shall be installed in the dry, or in isolation from stream flow by the installation of a bypass flume or culvert, or by pumping the stream flow around the work area. Exception may be granted if siltation or turbidity is reduced by installing the culvert in the flowing stream. The bypass reach shall be limited to the minimum distance necessary to complete the project. Fish stranded in the bypass reach shall be safely removed to the flowing stream.
(f) Wastewater, from project activities and dewatering, shall be routed to an area outside the ordinary high water line to allow removal of fine sediment and other contaminants prior to being discharged to state waters.
(g) Imported fill which will remain in the stream after culvert removal shall consist of clean rounded gravel ranging in size from one-quarter to three inches in diameter. The use of angular rock may be approved from June 16 to September 30, where rounded rock is unavailable. Angular rock shall be removed from the watercourse and the site restored to preproject conditions upon removal of the temporary culvert.

(h) The culvert and fill shall be removed, and the disturbed bed and bank areas shall be reshaped to preproject configuration. All disturbed areas shall be protected from erosion, within seven days of completion of the project, using vegetation or other means. The banks shall be revegetated within one year with native or other approved woody species. Vegetative cuttings shall be planted at a maximum interval of three feet (on center), and maintained as necessary for three years to ensure eighty percent survival. Where proposed, planting densities and maintenance requirements for rooted stock will be determined on a site-specific basis. The requirement to plant woody vegetation may be waived for areas where the potential for natural revegetation is adequate, or where other engineering or safety factors need to be considered.

(i) The temporary culvert shall be removed and the approaches shall be blocked to vehicular traffic prior to the expiration of the HPA.

(j) Temporary culverts may not be left in place for more than two years from the date of issuance of the HPA.

(3) Permanent culvert installation.

(a) In fish bearing waters or waters upstream of a fish passage barrier (which can reasonably be expected to be corrected, and if corrected, fish presence would be reestablished), culverts shall be designed and installed so as not to impede fish passage. Culverts shall only be approved for installation in spawning areas where full replacement of impacted habitat is provided by the applicant.

(b) To facilitate fish passage, culverts shall be designed to the following standards:

(i) Culverts may be approved for placement in small streams if placed on a flat gradient with the bottom of the culvert placed below the level of the streambed a minimum of twenty percent of the culvert diameter for round culverts, or twenty percent of the vertical rise for elliptical culverts (this depth consideration does not apply within bottomless culverts). Footings of bottomless culverts shall be buried sufficiently deep so they will not become exposed by scour within the culvert. The twenty percent placement below the streambed shall be measured at the culvert outlet. The culvert width at the bed, or footing width, shall be equal to or greater than the average width of the bed of the stream.

(ii) Where culvert placement is not feasible as described in (b)(i) of this subsection, the culvert design shall include the elements in (b)(ii)(A) through (E) of this subsection:

(A) Water depth at any location within culverts as installed and without a natural bed shall not be less than that identified in Table 1. The low flow design, to be used to determine the minimum depth of flow in the culvert, is the two-year seven-day low flow discharge for the subject basin or ninety-five percent exceedance flow for migration months of the fish species of concern. Where flow information is unavailable for the drainage in which the project will be conducted, calibrated flows from comparable gauged drainages may be used, or the depth may be determined using the installed no-flow condition.

(B) The high flow design discharge, used to determine maximum velocity in the culvert (see Table 1), is the flow that is not exceeded more than ten percent of the time during the months of adult fish migration. The two-year peak flood flow may be used where stream flow data are unavailable.

(C) The hydraulic drop is the abrupt drop in water surface measured at any point within or at the outlet of a culvert. The maximum hydraulic drop criteria must be satisfied at all flows between the low and high flow design criteria.
(D) The bottom of the culvert shall be placed below the natural channel grade a minimum of twenty percent of the culvert diameter for round culverts, or twenty percent of the vertical rise for elliptical culverts (this depth consideration does not apply within bottomless culverts). The downstream bed elevation, used for hydraulic calculations and culvert placement in relation to bed elevation, shall be taken at a point downstream at least four times the average width of the stream (this point need not exceed twenty-five feet from the downstream end of the culvert). The culvert capacity for flood design flow shall be determined by using the remaining capacity of the culvert.

Table 1. Fish Passage Design Criteria for Culvert Installation

Criteria	Adult Trout >6 in.(150mm)	Adult Pink, Chum Salmon	Adult Chinook, Coho, Sockeye, Steelhead
1. Velocity, Maximum (fps)			
Culvert Length (ft)			
a. 10 - 60	4.0	5.0	6.0
b. 60 - 100	4.0	4.0	5.0
c. 100 - 200	3.0	3.0	4.0
d. >200	2.0	2.0	3.0
2. Flow Depth Minimum (ft)	0.8	0.8	1.0
3. Hydraulic Drop, Maximum (ft)	0.8	0.8	1.0

(E) Appropriate statistical or hydraulic methods must be applied for the determination of flows in (b)(ii)(A) and (B) of this subsection. These design flow criteria may be modified for specific proposals as necessary to address unusual fish passage requirements, where other approved methods of empirical analysis are provided, or where the fish passage provisions of other special facilities are approved by the department.
(F) Culvert design shall include consideration of flood capacity for current conditions and future changes likely to be encountered within the stream channel, and debris and bedload passage.
(c) Culverts shall be installed according to an approved design to maintain structural integrity to the 100-year peak flow with consideration of the debris loading likely to be encountered. Exception may be granted if the applicant provides justification for a different level or a design that routes that flow past the culvert without jeopardizing the culvert or associated fill.
(d) Disturbance of the bed and banks shall be limited to that necessary to place the culvert and any required channel modification associated with it. Affected bed and bank areas outside the culvert and associated fill shall be restored to preproject configuration following installation of the culvert, and the banks shall be revegetated within one year with native or

other approved woody species. Vegetative cuttings shall be planted at a maximum interval of three feet (on center), and maintained as necessary for three years to ensure eighty percent survival. Where proposed, planting densities and maintenance requirements for rooted stock will be determined on a site-specific basis. The requirement to plant woody vegetation may be waived for areas where the potential for natural revegetation is adequate, or where other engineering or safety factors preclude them.

(e) Fill associated with the culvert installation shall be protected from erosion to the 100-year peak flow.

(f) Culverts shall be designed and installed to avoid inlet scouring and shall be designed in a manner to prevent erosion of streambanks downstream of the project.

(g) Where fish passage criteria are required, the culvert facility shall be maintained by the owner(s), such that fish passage design criteria in Table 1 are not exceeded. If the structure becomes a hindrance to fish passage, the owner shall be responsible for obtaining a HPA and providing prompt repair.

(h) The culvert shall be installed in the dry or in isolation from the stream flow by the installation of a bypass flume or culvert, or by pumping the stream flow around the work area. Exception may be granted if siltation or turbidity is reduced by installing the culvert in the flowing stream. The bypass reach shall be limited to the minimum distance necessary to complete the project. Fish stranded in the bypass reach shall be safely removed to the flowing stream.

(i) Wastewater, from project activities and dewatering, shall be routed to an area outside the ordinary high water line to allow removal of fine sediment and other contaminants prior to being discharged to state waters.

[Statutory Authority: RCW 75.08.080. 94-23-058 (Order 94-160), § 220-110-070, filed 11/14/94, effective 12/15/94. Statutory Authority: RCW 75.20.100 and 75.08.080. 83-09-019 (Order 83-25), § 220-110-070, filed 4/13/83.]

APPENDIX G

Instructions for Level B Spreadsheets and
Examples of Level B Spreadsheets Using Sample Data

Instructions for Using the Level B Spreadsheet

The Level B spreadsheet is available for download on WDFW's website, at: http://wdfw.wa.gov/hab/engineer/fishbarr.htm.

Using this spreadsheet requires one to input data from Table 3b and to input values by trial and error to perform calculations. In places, the user is asked to compare design and calculated values. When doing so, the design and calculated values need to be equal or within 5% of one another for the equations to function properly.

The units for the English version are feet, feet per second, and cubic feet per second. For the metric version the units are meters, meters per second, and cubic meters per second. The basin area and precipitation values are in English units for all versions.

Note: There are several Level B scenarios that are encountered regularly in the field where the spreadsheet developed by WDFW will not work. The WDFW spreadsheet was designed to be as simple to use as possible. This spreadsheet was designed only to analyze single culverts that contain no streambed material and are set with the invert elevation at the outlet being lower than the invert elevation at the inlet. Common situations where the WDFW spreadsheet will not work include: multiple culverts at a single site, culverts that are adversely sloped, and culverts that contain streambed material. Hydraulic conditions in these situations are very complex and require the use of additional modeling software. If you encounter one of these situations, collect all the standard Level B data (Including the invert elevations of all the culverts present) and forward the information to WDFW for analysis. WDFW will then conduct the hydraulic analysis and determine barrier status.

Step 1) Open the spreadsheet for the desired units and software version.

- LvlBEng.wb2 — Quattro Pro 6 for Windows, English Units
- LvlBMet.wb2 — Quattro Pro 6 for Windows, Metric Units
- LvlBEng.xls — Excel 97, English Units
- LvlBMet.xls — Excel 97, Metric Units

Step 2) Go to the Introduction Page to begin.

- Instruction text throughout the spreadsheet is in red.

Step 3) Go to the Hydrology Page.

- Follow the step-by-step instructions (red text) on the left side of the page.
- On the Hydrology Page the user is asked to input the following:

1. Stream name
2. Site ID
3. Sequencer
4. Hydrologic Region from Figure 1 in *Fish Passage Design Flows for Ungaged Catchments in Washington*, by P. Powers and C. Saunders, 1996 (revised 1998), published in Appendix C of *Design of Road Culverts for Fish Passage*, by Bates et al 2003; available online at: http://wdfw.wa.gov/hab/engineer/cm/. Note: this figure is in the Level B spreadsheet.

5. Drainage area (basin area measured from a USGS quadrant map, reported in square miles)
6. Precipitation (in inches; 2yr./24-hr. for region 1, or mean annual for all other regions; see precipitation map in Appendix H)

Step 4) Go to the X Section Page.

- Follow the step-by-step instructions (red text) on the left side of the page.
- On the X Section Page the user is asked to input the following:

1. Downstream control water surface elevation.
2. Water surface elevation 50 feet further downstream.
3. Station and elevations of the downstream control channel cross section.
4. The *estimated* water surface elevation at the fish passage design flow. Repeat until the calculated flow equals or is within 5% of the design flow.
5. The type of culvert: Round, Box, or Pipearch.

Step 5) Go to the appropriate culvert page: Round, Box, or *Pipearch.

- Follow the step-by-step instructions (red text) on the left side of the page.
- On the Round, Box, or *Pipearch page, the user is asked to input the following:

1. Diameter, or Span and Rise of the culvert.
2. Manning's n for the culvert.
3. Length of the culvert.
4. The elevation of the upstream invert.
5. The elevation of the downstream invert.
6. The *estimated* normal flow depth. Repeat until the calculated flow equals the design flow.

