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Streamflow Duration Assessment Method for the Pacific Northwest

EPA 910-K-14-001 | November 2015
www.epa.gov/measurements/streamflow-duration-assessment-method-pacific-northwest

Streamflow Duration Assessment Method for the Pacific Northwest

U.S. Environmental Protection Agency, Region 10

Appropriate Citation: Nadeau, Tracie-Lynn. 2015. Streamflow Duration Assessment Method for the Pacific Northwest. EPA 910-K-14-001, U.S. Environmental Protection Agency, Region 10, Seattle, WA

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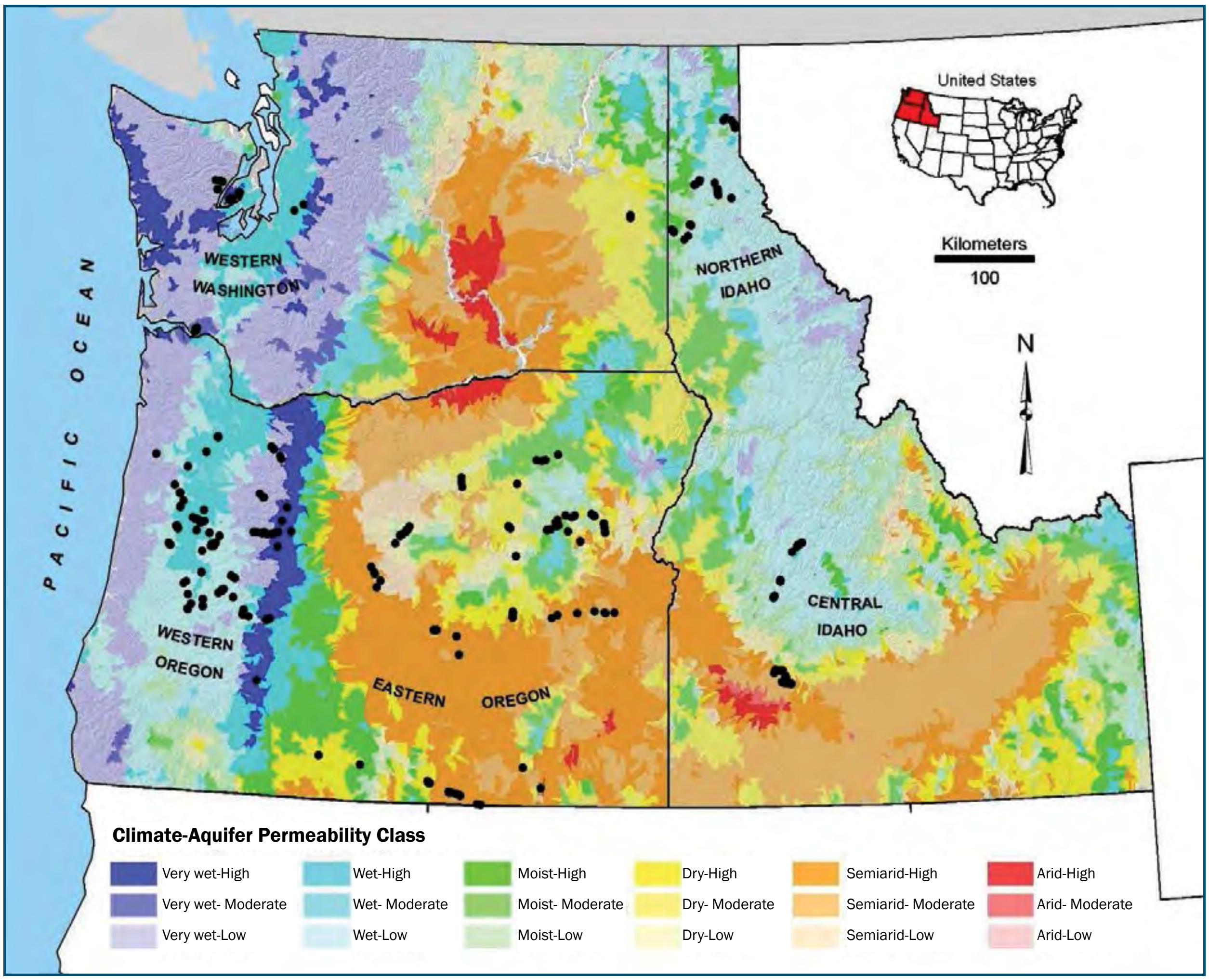
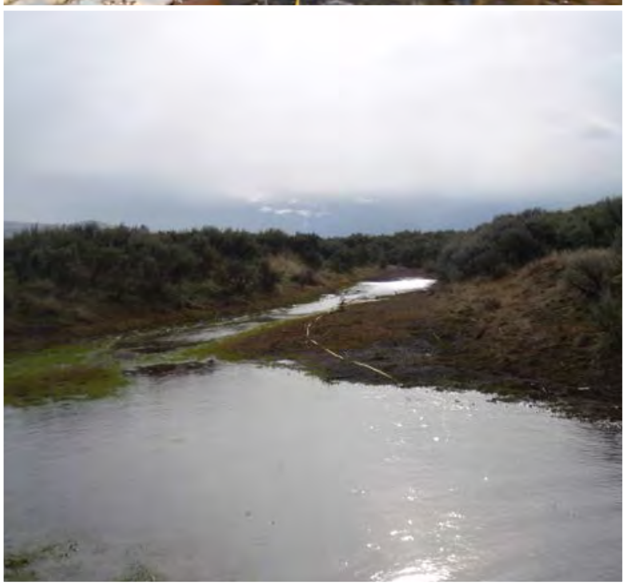


Three-state study area for the Streamflow Duration Assessment Method for the Pacific Northwest. Black dots indicate study stream sites in the five study regions (from Nadeau et al. 2015).



PURPOSE

The purpose of this manual and accompanying field assessment form is to guide natural resource professionals in evaluating the described indicators of streamflow to help distinguish between ephemeral, intermittent and perennial streams. This rapid assessment method has been developed and tested for applicability across Oregon, Idaho, and Washington, from the humid west side of the Cascade Mountains to the dry and semi-arid areas of the Snake River Plain and Basin and Range Province. The current method, substantively the same as the *Streamflow Duration Assessment Method for Oregon* (Nadeau 2011), summarizes the three-state study which supports the application of the method across the Pacific Northwest, and thus replaces the 2011 manual with a regionally consistent manual.

Section 1 contains an introduction to the method, including method development and validation, definitions of key terms, and sources of variability. Section 2 describes the indicators and provides assessment guidance. The final section describes how to draw conclusions based on the assessed indicators of flow.

This method can be used to distinguish between perennial, intermittent, and ephemeral streams, but is primarily designed to distinguish ephemeral streams from intermittent and perennial streams in a single site visit. It provides a scientifically supported, rapid assessment framework to support best professional judgment in a consistent, robust and repeatable way. While use of this method may inform a more robust stream assessment, it was specifically developed for the purpose of determining streamflow duration and does not provide a stand-alone assessment of stream function or condition.

ACKNOWLEDGMENTS

This method was initially developed in Oregon and has benefitted greatly from the input of many, as previously described (Nadeau 2011), on the path to becoming applicable across the Pacific Northwest. It is a data driven method that results from a validation study conducted in Oregon, Idaho, and Washington. A committed group of colleagues helped make the four year validation study (Nadeau et al. 2015) a reality: Jim Wigington, Scott Leibowitz, Ken Fritz, Joe Ebersole, Randy Comeleo (EPA), and Rob Coulombe (CSS-Dynamac). Rob Coulombe and the Dynamac crew—Blake Hatteberg, Lindsey Webb, Shawn Majors, Rachel LovellFord, and Howard Bruner—with their extensive time in the field at 264 study streams in the three-state area, were particularly instrumental in improving the on-the-ground usability of the method. We are grateful to colleagues across the Pacific Northwest who provided local knowledge for study site reconnaissance and/or additional hydrological observations at study streams during the course of the study: John Olson, Jess Jordan, Yvonne Vallette, Linda Storm, Jim Zokan, and Tina Tong.

Celeste Mazzacano, Scott Hoffman Black, and Michele Blackburn of the Xerces Society for Invertebrate Conservation reviewed the literature and current understanding of aquatic macroinvertebrates as indicators of streamflow duration in Oregon, Idaho, and Washington streams (Mazzacano and Black 2008; Blackburn and Mazzacano 2012) to identify the perennial indicators presented in Table 1, as well as produced the associated aquatic macroinvertebrate field guide for use with this method: www.epa.gov/measurements/streamflow-duration-assessment-method-pacific-northwest#documents.

Jess Jordan (U.S. Army Corps of Engineers) and Chris Rombough (Rombough Biological) developed the herpetofauna water-dependent life history stages presented in Table 2. Shannon Hubler (Oregon Department of Environmental Quality) provided data from ODEQ’s statewide stream monitoring database.

With sincere thanks to all,

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Section 1: Introduction

A stream* can be described as a channel containing flowing surface water including:

- *stormflow* – increased streamflow resulting from the relatively rapid runoff of precipitation from the land as interflow (rapid, unsaturated, subsurface flow), overland flow, or saturated flow from surface water tables close to the stream channel, or;
- *baseflow* – flow resulting from ground water entering the stream or sustained melt water from glaciers and snowmelt (observed during long gaps between rainfall events), or;
- a combination of both stormflow and baseflow, and;
- contributions of discharge from upstream tributaries as stormflow or baseflow, if present.

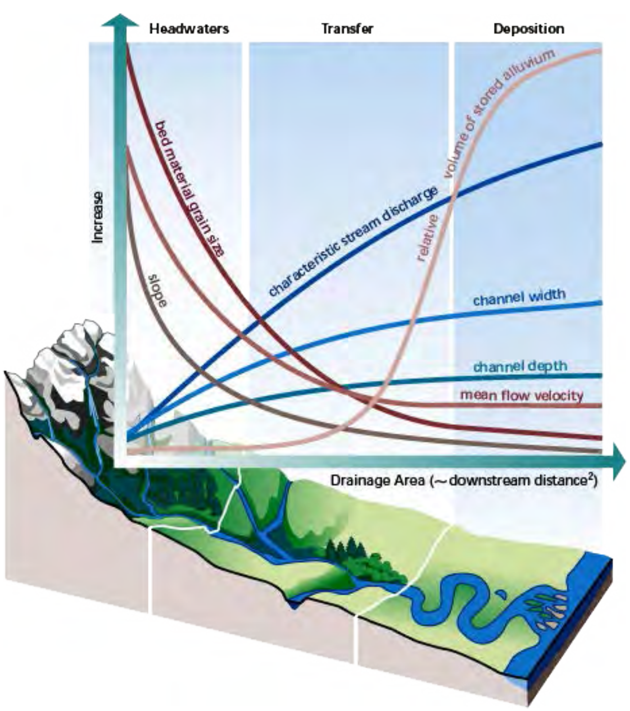
***Note:** For the purposes of this method the descriptor 'stream' is attached to the channel, and applies regardless of whether flow dries up seasonally or otherwise.