*Note: A table of common pipearch sizes is provided on the Pipearch Table page of the spreadsheet. A copy of the table is attached as Table 1.

Step 6) Go to the Summary Page.

- On the Summary Page all input data as well as the results of calculations are summarized in one table.
- Review all input values and resulting output.
- Return to the appropriate sheet to make any necessary corrections.
- When you are satisfied the analysis is complete, print this page for the report.

Table 1. Full-flow data for pipe arch (squash) culverts in English and metric units.

English						Metric			
Span (in)	Rise (in)	Span (ft)	Rise (ft)	Waterway Area (ft^2)	Hydraulic Radius (ft)	Span (m)	Rise (m)	Waterway Area (m^2)	Hydraulic Radius (m)
Corrugations 2 2/3 x 1/2 in.									
17	13	1.42	1.08	1.1	0.280	0.43	0.33	0.10	0.085
21	15	1.75	1.25	1.6	0.340	0.53	0.38	0.15	0.104
24	18	2.00	1.50	2.2	0.400	0.61	0.46	0.20	0.122
28	20	2.33	1.67	2.9	0.462	0.71	0.51	0.27	0.141
35	24	2.92	2.00	4.5	0.573	0.89	0.61	0.42	0.175
42	29	3.50	2.42	6.5	0.690	1.07	0.74	0.60	0.210
49	33	4.08	2.75	8.9	0.810	1.24	0.84	0.83	0.247
57	38	4.75	3.17	11.6	0.924	1.45	0.97	1.08	0.282
64	43	5.33	3.58	14.7	1.040	1.63	1.09	1.37	0.317
71	47	5.92	3.92	18.1	1.153	1.80	1.19	1.68	0.351
77	52	6.42	4.33	21.9	1.268	1.96	1.32	2.03	0.386
83	57	6.92	4.75	26.0	1.380	2.11	1.45	2.42	0.421
Corrugations 3 x 1 in.									
60	46	5.00	3.83	15.6	1.104	1.52	1.17	1.45	0.337
66	51	5.50	4.25	19.3	1.230	1.68	1.30	1.79	0.375
73	55	6.08	4.58	23.2	1.343	1.85	1.40	2.16	0.409
81	59	6.75	4.92	27.4	1.454	2.06	1.50	2.55	0.443
87	63	7.25	5.25	32.1	1.573	2.21	1.60	2.98	0.479
95	67	7.92	5.58	37.0	1.683	2.41	1.70	3.44	0.513
103	71	8.58	5.92	42.4	1.800	2.62	1.80	3.94	0.549
112	75	9.33	6.25	48.0	1.911	2.84	1.91	4.46	0.582
117	79	9.75	6.58	54.2	2.031	2.97	2.01	5.04	0.619
128	83	10.67	6.92	60.5	2.141	3.25	2.11	5.62	0.653
137	87	11.42	7.25	67.4	2.259	3.48	2.21	6.26	0.689
142	91	11.83	7.58	74.5	2.373	3.61	2.31	6.92	0.723
Corrugations 6 x 2 in.									
73	55	6.08	4.58	22	1.29	1.85	1.40	2.0	0.393
76	57	6.33	4.75	24	1.35	1.93	1.45	2.2	0.411
81	59	6.75	4.92	26	1.39	2.06	1.50	2.4	0.424
84	61	7.00	5.08	28	1.45	2.13	1.55	2.6	0.442
87	63	7.25	5.25	30	1.51	2.21	1.60	2.8	0.460
92	65	7.67	5.42	33	1.55	2.34	1.65	3.1	0.472
95	67	7.92	5.58	35	1.61	2.41	1.70	3.3	0.491
98	69	8.17	5.75	38	1.67	2.49	1.75	3.5	0.509
103	71	8.58	5.92	40	1.71	2.62	1.80	3.7	0.521
106	73	8.83	6.08	43	1.77	2.69	1.85	4.0	0.540
112	75	9.33	6.25	45	1.81	2.84	1.91	4.2	0.552
114	77	9.50	6.42	48	1.87	2.90	1.96	4.5	0.570
117	79	9.75	6.58	51	1.93	2.97	2.01	4.7	0.588
123	81	10.25	6.75	54	1.97	3.12	2.06	5.0	0.600
128	83	10.67	6.92	57	2.01	3.25	2.11	5.3	0.613
131	85	10.92	7.08	60	2.07	3.33	2.16	5.6	0.631
137	87	11.42	7.25	63	2.11	3.48	2.21	5.9	0.643
139	89	11.58	7.42	66	2.17	3.53	2.26	6.1	0.661
142	91	11.83	7.58	70	2.23	3.61	2.31	6.5	0.680
148	93	12.33	7.75	73	2.26	3.76	2.36	6.8	0.689
150	95	12.50	7.92	77	2.32	3.81	2.41	7.2	0.707
152	97	12.67	8.08	81	2.38	3.86	2.46	7.5	0.725
154	100	12.83	8.33	85	2.44	3.91	2.54	7.9	0.744
161	101	13.42	8.42	88	2.48	4.09	2.57	8.2	0.756
167	103	13.92	8.58	91	2.52	4.24	2.62	8.5	0.768
169	105	14.08	8.75	95	2.57	4.29	2.67	8.8	0.783
171	107	14.25	8.92	100	2.63	4.34	2.72	9.3	0.802
178	109	14.83	9.08	103	2.67	4.52	2.77	9.6	0.814
184	111	15.33	9.25	107	2.71	4.67	2.82	9.9	0.826
186	113	15.50	9.42	111	2.77	4.72	2.87	10.3	0.844

English						Metric			
Span (in)	Rise (in)	Span (ft)	Rise (ft)	Waterway Area (ft^2)	Hydraulic Radius (ft)	Span (m)	Rise (m)	Waterway Area (m^2)	Hydraulic Radius (m)
Corrugations 6 x 2 in.									
188	115	15.67	9.58	116	2.83	4.78	2.92	10.8	0.863
190	118	15.83	9.83	121	2.89	4.83	3.00	11.2	0.881
197	119	16.42	9.92	125	2.92	5.00	3.02	11.6	0.890
199	121	16.58	10.08	130	2.98	5.05	3.07	12.1	0.908

Example of Introduction Worksheet

Fish Passage Barrier Assessment and Prioritization Manual
2.3 Barrier Analysis
Level B
Spreadsheet Version: Excel 97, Metric Units
Updated: July 17, 2006

Introduction:

I. This spreadsheet calculates velocity and depth in a culvert at the high fish passage design flow and to compares the results of the analysis to WAC criteria.

NOTE: This version of the spreadsheet uses Manning's Equation and the Direct Step Method for analysis. Velocity and depth for culverts with submerged outlets and/or supercritical flow are not accurately calculated. Instead, rough estimates of velocity and depth are provided for these cases.

A. First High Fish Passage Design Flow, Qfp is determined by one of the following:
1. Regression calculation (Recommended for Western Washington.), or
2. Estimating with ordinary high water, OHW (Recommended for Eastern Washington.), or
3. Direct entry if Qfp is known.

B. The following WAC Criteria are used in this spreadsheet:

Culvert Length	**Maximum Velocity**	
10 - 99 feet (3 - 30 m)	4.0 fps	(1.22 mps)
100 - 200 feet (30 - 70 m)	3.0 fps	(0.91 mps)
Greater than 200 feet (>70 m)	2.0 fps	(0.61 mps)
Min. water depth:	1.0 ft	(0.30 m)
Max. hydraulic drop in fishway:	1.0 ft	(0.30 m)

C. Next the culvert is analyzed at Qfp without considering the influence of backwater. Using Manning's equation along with the culvert geometry, slope, roughness, and Qfp the flow depth and velocity are determined.
1. If either depth or velocity fail the WAC criteria, backwater must be analyzed.
2. If both depth and velocity at Qfp are acceptable, the culvert is not a barrier.

D. Finally, if necessary backwater is analyzed.
1. If backwater extends beyond the upstream end of the culvert, the velocity and and depth are checked at the upstream end of the culvert.
2. If backwater extends only part way through the culvert, the result of the Manning's equation analysis are used to determine if the culvert is a barrier.

II. Colors throughout the workbook represent the following:

Red Text:	Instructions
Blue Text:	Important Notes
Green boxes:	User input required.
Red Boxes:	Important Output
Standard Text:	General Information

III. Instructions on each page outline step by step procedures.

IV. Complete the worksheets in the following order:
1. Instructions
2. Hydrology
3. X Section
4. Box, or Round, or Pipearch
5. Summary

V. Go to the Hydrology worksheet to begin the analysis.

Example of Hydrology Worksheet with Sample Data

Level B - Hydrology Calculation Sheet

Instructions:

1. Enter the stream name, site ID and sequencer.

2. Select the hydrology method you would like to use to calculate the High Fish Passage Design Flow, Qfp.

   Enter: 1 for Regression, or
   2 for OHW, or
   3 for known Qfp.

**Note: Regression is recommended for Western Washington, and OHW is recommended for Eastern Washington.

3. You have chosen to use Regression.
   Complete steps 4a, 4b, and 4c below.

User Input: General Informatio

Stream Name:	Unnamed
Site ID:	370315
Sequencer:	1.1
Hydrology Method:	1

Regression Method

4a. Enter the Hydrologic Region and Drainage Area.
Note: See **Map worksheet, Figure 1 to determine your region.
(Valid Regions: 1, 2L, 2H, 2U, 3L, 3H, 4, 5, 6, 7, 8, 9)
Use "2L" or "3L" for regions 2 or 3 below elevation 1000 feet.
Use "2H" or "3H" for regions 2 or 3 above elevation 1000 feet.
Use "2U" for region 2 urban settings.

4b. Enter the Mean Annual Precipitation.

4c. Enter regression coefficients a, b, & c based on the Hydrologic Region.

Regression Coefficients Table

Hydrologic Region	a	b	c
1	6.99	0.95	1.01
2L	0.125	0.93	1.15
2H	141	0.72	0
2U	0.052	0.96	1.28
3L	0.666	0.95	0.82
3H	0.278	1.41	0.55
4	0.0178	0.9	1.68
5	9.45	0.836	0
6	1.64	0.657	0.799
7	5.97	0.589	0
8	4.89	0.69	0
9	0.772	0.764	0.663

User Input: Regression Method

Hydrologic Region:	2L
Drainage Area (sq mi):	0.67
Precipitation, inches:	46
Regression Coefficient a:	0.125
Regression Coefficient b:	0.93
Regression Coefficient c:	1.15

4d. You are finished with the Hydrology page.