Duration, frequency, and timing of streamflow or drying, as well as flow magnitude, are fundamental properties of streams (Poff and Ward 1989; Winter et al. 1998) which can influence the structure and function of stream ecosystems (e.g., Chadwick and Huryn 2007; Fritz et al. 2008b; Austin and Strauss 2011; Datry 2012). Watershed geology, climate, topography, soils, vegetation and human activities can all influence streamflow (Winter et al. 1998; Winter 2007). Water to support streams can originate from numerous sources within a watershed including overland flow from rainfall or snowmelt, shallow subsurface flow through the unsaturated zone, and ground-water discharge (Winter 2007). Streams may be perennial, intermittent or ephemeral. Perennial streams flow year-round during a typical year, receiving appreciable quantities of water from numerous sources but with consistent groundwater inputs required throughout the year (Winter et al. 1998; Winter 2007). In cases where groundwater aquifers are unable to supply sufficient quantities of water, intermittent streams cease to flow during dry periods (Mosley and McKerchar 1993; Rains and Mount 2002; Rains et al. 2006). Ephemeral streams flow only in direct response to precipitation including rainstorms, rain on snow events, or snowmelt. They do not receive appreciable quantities of water from any other source, and their channels are, at all times, above local water tables (Gordon et al. 2004; McDonough et al. 2011).

As a stream flows from its origin, water may be derived primarily from stormflow, baseflow, or some combination of the two. Streams typically continue to accumulate water from stormflow, baseflow and other tributaries as they flow downstream. As streams accumulate flow they commonly transition along a gradient from ephemeral to intermittent and perennial, but sometimes quickly transition from ephemeral to perennial in high gradient systems, or transition from perennial to ephemeral or to total cessation of surface flow. Often these changes are gradual and may not be obvious to the casual observer. There are, however, indicators of streamflow that can be used to characterize the flow duration of a stream along a particular reach as ephemeral, intermittent or perennial. In this manual, duration encompasses the concept of the cumulative time period of flow over the course of a year, which may vary interannually with climate, groundwater withdrawal or streamflow diversion, and other water use patterns. This manual presents an indicator-based method for assessing streamflow duration in the Pacific Northwest.

This method and accompanying assessment form are designed to assist the user in distinguishing between ephemeral, intermittent and perennial streams throughout the Pacific Northwest. Stream systems can be characterized by interactions among hydrologic, geomorphic (physical) and biological processes. These attributes, or dominant processes, vary along the length of a stream related to flow duration (Figure 1). To identify the indicators and apply the information presented in this manual to determine streamflow duration classes of streams, the evaluator should have experience making field observations in streams.

FIGURE 1. Hydrologic and geomorphic characteristics in relation to drainage area (FISRWG 1998)



Method Development and Validation Study

Interim Method

The Streamflow Duration Assessment Method was initially developed for Oregon through best professional judgment (BPJ) and results of a single season field test including more than 170 streams from both the humid and semi-arid sides of the Cascade Range. The Interim Method (Topping et al. 2009) uses ordinal scoring of 21 geomorphic, hydrologic, and biologic stream attributes based on abundance and prominence. Conclusions of streamflow duration in the Interim Method are based on the additive score of the assessed stream attributes compared to threshold values that separate perennial, intermittent and ephemeral classes. In addition, the Interim Method classifies streams as at least intermittent (i.e., intermittent or perennial) based on the presence of Single Indicator measures: fish, or water-dependent life stages of specific herpetological and macroinvertebrate species.

The Interim Method was made available to allow practitioners such as stream ecologists, aquatic ecologists, and hydrologists the opportunity to provide comment on their experiences using the method during a two-year field validation study of the method in Oregon.

Validation Study

This section summarizes relevant validation study conclusions (Nadeau et al. 2015)

Phase I, Oregon

To meet our objectives of developing a rapid streamflow duration assessment method that is consistent, robust, and repeatable, we undertook a two-year field validation study of the Interim Method. The study included 178 streams ranging across the hydrologic settings of Oregon, with an approximately equal distribution of streams from the humid west and semi-arid east side of the Cascade Range, and in the perennial, intermittent, and ephemeral classes. Study design maximized representation of a diversity of hydrologic landscapes, based on a hydrologic classification framework that includes indices of annual climate, seasonality, aquifer permeability, terrain, and soil permeability (Wigington et al. 2013). Method evaluation compared results with actual streamflow duration classes.

The first phase of the study addressed several primary questions: 1) What is the accuracy of the Interim Method? 2) Is it equally applicable in different (wet/dry) seasons? 3) Is it equally applicable in different hydrologic landscapes across the state? 4) Are these 21 stream attributes the most predictive indicators of streamflow? 5) Can results be improved by developing an alternative method (statistical analysis of data)?