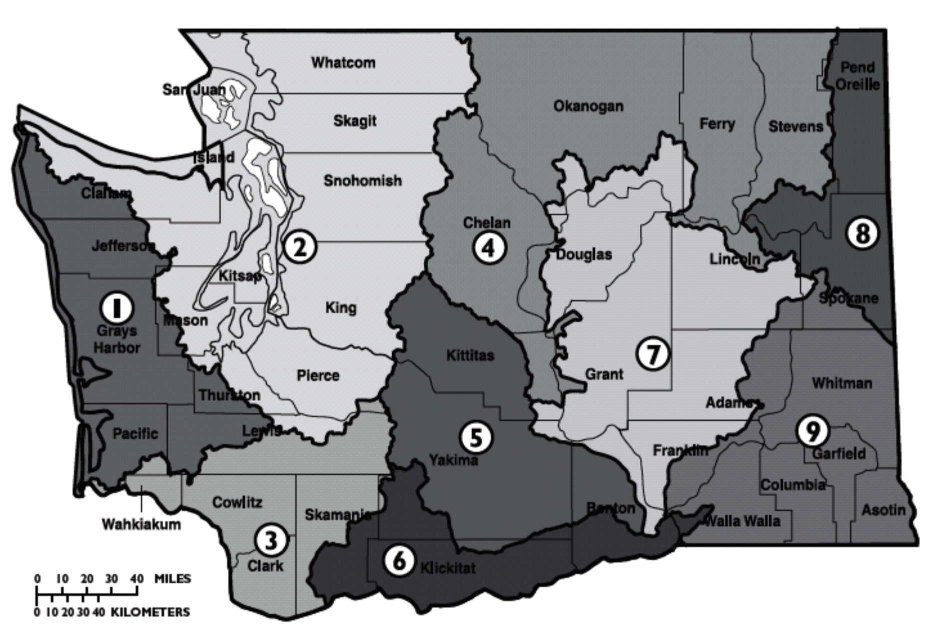
Go to the X Section worksheet.

Output: Regression Method

High Fish Passage Design Flow, Qfp (cms):	**0.20**

Map used to determine region for Hydrology Worksheet

Figure 1. Regions in Washington State used for development of regression equations (Source: USGS 1996)



Map figure from *Fish Passage Design Flows for Ungaged Catchments in Washington* , by P. Powers and C. Saunders, 1996 (revised 1998).

Published in Appendix C of *Design of Road Culverts for Fish Passage* , by Bates et al 2003; available online at:

http://wdfw.wa.gov/hab/engineer/cm/

Example of Cross Section Worksheet with Sample Data

Level B - Cross Section Calculation Sheet

Site Information

Stream:	Unnamed
Site ID:	370315
Sequencer:	1.1

Instructions:

1. Enter the water surface elev. at the downstream control.
2. Enter the water surface elevation downstream.
   *NOTE: Must be lower than the downstream control.
3. Enter the Manning's n value for the stream channel.

Mud, Sand	0.03	Gravel, Cobble	0.04
Riprap	0.04	Boulders	0.05
Bedrock	0.04		

4. Enter the stations and elevations for the cross section.
   *NOTE: All toe and bed elevations must be lower than the water surface elevations at the cross section.
5. Enter an ESTIMATED water surface elevation at Qfp.
6. Repeat step 5 until the Calculated Channel Flow approximate equals the Calculated Regression Flow at the right.
7. The Calculated Regression Flow from above will be used for High Fish Passage Design Flow.
8. Enter the Culvert Type: 1-Round, 2-Box, or 3-Pipearch.
9. You have completed the X Section page.

Go to the Round worksheet.

User Input: Stream Channel Information

Downstream Control Water Surface Elevation:	100.64	m
Water Surface Elevation 15 meters downstream of control:	100.32	m
Manning's "n" for the stream channel:	0.04	

User Input: Channel Cross Section Data

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB
STA	0	1.7	2.8	3.5	4.35	4.9	7.65
ELEV	100.80	100.52	100.58	100.53	100.44	100.47	100.87

Estimated water surface elevation at Qfp: 100.60 m

Output: Channel Data

Channel water surface slope 2.13%

LB WS STA	1.24					
RB WS STA	5.76					
AREAS	0.02	0.05	0.03	0.09	0.08	0.05
WP	1.25	1.10	0.70	0.85	0.55	2.78
R	0.01	0.04	0.04	0.11	0.14	0.02
Q	0.00	0.02	0.01	0.08	0.08	0.01

Calculated Channel Flow:	0.20	cms
Calculated Regression Flow:	0.20	cms

*From Hydrology Worksheet

Output: High Fish Passage Design Flow

High Fish Passage Design Flow, Qfp: 0.20 cms

Output: High Fish Passage Design Flow

Culvert Type: 1

Example of Round Culvert Worksheet with Sample Data

Level B - Calculation Sheet For Round Culvert

Output: Site Information

Stream:	Unnamed
Site ID:	370315
Sequencer:	1.1

Instructions:

1. Enter the culvert diameter.
2. Enter the culvert roughness, Manning's n value.

steel	0.012	corrugated metal, 1x3	0.027
concrete	0.014	corrugated matal, 2x6	0.033
paved invert	0.023	corrugated metal, 0.5x22/3	0.024

3. Enter the culvert length.
4. Enter the culvert upstream elevation.
5. Enter the culvert downstream elevation.
6. Enter the ESTIMATED flow depth in the culvert at Qfp.

Input: Culvert Information

Culvert Diameter (m):	0.76
Mannings n:	0.014
Length (m):	13.12
U/S Invert Elevation:	100.00
D/S Invert Elevation:	99.98
*Note: D/S Invert must be lower than U/S Invert.	
Normal Flow Depth (m):	0.37

7. Repeat step 6 until the Manning's Calculated Flow is approximately equal to the High Fish Passage Design Flow.

Output: Results of Manning's Equation

Downstream Water Surface, without backwater (m):	100.35
Theta (radians):	1.54
Flow area (sq m):	0.22
Wetted Perimeter (m):	1.17
Culvert Slope (m/m):	0.0015
Manning's Calculated Flow (cms):	0.20
High Fish Passage Design Flow (Qfp):	0.20
Calculated Velocity (mps):	0.91
Hydraulic Depth (m):	0.29
Froude Number:	0.54

*From X Section Worksheet

8. STOP! The Calculated Velocity in the culvert is acceptable.

Go to the Summary worksheet.

Output: WAC Criteria

Maximum Allowable Velocity (mps):	1.22
Minimum Allowable Depth (m):	0.30

9. The culvert is influenced by backwater. Go to step 10 to determine how far backwater extends into the culvert.

Output: Backwater Potential Evaluation

Tailwater Surface Elev. at downstream end of culvert (m):	100.60
Culvert Influenced by Backwater:	**Yes**
Outlet Submerged:	**No**
Length Submerged (m):	**0.00**
Tailwater elev. minus downstream invert elev. (m):	0.61
	0.76

*From X Section Worksheet

10. The table at the right describes the backwater analysis.

Go to the Summary Worksheet.

Output: Backwater Analysis - Results

Possible length of backwater (m):	382.39
Backwater length plus submerged length (m):	382.39
Length of Culvert (m):	13.12
Maximum Velocity in culvert (mps):	0.51
Minimum Depth in culvert (m):	0.61

The culvert is completely backwatered.
Velocity Barrier? No.
Depth Barrier? No.

Example of Summary Sheet with for a Round Culvert Satisfying Fish Passage Criteria

Fish Passage Barrier Assessment and Prioritization Manual
2.3 Barrier Analysis
Level B Spreadsheet
Spreadsheet Version: Excel 97, Metric Units
Updated: July 17, 2006

Summary

Site Information:		**Source Worksheet:**
Stream:	Unnamed	Hydrology
Site ID:	370315	"
Sequencer:	1.1	"

Hydrology:		
Hydrology Method Selected:	Regression Method.	Hydrology
Hydrologic Region:	2L	Hydrology
Basin Area (Square Miles):	0.67	"
Precipitation, inches:	46	"
Regression Coefficient a:	0.125	"
Regression Coefficient b:	0.93	"
Regression Coefficient c:	1.15	"

Downstream Channel Cross Section

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB	X Section
Station:	0	1.7	2.8	3.5	4.35	4.9	7.65	"
Elev.:	100.8	100.52	100.58	100.53	100.44	100.47	100.87	"

DS Control Water Surface Elevation:	100.64			X Section
Water Surface Elevation 50 ft (15.24 m) DS:	100.32			"
Manning's "n" for channel	0.04			"
Cross Section Water Surface Elevation at Qfp:	100.595			"
Culvert Length:	13.12	m		Round
Maximum Velocity:	1.22	mps	(WAC Criteria)	
Minimum Water Depth:	0.30	m	(WAC Criteria)	
Maximum hydraulic drop in fishway:	0.30	m	(WAC Criteria)	
Culvert Type:	Round Culvert			X Section

Culvert Analysis		
Round Culvert Diameter (m):	0.76	Round
		"
Manning's n for culvert:	0.0140	"
Culvert Length (m):	13.12	"
U/S Invert Elevation:	100.00	"
D/S Invert Elevation:	99.98	"
Normal Flow Depth (m):	0.37	"
Culvert Slope (m/m):	0.0015	"
Velocity w/o backwater (mps):	0.91	"
Water Surface Elevation at DS end of culvert:	100.60	"
Flow Depth at DS end of culvert:	0.61	"
Culvert Influenced by Backwater:	Yes	"
Outlet Submerged:	No	"
Length Submerged (m):	0.00	"
	382.39	"
Backwater length plus submerged length (m):	382.39	"
Maximum Velocity in culvert (mps):	0.51	"
Minimum Depth in culvert (m):	0.61	"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determinec **Regression Method.**

Qfp = 0.20 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater	**0.91 mps**	**Satisfies WAC criteria.**
Min. Depth (w/o backwater) =	**0.37 m**	**Satisfies WAC criteria.**

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwate Yes
The culvert is completely backwatered.
Is the culvert outlet submerged? No
0.00 Meters of the culvert are submerged.

Max. Velocity (w/ backwater)	**0.51 mps**	**Satisfies WAC criteria.**
Min. Depth (w/ backwater) =	**0.61 m**	**Satisfies WAC criteria.**

4. The Final Answer...

The culvert satisfies the WAC criteria without backwater.
The culvert is not a barrier.

Example of Summary Sheet with for a Fish Passage Barrier Round Culvert

Fish Passage Barrier Assessment and Prioritization Manual
2.3 Barrier Analysis
Level B Spreadsheet
Spreadsheet Version: Excel 97, Metric Units
Updated: July 17, 2006

Summary

Site Information:		**Source Worksheet:**
Stream:	Unnamed	**Hydrology**
Site ID:	998201	"
Sequencer:	1.1	"

Hydrology:		
Hydrology Method Selected:	Regression Method.	**Hydrology**
Hydrologic Region:	2L	**Hydrology**
Basin Area (Square Miles):	1.25	"
Precipitation, inches:	54	"
Regression Coefficient a:	0.125	"
Regression Coefficient b:	0.93	"
Regression Coefficient c:	1.15	"

Downstream Channel Cross Section

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB	X Section
Station:	0	3.7	4.6	5.2	5.7	6.6	9.3	"
Elev.:	101.03	100.2	100.3	100.22	100.12	100.22	100.62	"

DS Control Water Surface Elevation:	100.356			**X Section**
Water Surface Elevation 50 ft (15.24 m) DS:	100.28			"
Manning's "n" for channel	0.03			"
Cross Section Water Surface Elevation at Qfp:	100.39			"
Culvert Length:	17.91	m		**Round**
Maximum Velocity:	1.22	mps	(WAC Criteria)	
Minimum Water Depth:	0.30	m	(WAC Criteria)	
Maximum hydraulic drop in fishway:	0.30	m	(WAC Criteria)	
Culvert Type:	Round Culvert			**X Section**

Culvert Analysis		
Round Culvert Diameter (m):	0.61	**Round**
		"
Manning's n for culvert:	0.0140	"
Culvert Length (m):	17.91	"
U/S Invert Elevation:	100.00	"
D/S Invert Elevation:	99.92	"
Normal Flow Depth (m):	0.6	"
Culvert Slope (m/m):	0.0047	"
Velocity w/o backwater (mps):	1.47	"
Water Surface Elevation at DS end of culvert:	100.39	"
Flow Depth at DS end of culvert:	0.00	"
Culvert Influenced by Backwater:	No	"
Outlet Submerged:	No	"
Length Submerged (m):	0.00	"
	0.00	"
Backwater length plus submerged length (m):	0.00	"
Maximum Velocity in culvert (mps):	0.00	"
Minimum Depth in culvert (m):	0.00	"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determinec **Regression Method.**

Qfp = 0.43 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater 1.47 mps Does not satisfy WAC criteria.
Min. Depth (w/o backwater) = 0.60 m Satisfies WAC criteria.

Velocity does not satisfy WAC criteria, check backwater.

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwate No

Is the culvert outlet submerged? No
0.00 Meters of the culvert are submerged.

Max. Velocity (w/ backwater) 0.00 mps Satisfies WAC criteria.
Min. Depth (w/ backwater) = 0.00 m Does not satisfy WAC criteria.

4. The Final Answer...

The culvert does not satisfy WAC criteria.
The culvert is a barrier.

Example of Box Culvert Worksheet

Level B - Calculation Sheet For Box Culvert

Site Information

Stream:	0
Site ID:	0
Sequencer:	0

Instructions:

1a. Enter the box culvert span. (Width)
1b. Enter the box culvert rise. (Height)
2. Enter the culvert roughness, Manning's n value.

steel	0.012	corrugated metal, 1x3	0.027
concrete	0.014	corrugated matal, 2x6	0.033
paved invert	0.023	corrugated metal, 0.5x22/3	0.024

3. Enter the culvert length.
4. Enter the culvert upstream elevation.
5. Enter the culvert downstream elevation.
6. Enter the ESTIMATED flow depth in the culvert at Qfp.
7. Repeat step 6 until the Manning's Calculated Flow is approximately equal to the High Fish Passage Design Flow.

User Input:

Span (m):	
Rise (m):	
Mannings n:	
Length (m):	
U/S Invert Elevation:	
D/S Invert Elevation:	
*Note: D/S Invert must be lower than U/S Invert.	
Normal Flow Depth (m):	

Output: Results of Manning's Equation

Downstream Water Surface, without backwater (m):	0
Flow area (sq m):	0.00
Wetted Perimeter (m):	0.00
Culvert Slope (m/m):	0.0000
Manning's Calculated Flow (cms):	0.00
High Fish Passage Design Flow, Qfp	0.00
Calculated Velocity (mps):	0.00
Flow Depth (m):	0
Froude Number:	#DIV/0!

Output: WAC Criteria

#N/A
#N/A
#N/A

Maximum Allowable Velocity (mps):	#N/A
Minimum Allowable Depth (m):	0.00

Output: Potential Backwater Evaluation

#DIV/0!
#DIV/0!
#DIV/0!

	Tailwater Surface Elev. at downstream end of culvert (m):	0.00
	Culvert Influenced by Backwater:	No
	Outlet Submerged:	Yes
	Length Submerged (m):	0.00
	Tailwater elev. minus downstream invert elev. (m):	0.00
#	#DIV/0!	#DIV/0!
#	#DIV/0!	#DIV/0!
#	#DIV/0!	#DIV/0!
#	#DIV/0!	#DIV/0!

#DIV/0!

Output: Backwater Analysis - Results

#DIV/0!

#DIV/0!

	Possible length of backwater (m):	#DIV/0!
	Backwater length plus submerged length (m):	#DIV/0!
	Length of Culvert (m):	0.00
	#DIV/0!	
	#DIV/0!	
#	Maximum Velocity in culvert (mps):	0.00
#	Minimum Depth in culvert (m):	0.00
#	**#DIV/0!**	
#		
#		

#DIV/0!

Example of Pipearch Culvert Worksheet

Level B - Calculation Sheet For Pipearch Culvert

Site Information

Stream:	0
Site ID:	0
Sequencer:	0

Instructions:

1. Enter the measured culvert span. (Width)
2. Enter the measured culvert rise. (Height)
3. Enter the culvert length.
4. Enter the culvert upstream elevation.
5. Enter the culvert downstream elevation.

User Input: Culvert Information - Field Observatic

Measured Culvert Span (m):	
Measured Culvert Rise (m):	
Length (m):	
U/S Invert Elevation (m):	
D/S Invert Elevation (m):	

*Note: D/S Invert must be lower than U/S Invert.

6. Go to the Pipearch Table worksheet. Then return, and continue with step 7.

7. Enter the Full Flow Area from the Pipearch Table.
8. Enter the Hydraulic Radius from the Pipearch Table.

User Input: Pipearch Table

Flow Full Area (sq m):	
Hydraulic Radius (m):	

9. Enter the culvert roughness, Manning's n value.

steel	0.012	corrugated metal, 1x3	0.027
concrete	0.014	corrugated matal, 2x6	0.033
paved invert	0.023	corrugated metal, 0.5x2.67	0.024

10. Enter the ESTIMATED flow depth in the culvert at Qfp.

User Input: Culvert Properties

Mannings n:	
Normal Flow Depth (m):	

11. Repeat step 10 until the Manning's Calculated Flow is approximately equal to the High Fish Passage Design Flow.

Output: Results of Manning's Equation

Downstream Water Surface, without backwater (m):	0.00
Culvert Slope (m/m):	#DIV/0!
Relative depth, Flow Depth/Rise (m/m):	#DIV/0!
Flow area (sq m):	#DIV/0!
Hydraulic Radius (m):	#DIV/0!
Manning's Calculated Flow, cms:	#DIV/0!
High Fish Passage Design Flow, Qfp	0.00
Calculated Velocity, mps:	0.00
Hydraulic Depth (Rough Estimate as Flow Depth) (m):	0.00
Froude Number (Rough Estimate):	#DIV/0!

#N/A
#N/A
#N/A

Output: WAC Criteria

Maximum Allowable Velocity, mps:	#N/A
Minimum Allowable Depth, m:	0.00

13. STOP! The culvert is not influenced by backwater.

Go to the Summary Worksheet.

Output: Potential Backwater Evaluation

	Tailwater Surface Elev. at downstream end of culvert (m):	0.00
	Culvert Influenced by Backwater:	No
	Outlet Submerged:	Yes
	Length Submerged (m):	0.00
	Tailwater elev. minus downstream invert elev. (m):	0.00
#		#DIV/0!
#		#DIV/0!
#	Relative depth, Upstream Tailwater Depth/Rise (m/m):	#DIV/0!
#		#DIV/0!
#		#DIV/0!

#DIV/0!

Output: Backwater Analysis - Results

	Possible length of backwater (m):	0.00
	Backwater length plus submerged length (m):	0.00
	Length of Culvert (m):	0
	#DIV/0!	
	#DIV/0!	
#	Maximum Velocity in culvert (mps):	0.00
#	Minimum Depth in culvert (m):	0.00
#	#DIV/0!	
#	#DIV/0!	
#	#DIV/0!	

#DIV/0!

Example of Table Referred to for Pipearch Culvert Worksheet

Level B - Pipearch Table

Instructions:

1. Using the Pipearch Table at the right, choose the culvert which most closely matches the dimensions of the culvert being analyzed.
   *NOTE: The table has values for English and Metric units.
2. Determine the Full Flow Area for the culvert selected above.
3. Determine the Hydraulic Radius for the culvert selected above.

4. Return to the Pipearch Worksheet.

Corrugations 2 2/3 x 1/2 in.

		Span (ft)	Rise (ft)	Full Flow Area (ft2)	Hydraulic Radius (ft)	Span (m)	Rise (m)	Full Flow Area (m2)	Hydraulic Radius (m)
17	13	1.42	1.08	1.1	0.280	0.43	0.33	0.10	0.085
21	15	1.75	1.25	1.6	0.340	0.53	0.38	0.15	0.104
24	18	2.00	1.50	2.2	0.400	0.61	0.46	0.20	0.122
28	20	2.33	1.67	2.9	0.462	0.71	0.51	0.27	0.141
35	24	2.92	2.00	4.5	0.573	0.89	0.61	0.42	0.175
42	29	3.50	2.42	6.5	0.690	1.07	0.74	0.60	0.210
49	33	4.08	2.75	8.9	0.810	1.24	0.84	0.83	0.247
57	38	4.75	3.17	11.6	0.924	1.45	0.97	1.08	0.282
64	43	5.33	3.58	14.7	1.040	1.63	1.09	1.37	0.317
71	47	5.92	3.92	18.1	1.153	1.80	1.19	1.68	0.351
77	52	6.42	4.33	21.9	1.268	1.96	1.32	2.03	0.386
83	57	6.92	4.75	26.0	1.380	2.11	1.45	2.42	0.421

Corrugations 3 x 1 in.