The study included both wet and dry season sampling; in the Pacific Northwest, where the delivery of precipitation is generally greatest during the winter months, these correspond to wet winter/spring and dry summer seasons. Supplemental data were also collected at each site, particularly for those indicators that were considered problematic.

The Interim Method agreed with the known streamflow duration class for 62% of Oregon observations. The accuracy rate for distinguishing between ephemeral and 'at least intermittent' (i.e., intermittent or perennial) streams was 81%. The high error rate of the Interim Method as applied in Oregon highlighted the need for an alternative method to more accurately determine streamflow duration. Analyses of the Oregon data found that a subset of the Interim Method and supplemental indicators appeared to have the strongest explanatory power in separating the perennial, intermittent, and ephemeral stream classes. Based on analyses of the Oregon data, the Revised Method was developed. Comprised of five indicators--wetland plants in/near streambed, reach slope, and three aquatic macroinvertebrate indicators, the Revised Method correctly classified 307 of the 356 Oregon observations, which is 86% correct compared with 62% accuracy of the Interim Method. Additionally, accuracy rates for distinguishing between ephemeral and 'at least intermittent' classes (i.e., intermittent or perennial) rose from 81% to 95% with the Revised Method. The Revised Method was significantly more accurate ($p < 0.0001$) than the Interim Method for predicting all three streamflow classes and for 'at least intermittent' accuracy.

The Revised Method subsequently became the basis for the Final *Streamflow Duration Assessment Method for Oregon* (Nadeau 2011), in which the five indicators are evaluated using a decision-tree, similar to using a dichotomous key. Additionally, the presence of certain vertebrate organisms that require the sustained presence of water for their growth and development are included as Single Indicators that a stream has at least intermittent flow.

Phase II, Idaho and Washington

In the second phase, we evaluated the regional applicability of the methods developed in Oregon by testing the Interim and Revised methods on 86 study reaches across a variety of hydrologic landscapes, and stream types, in Washington and Idaho. As in the first phase of the study, study streams were tested in both wet and dry seasons, and method evaluation compared results with actual streamflow duration classes. The Revised Method correctly classified 84% of observations from the three-state study area (see inside front cover map) and distinguished between ephemeral and 'at least intermittent' with 94% accuracy, compared with 62% overall accuracy and 82% 'at least intermittent' accuracy of the Interim (BPJ) Method.

During this phase of the study, we also compared the Revised Method, which was developed from Oregon data alone, with a similar approach (Combined Method) that was based on combined field data from Oregon, Washington, and Idaho. The Combined Method, which required two additional indicators, did not significantly outperform the Revised Method, so we ruled it out as providing an improved on-the-ground streamflow duration assessment method for the Pacific Northwest.

Relevant Conclusions

Based on results of our three-state study the Revised Method, already in use in Oregon, is the method described herein as the *Streamflow Duration Assessment Method for the Pacific Northwest*. This decision-tree method (see Section 3) is based on stream attributes—four biological and one physical—that are measurable, rather than subjective. Developed through statistical analyses of field data, it provides a more simplified approach with significantly higher accuracy than the additive, weighted scale Interim Method.

Because of the diverse hydrology, climatic regimes, and distinct winter-wet and summer-dry seasons of the Pacific Northwest, we also explored the accuracy of the compared methods in different regions, climate classes, and seasons. The current method consistently outperforms the Interim Method in all categories. Performance of the current method does vary somewhat in different hydrological settings and at different times; for instance, it performs better during the spring for semiarid and very wet climate classes, while classification is more accurate during the fall for wet climates. However, overall accuracy for determining 'at least intermittent' status is nearly 90% or greater in all categories.

Examining the accuracy of Single Indicators—organisms that require the sustained presence of water for their growth and development—at all study sites showed that while the absence of Single Indicator measures is not indicative of streamflow duration, their presence is strongly predictive. The presence accuracy[1] for fish was 100%, and that of water dependent herpetological life history stages (Table 2) was 97%. This means that 100% of the time that fish were found at a study stream, the stream was intermittent or perennial, and 97% of the time that the described herpetological organisms (Table 2) were found at a study stream, that stream was likewise at least intermittent. In other words, while the classes of organisms that make up the Single Indicator measures are often not found in streams assessed as perennial or intermittent, when they are found they are a very accurate indication of perennial or intermittent status. This confirms their usefulness as indicators determining a stream is 'at least intermittent.'

Finally, we calculated user accuracies—accuracy of the method when applied by a user in the field—using data from all study reaches. For all stream types—ephemeral, intermittent, and perennial—user accuracies were higher for the *Streamflow Duration Assessment Method for the Pacific Northwest* than for the Interim Method. User accuracy was 92% for the current method in determining the ephemeral class of streams.

1 the number of observations where the indicator group was present and the actual streamflow duration class was at least intermittent, divided by the total number where the indicator was present.

There was also a high level of repeatability between duplicate assessments (n=35), but that may be due, in part, to the level of field crew training in the study.

Relevant Definitions

As used by this method:

Channel is an area that contains flowing water (continuously or not) that is confined by banks and a bed.

Dry Channel is an area confined by banks and a bed that at times contains flowing water, but at the time of assessment does not contain flowing water (it may contain disconnected pools with no sign of connecting flow).

Wet Channel is an area confined by banks and a bed that contains flowing water at the time of assessment (flow may be interstitial).