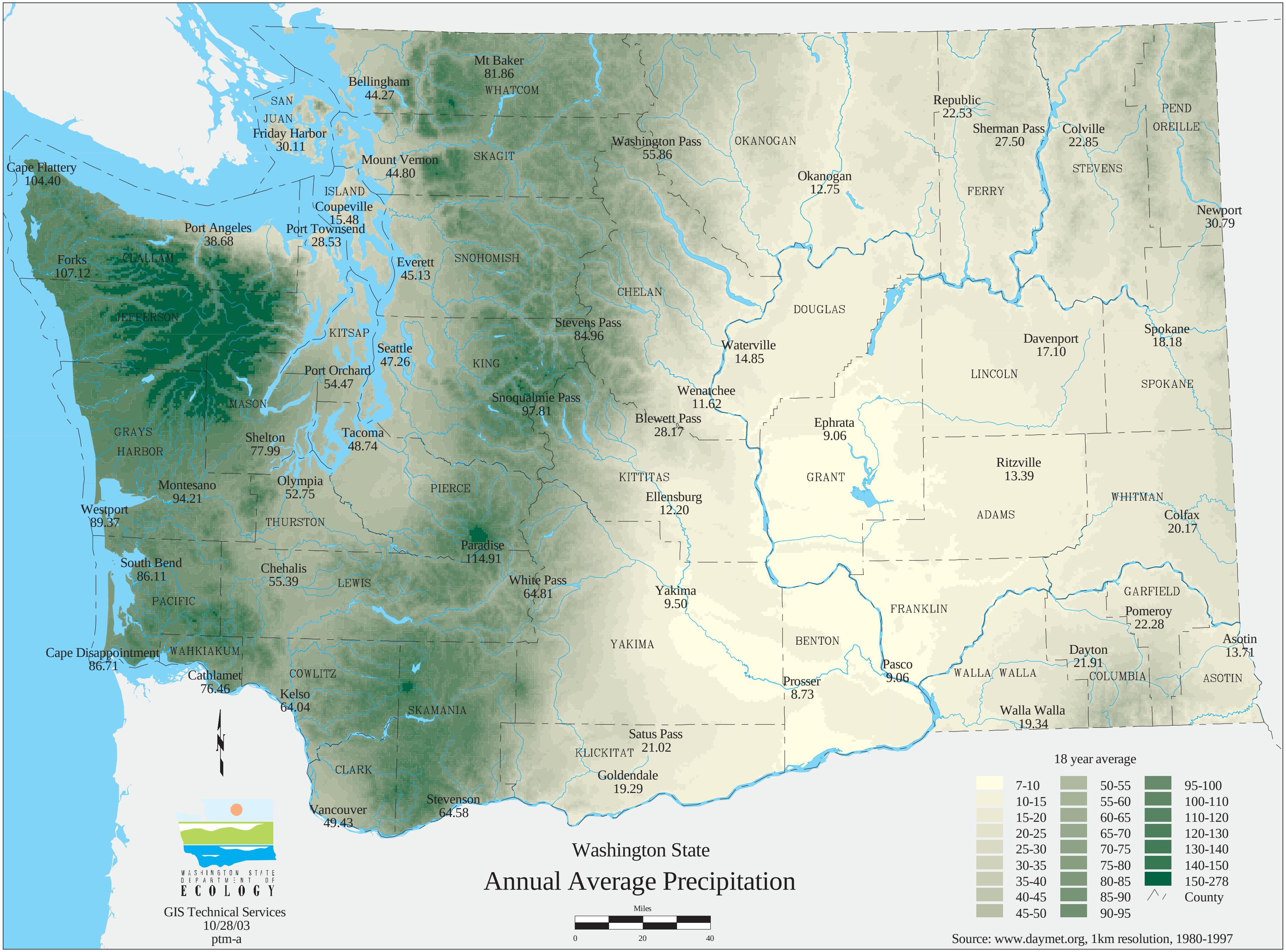
60	46	5.00	3.83	15.6	1.104	1.52	1.17	1.45	0.336
66	51	5.50	4.25	19.3	1.230	1.68	1.30	1.79	0.375
73	*55*	*6.08*	*4.58*	*23.2*	*1.343*	*1.85*	*1.40*	*2.16*	*0.409*
81	59	6.75	4.92	27.4	1.454	2.06	1.50	2.55	0.443
87	63	7.25	5.25	32.1	1.573	2.21	1.60	2.98	0.479
95	67	7.92	5.58	37.0	1.683	2.41	1.70	3.44	0.513
103	71	8.58	5.92	42.4	1.800	2.62	1.80	3.94	0.549
112	75	9.33	6.25	48.0	1.911	2.84	1.91	4.46	0.582
117	79	9.75	6.58	54.2	2.031	2.97	2.01	5.04	0.619
128	83	10.67	6.92	60.5	2.141	3.25	2.11	5.62	0.653
137	87	11.42	7.25	67.4	2.259	3.48	2.21	6.26	0.689
142	91	11.83	7.58	74.5	2.373	3.61	2.31	6.92	0.723

Corrugations 6 x 2 in.

73	55	6.08	4.58	22	1.29	1.85	1.40	2.0	0.393
76	57	6.33	4.75	24	1.35	1.93	1.45	2.2	0.411
81	59	6.75	4.92	26	1.39	2.06	1.50	2.4	0.424
84	61	7.00	5.08	28	1.45	2.13	1.55	2.6	0.442
87	63	7.25	5.25	30	1.51	2.21	1.60	2.8	0.460
92	65	7.67	5.42	33	1.55	2.34	1.65	3.1	0.472
95	67	7.92	5.58	35	1.61	2.41	1.70	3.3	0.491
98	69	8.17	5.75	38	1.67	2.49	1.75	3.5	0.509
103	71	8.58	5.92	40	1.71	2.62	1.80	3.7	0.521
106	73	8.83	6.08	43	1.77	2.69	1.85	4.0	0.539
112	75	9.33	6.25	45	1.81	2.84	1.91	4.2	0.552
114	77	9.50	6.42	48	1.87	2.90	1.96	4.5	0.570
117	79	9.75	6.58	51	1.93	2.97	2.01	4.7	0.588
123	81	10.25	6.75	54	1.97	3.12	2.06	5.0	0.600
128	83	10.67	6.92	57	2.01	3.25	2.11	5.3	0.613
131	85	10.92	7.08	60	2.07	3.33	2.16	5.6	0.631
137	87	11.42	7.25	63	2.11	3.48	2.21	5.9	0.643
139	89	11.58	7.42	66	2.17	3.53	2.26	6.1	0.661
142	91	11.83	7.58	70	2.23	3.61	2.31	6.5	0.680
148	93	12.33	7.75	73	2.26	3.76	2.36	6.8	0.689
150	95	12.50	7.92	77	2.32	3.81	2.41	7.2	0.707
152	97	12.67	8.08	81	2.38	3.86	2.46	7.5	0.725
154	100	12.83	8.33	85	2.44	3.91	2.54	7.9	0.744
161	101	13.42	8.42	88	2.48	4.09	2.57	8.2	0.756
167	103	13.92	8.58	91	2.52	4.24	2.62	8.5	0.768
169	105	14.08	8.75	95	2.57	4.29	2.67	8.8	0.783
171	107	14.25	8.92	100	2.63	4.34	2.72	9.3	0.802
178	109	14.83	9.08	103	2.67	4.52	2.77	9.6	0.814
184	111	15.33	9.25	107	2.71	4.67	2.82	9.9	0.826
186	113	15.50	9.42	111	2.77	4.72	2.87	10.3	0.844
188	115	15.67	9.58	116	2.83	4.78	2.92	10.8	0.863
190	118	15.83	9.83	121	2.89	4.83	3.00	11.2	0.881
197	119	16.42	9.92	125	2.92	5.00	3.02	11.6	0.890
199	121	16.58	10.08	130	2.98	5.05	3.07	12.1	0.908

APPENDIX H

Washington State Average Precipitation Map


Washington State
Annual Average Precipitation
18 year average
7-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-110
110-120
120-130
130-140
140-150
150-278
County
Source: www.daymet.org, 1km resolution, 1980-1997
Miles
0
20
40
N
WASHINGTON STATE DEPARTMENT OF ECOLOGY
GIS Technical Services
10/28/03
ptm-a
Mt Baker 81.86
Bellingham 44.27
WHATCOM
SAN JUAN
Friday Harbor 30.11
Cape Flattery 104.40
Mount Vernon 44.80
SKAGIT
ISLAND
Coupeville 15.48
Port Angeles 38.68
Port Townsend 28.53
Forks 107.12
CLALLAM
Everett 45.13
SNOHOMISH
JEFFERSON
KITSAP
Seattle 47.26
Port Orchard 54.47
KING
MASON
GRAYS HARBOR
Shelton 77.99
Tacoma 48.74
Montesano 94.21
Olympia 52.75
PIERCE
Westport 89.37
THURSTON
Paradise 114.91
South Bend 86.11
Chehalis 55.39
LEWIS
PACIFIC
White Pass 64.81
Cape Disappointment 86.71
WAHKIAKUM
Cathlamet 76.46
COWLITZ
Kelso 64.04
SKAMANIA
CLARK
Vancouver 49.43
Stevenson 64.58
Washington Pass 55.86
OKANOGAN
Okanogan 12.75
CHELAN
Stevens Pass 84.96
Snoqualmie Pass 97.81
Blewett Pass 28.17
Wenatchee 11.62
Waterville 14.85
DOUGLAS
KITTITAS
Ellensburg 12.20
Yakima 9.50
YAKIMA
KLICKITAT
Satus Pass 21.02
Goldendale 19.29
Ephrata 9.06
GRANT
BENTON
Prosser 8.73
Pasco 9.06
FRANKLIN
Republic 22.53
Sherman Pass 27.50
Colville 22.85
FERRY
STEVENS
PEND OREILLE
Newport 30.79
Davenport 17.10
LINCOLN
Spokane 18.18
SPOKANE
Ritzville 13.39
ADAMS
WHITMAN
Colfax 20.17
GARFIELD
Pomeroy 22.28
Asotin 13.71
ASOTIN
Dayton 21.91
COLUMBIA
WALLA WALLA
Walla Walla 19.34

APPENDIX I

Screening Requirements for Surface Water Diversions

Screening Requirements for Water Diversions

Washington State Laws RCW 77.57.070 (formerly RCW 77.55.320; RCW 77.57.010 (formerly RCW 77.55.040), RCW 77.57.040 (formerly RCW 77.55.070) require all diversions from waters of the state to be screened to protect fish.

These laws and the following design criteria are essential for the protection of fish at surface water diversions. Fish drawn into hydropower, irrigation, water supply, and other diversions are usually lost from the fish resources of the state of Washington.

The following criteria are based on the philosophy of physically excluding fish from being entrained in water diverted without becoming impinged on the diversion screen. The approach velocity and screen mesh opening criteria are based upon the swimming stamina of emergent size fry in low water temperature conditions. It is recognized that there may be locations at which design for these conditions may not be warranted. Unless conclusive data from studies acceptable to Washington Department of Fish and Wildlife indicate otherwise, it is assumed that these extreme conditions exist at some time of the year at all screen sites.

Additional criteria may be required for unique situations, large facilities or intakes within marine waters.

I. Screen Location and Orientation

A. Fish screens in rivers and streams shall be constructed within the flowing stream at the point of diversion and parallel to the stream flow. The screen face shall be continuous with the adjacent bankline. A smooth transition between the screen and bankline shall be provided to prevent eddies in front, upstream and downstream of the screen.

Where it can be thoroughly demonstrated that flow characteristics or site conditions make construction or operation of fish screens at the diversion entrance impractical, the screens may be installed in the canal downstream of the diversion.

B. Diversion intakes in lakes and reservoirs shall be located offshore in deep water to minimize the exposure of juvenile fish to the screen. Salmon and trout fry generally inhabit shallow water areas near shore.

C. Screens constructed in canals and ditches shall be located as close as practical to the diversion. They shall be oriented so the angle between the face of the screen and the approaching flow is no more than 45. All screens constructed downstream of the diversion shall be provided with an efficient bypass system.

II. Approach Velocity

The approach velocity is defined as the component of the local water velocity vector perpendicular to the face of the screen. Juvenile fish must be able to swim at a speed equal or greater than the approach velocity for an extended length of time to avoid impingement on the screen. The following approach velocity criteria are maximum velocities that shall not be exceeded anywhere on the face of the screen. A maximum approach velocity of 0.4 feet per second is allowed.

The approach velocity is calculated based on the gross screen area not the net open area of the screen mesh.

The intake structure and/or fish screen shall be designed to assure that the diverted flow is uniformly distributed through the screen so the maximum approach velocity is not exceeded.

III. Minimum Screen Area

The minimum required screen area is determined by dividing the maximum diverted flow by the maximum allowable approach velocity. To find the screen area in square feet, divide the diverted flow in cubic feet per second (450 gpm = 1.0 cubic foot per second) by the approach velocity 0.4 feet per second):

$$MinimumScreenArea = \frac{DivertedFlow(cubic feet/second)}{ApproachVelocity(feet per second)}$$

The minimum required screen area must be submerged during lowest stream flows and may not include any area that is blocked by screen guides or structural members.

Diversions less than or equal to 180 gallons/minute (0.4 cfs) require a minimum submerged screen area of 1.0 square foot, which is the smallest practical screening device.

IV. Sweeping Velocity

The sweeping velocity is defined as the component of the water velocity vector parallel to and immediately upstream of the screen surface. The sweeping velocity shall equal or exceed the maximum allowable approach velocity. The sweeping velocity requirement is satisfied by a combination of proper orientation (angle of screen 45 to the approaching flow) of the screen relative to the approaching flow and adequate bypass flow.

V. Screen Mesh Size, Shape, and Type of Material

Screen openings may be round, square, rectangular, or any combination thereof, provided structural integrity and cleaning operations are not impaired.

Screen mesh criteria is based on the assumption that steelhead and/or resident trout fry are ubiquitous in the state of Washington and will be present at all diversion sites.

Following are the maximum screen openings allowable for emergent salmonid fry. The maximum opening applies to the entire screen structure including the screen mesh, guides, and seals. The profile bar criteria is applied to the narrow dimension of rectangular slots or mesh.

Woven Wire Mesh	Profile Bar	Perforated Plate
0.087 inch (6-14 mesh)	1.75 mm (0.069 inch)	0.094 inch (3/32 inch)

The allowable woven wire mesh openings is the greatest open space distance between mesh wires. An example allowable mesh specifications is provided; there are other standard allowable openings available. The mesh specification gives the number of mesh openings per lineal inch followed by the gauge of the wires. For example, 6-14 mesh has six mesh openings per inch of screen. It is constructed with 6, 14-gauge (0.080 inch diameter) wires per inch.

The profile bar openings are the maximum allowable space between bars. The allowable perforated plate openings are the diameter of circular perforations. Perforated slots are treated as profile bars.

Screens may be constructed of any durable material; woven, welded, or perforated. The screen material must be resistant to corrosion and ultraviolet damage.

For longevity and durability, minimum wire diameter for woven mesh shall be 0.060 inch (18 gauge) on fixed panel screens, where they are not subjected to impact of debris. Minimum wire diameter for woven mesh shall be 0.080 inch (14 gauge) for rotary drum screens, traveling belt screens, and in areas where there is a potential for damage from floating debris or cleaning operations.

VI. Bypass

All screens constructed downstream of the diversion shall be provided with an efficient bypass system to rapidly collect juvenile fish and safely transport them back to the river. The downstream end of the screen shall terminate at the entrance to the bypass system. It is the water diversion owner's responsibility to obtain necessary water rights to operate the fish bypass; failure to do so may be considered failure to meet state screening law requirements.

VII. Cleaning

Fish screens shall be cleaned as frequently as necessary to prevent obstruction of flow and violation of the approach velocity criterion. Automatic cleaning devices will be required on large screen facilities.

Additional detailed information is available explaining the background and justification of these criteria and showing standard details of flow distributors, acceptable bypass designs, and screen areas required for various flows.

For further information on fish screening contact:

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APPENDIX J

Habitat Assessment Field Form

PHYSICAL HABITAT SURVEY FIELD FORM (06/14/2008)

[1]Survey ID:____________ [2]Date:_________ [3]Observers:___________

[4]Stream Name:________________ [5]Tributary To:_________________

[6]WRIA:________[7]Position:____________________________________

[8]Section Surveyed:_____________________[9]Survey Method:_______

[10]Reach #:__________[11]Begin CR:________ [12]End CR:_____________

[13]Spawning HQM:___ [14]Rearing HQM:_____ [15]Spring Influence:______

[16]Instream Cover:_______ [17]Juvenile Abundance:_______[18]Temp.:____

[19]Canopy:_____________________ [20]Additional Features:___________

[21]Limiting Factors:_____________________[22]Culverted Length:_______

[23]Sampling Frequency: ~30/160 ~60/320 ~60 meters per reach

Chain Reading	Habitat Type	Length	Wetted Width	Scour Width	Depth	Gradient	% Boulder/Rubble/Gravel/ Sand

HABITAT FORM INSTRUCTIONS

1) Should be the same as the barrier site ID.
2) Date of survey.
3) Names of field crew conducting the survey.
4) Name of stream being surveyed.
5) Name of stream at first major confluence.
6) Watershed Resource Inventory Area (WRIA) number.
7) Location of the beginning of the reach (*e.g*., at barrier culvert Site 370054 on Jones Road; or; at left bank tributary entering at 1543 meters upstream Site 370054).
8) Starting and ending point of the survey
9) Type of survey being conducted. PS - Full Physical Survey; RSFS - Reduced Sample Full Survey.
10) Number of reach being sampled.
11) Hip chain reading at the beginning of the reach in meters.
12) Hip chain reading at the end of the reach in meters.
13) Habitat Quality Modifier assigned to spawning habitat for the reach. Appropriate values: Good - 1, Fair - 0.67, Poor - 0.33, Very poor with no habitat value - 0.
14) Habitat Quality Modifier assigned to rearing habitat for the reach. Appropriate values: Good - 1, Fair - 0.67, Poor - 0.33, Very poor with no habitat value - 0.
15) Estimate of the spring contribution to the flow of the stream. Absent - 0, Slight - 1, Moderate - 2, Pronounced - 3.
16) Characterize the amount of instream cover using low, medium, high.
17) A visual estimate of fry abundance using low, medium, high.
18) Temperature in degrees Celsius.
19) Percent canopy cover. Note dominant species.
20) The number of features encountered including human-made and natural.
21) If a habitat quality modifier of less the 1 was assigned, explain why.
22) Total length of all culverts in the reach in meters.
23) Either 30 meters out of 160 meters, 60 meters out of 320 meters, or 60 meters per reach.

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: The percent gradient for each sample section.
% Boulder/Rubble/Gravel/Sand: Visual estimate of the percent composition of each substrate category in each habitat type (*e.g.*, 15/35/40/10).

APPENDIX K

Physical Habitat Survey

Data Entry Spreadsheet

Input Page, Output Page, and Comments pages with Sample Data

WDFW - Habitat Program

PHYSICAL HABITAT SURVEY - INPUT FILE (Ver. 4d)

Survey Method :	RSFS	Date:	11/24/2009
Stream Name:	unnamed	Observer(s):	Bauder;Phinney
Tributary To:	Schneider Cr	Section surveyed:	Inlet of 997161 to end of fish use
WRIA #:	14		1121.3 m upstream
Sample Frequency:	60m/Reach	Filename:	997161.xls

REACH #1 FIELD DATA

REACH #1		Begin(m):	0	End(m): 405	Reach Length(m):	405
Quality		Position:	Inlet end 997161			
spawning:	0.67	Instream Cover:	Low; LWD			
rearing:	1	Juv. Abundance:	None observed			
		Canopy:	60%; mixed			
T (C):	6	Limiting Factors:	Fines			
		Feature SiteID:	None			
T @trib:		Total culverted length:	0	m	Est. Drainage Area:	0.35 mi²

Species Expected to Benefit (x =Yes, blank = No)

Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull	
	x		x	x		x	x		

SAMPLE DATA

Spring influences are (see below):	1	Reg. Constant (for 60-d low flow calc.):	1.04
(absent-0, slight-1, mod.-2, pronounced-3)		*Olympic Coastal = 0.49*	
1.) relatively regular, rectangular cross-section, minor variations in depth		*Cascade/E. Puget = 1.04*	
2.) Poorly defined bars and thalweg / very low, flat floodplain		*Columbia/E. WA=0.12*	
3.) bank vegetation along a distinct line, at a small distance above the H2O surface; moss on exposed surfaces of rocks		*Northern/NE Mts.=0.097*	

REACH #1 HABITAT MEASUREMENT

TYPE	L	W	SLW	D	GRAD	B	R	G	S	SUM BRGS
rf	5.4	1.75	2.1	0.08	0.025	0	0	40	60	100
pl	1.5	1.75	1.95	0.23	0	0	0	50	50	100
rf	8.6	1.9	2.25	0.09	0.03	0	0	60	40	100
pl	2.3	2.55	2.55	0.28		0	2	18	80	100
rf	12.7									0
pl	2.5									0
rf	9.9									0
pl	2.6									0
rf	6.8									0
pl	2									0
rf	5.7				0.05					0
										0
										0

REACH #2 FIELD DATA

REACH #2		Begin(m): 405	End(m): 748.9	Reach Length(m):	343.9
Quality		Position:	Confluence with LB NFB trib		
spawning:	0.33	Instream Cover:	Moderate; LWD		
rearing:	1	Juv. Abundance:	None observed		
		Canopy:	70%; mixed		
T (C):	6	Limiting Factors:	Heavy fines		
		Feature SiteID:	930893		
T @trib:		Total culverted length:	12.37	Est. Drainage Area:	0.29 mi²

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): 1

(absent-0, slight-1, mod.-2, pronounced-3)

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 above the H2O surface; moss on exposed surfaces of rocks