Ephemeral Stream flows only in direct response to precipitation. Water typically flows only during and shortly after large precipitation events. An ephemeral stream may or may not have a well-defined channel, the streambed is always above the water table, and stormwater runoff is the primary source of water. An ephemeral stream typically lacks biological, hydrological and in some instances physical characteristics commonly associated with the continuous or intermittent conveyance of water.

Groundwater occurs at the subsurface under saturated conditions and contains water that is free to move under the influence of gravity, often horizontally to stream channels when a confining layer blocks downward percolation.

Hyporheic Zone is the zone under and adjacent to the channel where stream water infiltrates, mixes with local and/or regional groundwater, and returns to the stream. The dimensions of the hyporheic zone are controlled by the distribution and characteristics of alluvial deposits and by hydraulic gradients between streams and local groundwater. It may be up to two to three feet deep in small streams, and is the site of both biological and chemical activity associated with stream function.

Intermittent Stream is a channel that contains water for only part of the year, typically during winter and spring when the streambed may be below the water table and/or when snowmelt from surrounding uplands provides sustained flow. The channel may or may not be well-defined. The flow may vary greatly with stormwater runoff. An intermittent stream may lack the biological and hydrological characteristics commonly associated with the continuous conveyance of water.

Normal Precipitation is defined as the 30-year average, provided by National Oceanographic and Atmospheric Administration National Climatic Data Center, computed at the end of each decade. These data are available as annual and monthly means.

Perennial Stream contains water continuously during a year of normal rainfall, often with the streambed located below the water table for most of the year. Groundwater supplies the baseflow for perennial streams, but flow is also supplemented by stormwater runoff and snowmelt. A perennial stream exhibits the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water.

Stream Origin is the point where flow first appears on the land surface with enough force to disturb the substrate creating a lasting sign of flow. Stream origins are often wetlands, springs, seeps or headcuts.

Swales can be wetlands or uplands (when assessed under the USACE 1987 Wetlands Delineation Manual or appropriate Regional supplements) and primarily serve as a vegetated flow path occurring in a slight depression in the landscape but lacking differentiation between bed and bank. Swales often connect uplands to wetlands or streams, connect wetlands together, or connect upstream and downstream reaches of small streams that flow through a colluvial fan or an abrupt change in grade.

Thalweg is the deepest part of a stream channel and the last part of the stream to contain flowing water as a stream dries up. As used in this method, the thalweg comprises the "lowest flow" pathway and typically spans approximately 5 to 20% of the channel width.

Water Table is the surface elevation of the saturated zone below which all interconnected voids are filled with water and at which the pressure is atmospheric, commonly identified as the top of the local (i.e., floodplain) or regional groundwater aquifer.

Considerations When Assessing Indicators of Streamflow

Spatial Variability

Spatial variation in stream indicators occurs within and among stream systems. Sources of variation between stream systems are due primarily to physiographic province (geology and soils) and climate (seasonal patterns of precipitation, snowmelt, and evapotranspiration). For example, riffles and pools result from in-channel structures and these structures can vary between rocks and boulders in the mountains and roots and wood debris in the alluvial valleys. The method was designed to apply to all stream systems within the diverse hydrologic landscape regions ofthe Pacific Northwest.

A substantial amount of variability can also occur along the length of a given stream system. Common sources of variation within a stream system include:

- Longitudinal changes in stream indicators related to increasing duration and volume of flow. As streams gain or lose streamflow, the presence of indicators changes.
- Longitudinal changes due to variables such as channel gradient and valley width, which affect physical processes and thus may directly or indirectly affect indicators.
- Temporal variation of flow related to seasonal precipitation and evapotranspiration pattern. For instance, in western Oregon the strong seasonal rainfall pattern - several months of wet weather followed by several months of dry weather - supports the establishment of intermittent streams. Due to these long periods of rain many of the intermittent streams in western Oregon may carry close to the yearly discharge associated with a perennial stream of the same size.
- Transitions in land use, for instance from commercial forest to pasture/grazing, from pasture grazing to cultivated farm, or cultivated farm to an urban setting.
- The size of the stream; streams develop different channel dimensions due to differences in flow magnitude, landscape position, land use history, and other factors.

Reach Selection

This manual lays out a method for assessing indicators of streamflow duration. However, flow characteristics often vary along the length of a stream, resulting in gradual transitions in flow duration. Recognizing that in many streams flow duration exists on a continuum, choosing the reach on which to conduct an assessment can influence the resulting conclusion about flow duration.

Assessments should be made for a representative reach, rather than at one point of a stream. **A representative reach for stream assessments is equivalent to 35 - 40 channel widths of the stream** (Peck et al. 2006). Reach length is measured along the thalweg. For narrow streams, the length of the assessment reach should be a minimum of 30 meters. If the assessment reach is near a culvert or road crossing, the assessment reach should begin a minimum of 10 meters from the culvert or road crossing feature.

Assessments should begin by first walking the length of the channel, to the extent feasible, from the stream origin to the downstream confluence with a larger stream. This initial review of the site allows the evaluator to examine the overall form of the channel, landscape, and parent material, and variation within these attributes as the channel develops or disappears upstream and downstream. We recommend walking alongside, rather than in, the channel for the initial review to avoid unnecessary disturbance to the stream and maximize the opportunity to observe single indicator organisms (i.e., fish and herpetological species). Walking the channel also allows the assessor to observe characteristics of the watershed such as land use and sources of flow (e.g., stormwater pipes, springs, seeps, and upstream tributaries). Once these observations are made, the assessor can identify the areas along the stream channel where these various sources (stormflow, tributaries or groundwater) or sinks (alluvial fans, abrupt change in bed slope, etc.) of water may cause abrupt changes in flow duration. Similarly, the assessor can identify if the stream segment in question is generally uniform or might best be assessed as two or more distinct reaches.

For some purposes (e.g., regulatory) the reach in question will often be predetermined by property ownership or proposed activities; the above process for assessing the stream should be followed to the extent possible, and if the reach in question is generally uniform one assessment is appropriate. If the reach in question is not uniform, two or more assessments are recommended to fully describe the changes along the reach. Regardless of the number of reaches assessed, decisions should be made in conjunction with best professional judgment to reach a conclusion on flow duration as ephemeral, intermittent, or perennial.

Recent Precipitation

The rate and duration of flow in stream channels is influenced by climate and by recent weather. Recent rainfall can influence the presence of indicators. Evaluators should note recent rainfall events on the assessment form, and consider the timing of field evaluations in assessing the applicability of individual indicators.

Ditches and Modified Natural Streams

This method can be used, in combination with best professional judgment, to assess the flow duration of natural streams, modified natural streams, and ditches dug in wetlands or uplands.

When assessing a reach that is a ditch or modified natural stream, it is important to walk the entire reach and locate the inflow point or origin as well as the downstream terminus of flow (most often a confluence with another channel). Similarly, any disturbance or modifications to the stream channel should be noted on the assessment form, especially if it affects applicability of assessment indicators. For highly modified streams, an alternative assessment method may be necessary to identify flow duration. Visiting the site multiple times or conducting hydrologic monitoring may also be necessary. **For all assessments, disturbances or modifications to the stream or its catchment that may affect the presence of the streamflow duration indicators should be noted.**

Disturbed or Altered Streams

Assessors should be alert for natural or human-induced disturbances that affect streamflow duration and/or the presence of indicators. Streamflow duration can be directly affected by flow diversions, urbanization and stormwater management, septic inflows, agricultural and irrigation practices, vegetation management, or other activities. The presence of indicators can be affected by changes in streamflow, and can also be affected by disturbances that may not substantially affect streamflow (for instance, grading, grazing, recent fire, beaver activity, riparian management, culvert installation, and bank stabilization). **Such disturbances should be described in the "Notes" section of the field assessment form.** Similarly, natural sources of variation should also be noted such as fractured bedrock, volcanic parent material, recent or large relic colluvial activity (landslides or debris flows), and drought or unusually high precipitation.

Urbanized and impaired streams experiencing multiple stressors may be poor in biologic species, raising concerns about the effective application of this method in those situations given the importance of macroinvertebrate indicators in drawing conclusions. A query of the Oregon Department of Environmental Quality's statewide monitoring data of primarily perennial streams, which includes the most impaired streams in the state, indicated that of more than 2000 macroinvertebrate samples collected, all had at least one mayfly (Ephemeroptera) individual. Additionally, only 37 samples had less than 6 mayfly individuals; these low counts could be due to very high levels of disturbance or sampling error.[2] Based on these data, this method should be widely applicable, except in extreme instances of disturbance.

2 Shannon Hubler, Oregon Department of Environmental Quality, June 2011

Section 2: Conducting Field Assessments

Suggested Field Equipment

- This manual, associated assessment forms, and an all-weather notebook.
- Global Positioning System (GPS) – used to identify the boundaries of the reach assessed.
- Clinometer – used to measure channel slope.[3]
- Tape measure – for measuring reach width and length.
- Kicknet or small net and tray – used to sample aquatic insects and amphibians.
- Hand lens – to assist with macroinvertebrate and plant identification.
- Camera – used to photograph and document site features.
- Polarized sun glasses – for eliminating surface glare when looking for fish, amphibians, and macroinvertebrates.
- Shovel, rock hammer, pick or other digging tool – to facilitate hydrological observations/determination of hyporheic flow.
- Macroinvertebrate field guides (e.g., *Macroinvertebrate Indicators of Streamflow Duration for the Pacific Northwest: Companion Field Guide*[4], Blackburn and Mazzacano, 2012; *Stream Insects of the Pacific Northwest*, Edwards, 2008; *Macroinvertebrates of the Pacific Northwest*, Adams and Vaughan, 2003).
- Hydrophytic plant identification guides (e.g., *Wetland Plants of Oregon and Washington*, Guard, 1995; *A Field Guide to Common Wetland Plants of Western Washington and Northwest Oregon*, Cooke, 1997) and current National Wetland Plant List for indicator status.[5]
- Herpetological field guides (e.g., *Amphibians of Oregon, Washington and British Columbia*, Corkran and Thoms, 1996; *A Field Guide to Western Reptiles and Amphibians*, Stebbins, 2003).