Reg. Constant (for 60-d low flow calc.): 1.04

Olympic/Coastal = 0.49

Cascade/E. Puget = 1.04

Columbia/E. WA=0.12

Northern/NE Mts.=0.097

REACH #2 HABITAT MEASUREMENT

TYPE	L	W	SLW	D	GRAD	B	R	G	S	SUM BRGS
rf	2	2.3	2.8	0.09	0.05	0	3	57	40	100
pl	6.7	1.65	1.65	0.35		0	0	20	80	100
rf	2	1.65	1.8	0.12	0.06	0	0	60	40	100
pl	2.6	1.6	1.65	0.31		0	2	13	85	100
rf	1.4									0
pl	3.5									0
rf	1.2									0
pl	1.1									0
rf	11.6									0
pl	4.9									0
rf	7.5									0
pl	5.4									0
rf	4.8									0
pl	3.6									0
rf	1.7									0
										0

REACH #3 FIELD DATA

REACH #3		Begin(m): 748.9	End(m): 1121.3	Reach Length(m):	372.4
Quality		Position:	Inlet end 930893		
spawning:	0	Instream Cover:	Low; LWD		
rearing:	0.67	Juv. Abundance:	None observed		
		Canopy:	80%; mixed		
T (C):	6	Limiting Factors:	No significant gravels (all fines); Low summer flows		
		Feature SiteID:	None		
T @trib:		Total culverted length	0 m	Est. Drainage Area:	0.15 mi²

Species Expected to Benefit (x =Yes, blank = No)

Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull	
			x	x		x	x		

Spring influences are (see below): 1

(absent-0, slight-1, mod.-2, pronounced-3)

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 above the H2O surface; moss on exposed surfaces of rocks

Reg. Constant (for 60-d low flow calc.): 1.04

Olympic/Coastal = 0.49

Cascade/E. Puget = 1.04

Columbia/E. WA=0.12

Northern/NE Mts.=0.097

REACH #3 HABITAT MEASUREMENT

TYPE	L	W	SLW	D	GRAD	B	R	G	S	SUM BRGS
pl	60	4.4	4.4	0.1	0.005	0	0	0	100	100
										0

WDFW - HABITAT PROGRAM
PHYSICAL SURVEY OF POTENTIAL HABITAT (Ver. 4d)

Stream Name:	unnamed	**Date:**	11/24/2009
Tributary To:	Schneider Cr	**Observer(s):**	Bauder;Phinney
WRIA #:	14	**Section surveyed:**	Inlet of 997161 to end of fish use
Sample Frequency:	60m/Reach		1121.3 m upstream
Survey Method:	RSFS	**Filename:**	997161.xls

Summary of Information - Total Stream Length

Total Length Surveyed:	1121.30 m	Tot. Length Culverted:	12.37 m
Total Length Sampled:	180.00 m	Percent of Stream Length	
Percent Sampled:	16.05 %	Culverted:	1.10 %

Measured Pool Area:	2046.36 m²		
Measured Riffle Area	956.24 m²	**Total Spawning Area:**	**372.00 m²**
Measured Rapid Area:	0.00 m²	**Total Rearing Area:**	**2079.44 m²**
Measured Pond Area:	0.00 m²		
Total Measured Stream Area:	**3002.61 m²**		

POOL : RIFFLE : RAPID : POND RATIO (%)

Pool= 68.15 Riffle= 31.85 Rapid= 0.00 Pond= 0.00

PRODUCTION AREA CALCULATIONS

	Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull
Reach 1	0.00	279.20	0.00	683.23	683.23	0.00	683.23	683.23	0.00
Reach 2	0.00	0.00	0.00	444.76	444.76	0.00	444.76	444.76	0.00
Reach 3	0.00	0.00	0.00	951.46	951.46	0.00	951.46	951.46	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	279.20	0.00	2079.44	2079.44	0.00	2079.44	2079.44	0.00

** Spawning habitat used for sockeye, chum and pink, rearing used for all other species.*

ADJUSTED PRODUCTION AREAS

	Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull
Reach 1	0.00	279.20	0.00	604.25	604.25	0.00	604.25	683.23	0.00
Reach 2	0.00	0.00	0.00	393.35	393.35	0.00	393.35	444.76	0.00
Reach 3	0.00	0.00	0.00	841.47	841.47	0.00	841.47	951.46	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	279.20	0.00	1839.06	1839.06	0.00	1839.06	2079.44	0.00

Summary of Information - Reach #1

Starting Position:	Inlet end 997161	Length of Reach Culverted:	0.00 m
Length of Reach:	405.00 m	Percent of Reach Culverted:	0.0 %
Length Sampled:	60.00 m	Estimated drainage area:	0.35 mi²

Canopy:	60%; mixed
Instream Cover:	Low; LWD
Juv. Abundance:	None observed
Limiting Factors:	Fines
Feature Site ID:	None

Spring influences are (see below):	1	Reg. Constant (for 60-d low flow calc.):	1.04
(absent-0, slight-1, mod.-2, pronounced-3)		*Olympic/Coastal = 0.49*	
1.) relatively regular, rectangular cross-section, minor variations in depth		*Cascade/E. Puget = 1.04*	
2.) Poorly defined bars and thalweg / very low, flat floodplain		*Columbia/E. WA=0.12*	
3.) bank vegetation along a distinct line, at a small distance above the H2O surface; moss on exposed surfaces of rocks		*Northern/NE Mts.=0.097*	

Species Expected to Benefit

	Sockeye	Chum	Pink	Coho	SR Cutthroat	Chinook	Steelhead	Res Trout	Bull
	no	yes	no	yes	yes	no	yes	yes	no

Pool : Riffle : Rapid : Pond Ratio (%)

Pool= 20.73 Riffle= 79.27 Rapid= 0.00 Pond= 0.00

Pool L sampled:	10.90 m	Pool Gravel %:	34.00
Riffle L sampled:	49.10 m	Riffle Gravel %:	50.00
Rapid L sampled:	0.00 m	Rapid Gravel %:	0.00
Pond L sampled:	0.00 m	Pond Gravel %:	0.00
Ave. Pool Depth:	0.26 m	Flow:	cfs
Ave. Riffle Depth:	0.085 m	Ave. Grad.:	2.63 %
Ave. Rapid Depth:	0.00 m	Ave. Temp:	6.0 °C
Ave. Pond Depth:	0.00 m	T @ trib.:	0.0 °C

Substrate Composition (%): Boulder= 0.00 Rubble= 0.50 Gravel= 42.00 Sand= 57.50

Wetted (Measured) Area

Ave. Pool Width:	2.15 m	Pool Area (W):	158.19 m²
Ave. Riffle Width:	1.825 m	Riffle Area (W):	604.85 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):	**763.04 m²**

Scour Line Width Area

Ave. Pool W(SLW):	2.25 m	Pool Area (SLW):	165.54 m²
Ave. Riffle W(SLW):	2.18 m	Riffle Area (SLW):	720.85 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):	**886.39 m²**

60-day Low Flow Area

60-day Low Flow:	0.010 cfs	Pool Area (60dLF):	146.62 m²
Low-Flow Depth:	0.071 m	Riffle Area (60dLF):	536.60 m²
Low-Flow Width:	1.52 m	Rapid Area (60dLF):	0.00 m²
		Pond Area (60dLF):	0.00 m²
Pool Factor:	0.89		
Riffle/Rapid Factor:	0.83	**Total Reach Area (60dLF):**	**683.23 m²**
Pond Factor:	1.00		

QUALITY MODIFIERS:

spawning:	0.67	**Spawning Area:**	**279.20 m²**
rearing:	1.00	**Rearing Area:**	**683.23 m²**

Summary of Information - Reach #2

Starting Position:	Confluence with LB NFB trib	Length of Reach Culverted:	12.37 m
Length of Reach:	343.90 m	Percent of Reach Culverted:	3.6 %
Length Sampled:	60.00 m	Estimated drainage area:	0.29 mi²

Canopy:	70%; mixed
Instream Cover:	Moderate; LWD
Juv. Abundance:	None observed
Limiting Factors:	Heavy fines
Feature Site ID:	930893

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= 41.53 Riffle= 58.47 Rapid= 0.00 Pond= 0.00

Pool L sampled:	27.80 m	Pool Gravel %:	16.50
Riffle L sampled:	32.20 m	Riffle Gravel %:	58.50
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:	0.11 m	Ave. Grad.:	5.50 %
Ave. Rapid Depth:	0.00 m	Ave. Temp:	6.0 °C
Ave. Pond Depth:	0.00 m	T @ trib.:	0.0 °C

Substrate Composition (%): Boulder = 0.00 Rubble = 1.25 Gravel = 37.50 Sand = 61.25

Wetted (Measured) Area

Ave. Pool Width:	1.63 m	Pool Area (W):	249.61 m²
Ave. Riffle Width:	1.98 m	Riffle Area (W):	351.39 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):	**601.01 m²**

Scour Line Width Area

Ave. Pool W(SLW):	1.65 m	Pool Area (SLW):	253.45 m²
Ave. Riffle W(SLW):	2.30 m	Riffle Area (SLW):	409.22 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):	**662.67 m²**

60-day Low Flow Area

60-day Low Flow:	0.009 cfs	Pool Area (60dLF):	203.54 m²
Low-Flow Depth:	0.056 m	Riffle Area (60dLF):	241.22 m²
Low-Flow Width:	1.05 m	Rapid Area (60dLF):	0.00 m²
		Pond Area (60dLF):	0.00 m²
Pool Factor	0.72		
Riffle/Rapid Factor:	0.53	**Total Reach Area (60dLF):**	**444.76 m²**
Pond Factor:	1.00		

QUALITY MODIFIERS:

spawning:	0.33	**Spawning Area:**	**92.80 m²**
rearing:	1.00	**Rearing Area:**	**444.76 m²**

Summary of Information - Reach #3

Starting Position:	Inlet end 930893	Length of Reach Culverted:	0.00 m
Length of Reach:	372.40 m	Percent of Reach Culverted:	0.0 %
Length Sampled:	60.00 m	Estimated drainage area:	0.15 mi²

Canopy:	80%; mixed
Instream Cover:	Low; LWD
Juv. Abundance:	None observed
Limiting Factors:	No significant gravels (all fines); Low summer flows
Feature Site ID:	None

Spring influences are (see below):	1	Reg. Constant (for 60-d low flow calc.):	1.04
(absent-0, slight-1, mod.-2, pronounced-3)		*Olympic / Coastal = 0.49*	
1.)Relatively regular, rectangular cross-section, minor variations in depth		*Cascade / E. Puget = 1.04*	
2.)Poorly defined bars and thalweg		*Columbia / E. WA = 0.12*	
3.)Bank vegetation along a distinct line, at a small distance above the H2O distance; moss on exposed surfaces of rocks		*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:	0.70 m	Flow:	cfs
Ave. Riffle Depth:	0.00 m	Ave. Grad.:	0.50 %
Ave. Rapid Depth:	0.00 m	Ave. Temp:	6.0 °C
Ave. Pond Depth:	0.00 m	T @ trib.:	0.0 °C

Substrate Composition (%): Boulder = 0.00 Rubble = 0.00 Gravel = 0.00 Sand = 100.00

Wetted (Measured) Area

Ave. Pool Width:	4.40 m	Pool Area (W)	1638.56 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):	**1638.56 m²**

Scour Line Width Area

Ave. Pool W(SLW):	4.40 m	Pool Area (SLW):	1638.56 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):	**1638.56 m²**

60-day Low Flow Area

60-day Low Flow:	0.004 cfs	Pool Area (60dLF):	1420.09 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):**	**1420.09 m²**
Pond Factor:	1.00		

QUALITY MODIFIERS:

spawning:	0.00	**Spawning Area:**	**0.00 m²**
rearing:	0.67	**Rearing Area:**	**951.46 m²**

WDFW HABITAT PROGRAM - PHYSICAL SURVEY OF POTENTIAL HABITAT
FISH ACCESS CHECK COMMENTS

Stream Name:	unnamed	**Date:**	11/24/2009
Tributary To:	Schneider Cr	**Observer(s):**	Bauder;Phinney
WRIA #:	14	**Section surveyed:**	Outlet of 997161 to confluence with Schneider Cr
Filename:	997161.xls		
		Total Length (m):	207.9

Hip Chain	Comment
0	Begin DS check at outlet end 0.91m PCC RND. **997161.**
9.6	Barbed wire fence at edge of WSDOT right-of-way.
58.5	Inlet end 0.61m PVC RND. **Site 930891.**
68.5	Outlet end **930891.**
90	Live adult chum observed.
149.4	Approximately 0.70m drop between two alders.
207.9	Confluence with Schneider Creek. **End DS check.**
149.4-207.9	Numerous live and dead chum present.

WDFW HABITAT PROGRAM - PHYSICAL SURVEY OF POTENTIAL HABITAT
UPSTREAM SURVEY COMMENTS

Stream Name:	unnamed	**Date:**	11/24/2009
Tributary To:	Schneider Cr	**Observer(s):**	Bauder;Phinney
WRIA #:	14	**Section surveyed:**	Inlet of 997161 to end of fish use
Sample Frequency:	60m/Reach		1121.3 m upstream
Filename:	997161.xls		

Hip Chain	Comment
Reach 1	
0	Begin survey at inlet end 0.91m PCC RND. **WSDOT 997161.**
2.7	RB ditch contribution at US end wingwall. Some cobble in channel, possible bed control.
347	Gradient increases slightly.
351.3	Gradient check = 5%.
405.4	LB confluence, ~20% mainstem flow, too steep, NFB. **End Reach 1.**
Reach 2	
473	LB spring input.
477	LB ephemeral drain.
570	Small bedrock cascade.
619	LB ephemeral drain.
716.2	LB confluence **(Trib A),** >20% mainstem flow, no reach break.
731.2	Large wood in stream creating a 0.24 m drop.
734	Bedrock cascade.
737.2	Outlet end 0.91m PVC RND. **Site 930893.**
748.9	Inlet end **930893. End Reach 2.**
Reach 3	
765	Stream enters forested wetland.
813.3	Braiding in wetland - channel poorly defined.
965	LB spring seep input.
980	Stream leaves evergreen canopy, now primarily young alder.
1039	LB confluence; too small, NFB. Spring source ~20m from mainstem.
1121.3	Several spring sources with no defined channel above. **End of Survey.**

APPENDIX L

Estimate of Potential Low Flow Habitat
60 Day Low Flow Methodology

October 17, 1994

ESTIMATE OF POTENTIAL LOW FLOW HABITAT

Objective

The objective of this study is to estimate, from channel characteristics, measurable throughout the field season, the relative areas of summer low flow rearing habitat in streams across the state.

Method

This method for estimating relative potential aquatic habitat is based on regional estimates of 60-dy low flow per unit watershed area (i.e., cubic feet per second per square mile) combined with channel characteristics measured in the physical survey.

The physical survey distinguishes four geomorphic stream features: riffles, rapids, pools, and ponds. These features are generally categorized into two habitat types: pools (i.e., pools and ponds), and riffles (i.e., all other habitat types). Pools are characterized by low gradients (<1%), reduced flow velocities, and often greater water depths than in surrounding areas. Ponds are pools which have average widths and lengths at least five times the average widths and lengths of pools in the downstream reach. Riffle habitat types are characterized by shallow, swift, turbulent flow over completely or partially submerged obstructions.

Regional stream gage data were used to generate regression equations of the form:

$$Q_{60} = (CA) / 35.3$$

(Eq. 1)

where Q_{60} = 60-day low flow (cubic meters per second),
A = watershed area (square miles), and
C = a regional constant.

From this equation, Q_{60} can be estimated for each stream in the survey. In this preliminary study, Washington was divided into four hydrologic regions: 1) Olympic Peninsula/south coast, 2) Cascade (east Puget Sound), 3) Columbia/Eastern Washington, and 4) Northern/North-eastern mountains. These divisions are based on evaluation of USGS analyses of low flow characteristics of streams in Washington rather than on direct statistical analysis of low flow data. Due to scarcity of 60-day low flow data, regression relationships for the Olympic/south coast and the Northern/north-eastern mountain regions were developed from 7-day low flow data and increased by a factor representing the regional relationship between 60-day low flow and 7-day low flow. The Cascade/east Puget Sound 60-day low flow values were interpolated from 30-day and 90-day low flow data. Regional constants are shown in Table 1.
Table 1. Regional constants for 60-day low flow per square mile of watershed area.

Region	Constant	Standard Error	R^2	Observations
Olympic/coastal	0.49	0.023	0.36	168
Cascade/east Puget Sound	1.04	0.140	0.28	46
Columbia/Eastern Washington	0.12	0.021	0.22	17
Northern/N-E mountains	0.097	0.011	0.22	70

Water surface area at 60-day low flow conditions was used to estimate relative potential habitat. Two hydraulic equations were used to estimate average flow geometry in the riffles:

$$Q = AV, \quad \text{(Eq. 2)}$$

where Q = flow, in cubic meters per second,
A = cross-sectional area of flow, in square meters,
V = average velocity of flow, in meters per second;

and Manning's equation,

$$V = (1/n)\, R^{2/3} S^{1/2}, \quad \text{(Eq. 3)}$$

where n = Manning's roughness factor,
R = the hydraulic radius (in m) = flow area/wetted perimeter,
S = the gradient.

Certain simplifying assumptions were made in order to estimate the low flow riffle area:

1) the riffles are wide in relation to their depth (i.e., width/depth > 10) during the period of measurement and at low flow;

2) the width/depth ratio (W/D) remains constant between the time of the stream survey and summer low-flow conditions,

3) the cross-sectional shape of the riffle bottom is approximately triangular, i.e., the depth increases gradually from the banks to the thalweg so that

$$A = (WD) / 2$$

(Eq. 4)

4) the surface area of rapids changes, in response to changes in flow, by the same factor as that of the riffles;

5) the roughness factor, n, is approximately 0.1 under low-flow conditions.

By combining equations 2, 3, and 4, average 60-day low-flow riffle depth (D_{60}) and width (W_{60}) were calculated as

$$D_{60} = [(0.318\ Q_{60}D_s) / (S^{0.5}W_s)]^{0.375}$$

(Eq. 5)

where D_s = the average riffle depth (in m) measured during the survey,
W_s = the average riffle width (in m) measured during the survey, and

$$W_{60} = (W_s\ D_{60}) / D_s$$

(Eq. 6)

The ratio W_{60}/W_s is the factor used in calculating riffle and rapid surface areas at Q_{60}, i.e.,

$$A_{60}\ (\text{riffle}) = A_s\ (\text{riffle}) * W_{60}/W_s, \text{ and} \quad (\text{Eq. 7})$$
$$A_{60}\ (\text{rapid}) = A_s\ (\text{rapid}) * W_{60}/W_s \quad (\text{Eq. 8}).$$

Pool depth is assumed to change by an amount equal to the change in the riffle depth. Pool area is assumed to change by a factor equal to the square of the ratio of the low-flow depth to the average measured depth, i.e.,

$$A_{60}\ (\text{pool}) = A_s\ (\text{pool})*[D_s(\text{pool})-(D_s-D_{60})/D_s(\text{pool})]^2 \ (\text{Eq. 9}).$$

Pond depth and surface area is assumed to be relatively insensitive to changes in flow. It is suggested that a factor of 1.0 be assigned to pond area, i.e.,

$$A_{60}\ (\text{pond}) = A_s\ (\text{pond}).$$

(Eq. 10)

Discussion

Individual stream systems may vary substantially in their low-flow characteristics from the regional averages developed for use in this habitat estimate. One particularly important aspect of streams which will cause them to deviate from regional low-flow estimates is contributions to base flow by springs; the habitat offered by these streams will be seriously underestimated by this method.

It is suggested that the physical survey of streams include a checklist designed to identify spring-fed systems. Indicators of spring-dominated hydrology include:

1) a relatively regular, rectangular cross-section, with minor variations in depth,

2) very low, flat floodplains, and

3) bank vegetation established along a distinct line, at a small distance above the water surface; moss on the exposed surfaces of rocks in the channel is a strong indicator of spring-fed flow.

The presence of these indicators could be noted in the physical survey on a scale of zero to three as: absent (0), slight (1), moderate (2), and pronounced (3).

The low-flow habitat factors estimated by this method should be increased according to the degree of spring influence, as identified in the physical survey, i.e.,

$$F_{sp} = 1.0 - \frac{(1-F)\ (3-N)}{3}$$

(Eq. 11)

where F_{sp} = the low flow habitat factor, modified for spring influence,
F = the previously calculated low flow habitat factor, and
N = the degree of indicators of spring influence identified during the physical survey.

Thus, where the indicators are identified as pronounced, the habitat factors will be 1.0; where no spring-fed indicators are evident the habitat factors will be as previously calculated.

Several other possibilities exist for the improvement of the estimates yielded by this method. For example, the regional low-flow constants (C) could be improved by subdividing the regions, by the inclusion of a larger number of stream gages, and by considering climatic and watershed factors such as precipitation and elevation.

Additionally, this method assumes that the resistance offered to flow by the streambed is constant. Resistance is represented by the roughness factor, n, in Manning's equation. Manning's n becomes highly variable when the average substrate particle is more than 10% of flow depth. The Manning's n assumed for this analysis (i.e., 0.1) would occur throughout a range of depths and substrate textures, for instance, at an average depth of 1 foot and an average particle size (by weight) of 6.2 inches, at an average depth of 8 inches and an average particle size of 4.5 inches, and at an average depth of 4 inches and an average particle size of 2.5 inches. The effect of assuming this constant value for Manning's n is that the low-flow surface areas of streams with fine-textured, smooth substrates may be overestimated. Thus, the hydraulic calculations could be refined by varying the roughness factor according to the substrate texture and the Q_{60}.