3 Channel slope can also be determined from topographic maps or surveys.

4 Developed for use with this method, available at: http://www.epa.gov/region10/pdf/water/sdam/macroinvertebrate_field_guide.pdf

5 Available at: http://rsgisias.crrel.usace.army.mil/NWPL/

General Guidance for Completing the Field Assessment Form

The Streamflow Duration Assessment Method for the Pacific Northwest relies upon the assessment of five indicators of flow duration and on the assessor's understanding of the site. As with wetland delineation, for best results we recommend that the method be applied during the growing season. As described in the *Ditches and Modified Natural Streams* section above, be aware that modifications to the site or areas upstream of the site may affect the presence of the indicators. Similarly, natural variation such as interannual variation in precipitation can affect the presence of the indicators used in this method. **Therefore, it is important to accurately complete the entire field assessment form, including information for date, project, evaluator, waterway name and location, recent precipitation, observed hydrologic status, and channel width.**

If the stream does not have a defined channel (i.e., bed and banks are not apparent), estimate the width of the flow path and describe in the "Additional Notes" section. Any other relevant observations should also be recorded in the "Additional Notes" section of the form. These may include the local geology, runoff rates, hydrologic unit codes, evidence of stream modifications or hydrologic alterations upstream of the assessment area (e.g., dams, diversions, stormwater discharge), and recent land clearing activities upstream. All pertinent observations should be recorded on the form, including a clear and repeatable way of identifying the boundaries of the reach being assessed and the reasons for choosing those boundaries.

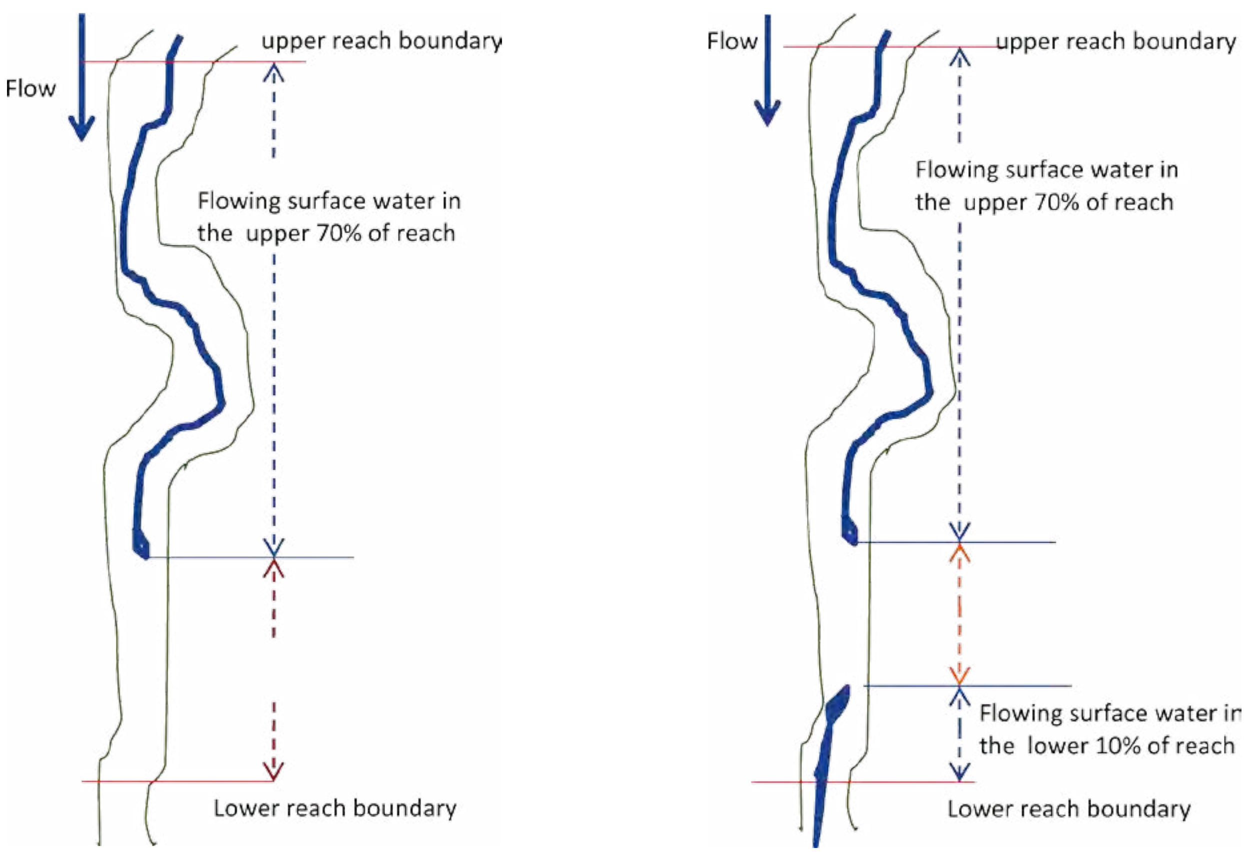
Observed Hydrology

Observed hydrology in the assessment reach informs determination of streamflow duration. The field evaluator should record hydrological observations describing percentage of assessment reach with surface flow, percentage of reach with any flow (surface or hyporheic), and number of pools in the reach in the designated area of the assessment form.

Stream reach flow

- Observe the stream for the entire length of the assessment reach.
- Visually estimate the percentage of the reach length that has flowing surface water.
- Estimate the percentage of the reach length that has flowing surface water or sub-surface (hyporheic) flow (see below).
- If there is uncertainty about how to best characterize a particular assessment reach, specific observations should be described on the assessment form, using diagrams or pictures in support of observations.

FIGURE 2. Examples of recording hydrological observations (figure: R. Coulombe)



2A:
Recorded observation
% of reach with surface flow = 70%
% of reach with any flow = 70%
isolated pools = 0

2B:
Recorded observation
% of reach with surface flow = 80%
% of reach with any flow = 100%
isolated pools = 0

Figure 2C: There is pooling (above left) near the bottom of the study reach; surface water is flowing into this area, but there is none flowing out and there is no sign of flowing water below the pooled area (above right).

Recorded observation
% reach with surface flow = 90% (no observed surface flow along the lowest 10% of the reach)
% reach with any flow =90% (there was no evidence of hyporheic flow below the pooled area or immediately below the reach)

Figure 2D: There is NO evidence of flowing water into or out of this long pool; yellow lines are the assessment reach boundaries.

Recorded observation
% of reach with surface flow = 0%
% of reach with any flow = 0%
# of pools = 1
Observation comment – "One long stagnant pool covering most of the reach."

Hyporheic flow

Because it occurs below the surface of the streambed, hyporheic flow is not easily observed. However, there are some observable signs of the presence of hyporheic flow, including:

- Flowing surface water disappearing into alluvium deposits, and reappearing downstream. This is common when there is a large, recent alluvium deposit created by a downed log or other grade-control structure.
- Water flowing out of the streambed (alluvium) and into isolated pools.
- Flowing water below the surface of the streambed, observed by moving streambed rocks or digging a small hole in the streambed.
- At sites where the observed surface flow is less than 100%, look for evidence of hyporheic flow and use best professional judgment in entering observations on the data form. Figure 2 (A – D) provides examples of how to record hydrological observations.

Indicators of Streamflow Duration

Identification of stream type is accomplished by evaluating five indicators of streamflow duration, which are then considered sequentially using a decision-tree. Natural disturbances such as recent landslides and wildfires could mask the presence of some indicators. Similarly, human modifications to streams, such as toxic pollution or cement lined channels, could also preclude some indicators from forming. These situations should be explained in the "Notes" section of the assessment form.

Indicator assessment is based on direct observation and should not include predictions of what could or should be present. Disturbances and modifications to the stream should be described in the "Notes" section of the assessment form and taken into consideration when drawing conclusions from the information collected. It is also important to explain the rationale behind conclusions reached, and when necessary that rationale should be supported with photos and other documentation of the reach condition and any disturbances or modifications that were taken into consideration. Stream reaches are categorized as perennial, intermittent, or ephemeral on the basis of five indicators. To apply this method, all indicators should first be evaluated, and the field assessment form (Appendix B) completed. The indicators are then considered sequentially, similar to using a dichotomous key (see *Drawing Conclusions*). The answers to each step of the key determine the relevant indicator for the next step.

Macroinvertebrate Indicators (1 - 3)

Many macroinvertebrates require the presence of water, and in many cases flowing water, for their growth and development. Such macroinvertebrates are good indicators of streamflow duration because they require aquatic habitat to complete specific life stages. For example, clams cannot survive outside of water, in contrast to some stoneflies or alderflies that resist desiccation in some seasons of the year by burrowing into the hyporheic zone. Some macroinvertebrates can survive short periods of drying in damp soils below the surface, or in egg or larval stages resistant to drying. Others are quick to colonize temporary water and complete the aquatic portion of their life cycle during the wettest part of the year when sustained flows are most likely.

The three macroinvertebrate indicators used here are assessed within the defined reach using a single search. The assessment for all three macroinvertebrate indicators requires a minimum 15 minute search time to sample the range of habitats present, including: water under overhanging banks or roots, in pools and riffles, accumulations of organic debris (e.g., leaves), woody debris, and the substrate (pick up rocks and loose gravel, also look for empty clam shells washed up on the bank in the coarse sand).

A kicknet or D-frame net and a hand lens are required to collect and identify specimens. Begin sampling at the most downstream point in the assessment reach and move upstream to each new sampling site. Place the kicknet perpendicular against the streambed and stir the substrate upstream of the net for a minimum of one minute, empty contents of the net into a white tray with fresh water for counting and identification. Many individuals will appear the same until seen against a contrasted

Figure 3: Example of caddisfly casings: A) the Limnephilidae family, and B) abundant casings from an intermittent stream in the Ochoco Mountains, central Oregon.

color background, and some bivalves and other macroinvertebrates can be pea-sized or smaller. Sweeping grass and shrubs in the riparian zone immediately adjacent to the active channel with a funnel-shaped insect net may collect emergent aquatic insects such as stoneflies or caddisflies.

Dry channels: The reach should first be walked to ascertain whether it is completely dry, or if areas of standing water where aquatic macroinvertebrates may collect remain. Focus the search on areas of likely refuge such as any remaining pools or areas of moist substrate for living macroinvertebrates, the sandy channel margins for mussel and aquatic snail shells, and under cobbles and other larger bed materials for caddisfly casings. Casings of emergent mayflies or stoneflies may be observed on dry cobbles or on stream-side vegetation. In summary, we recommend a sampling methodology consistent to that recommended by the Xerces Society report on using aquatic macroinvertebrates as indicators of streamflow duration (Mazzacano and Black 2008).

Searching is complete when:

- at least 6 samples have been collected across the range of habitat types and a minimum of 15 minutes of effort expended (not including specimen identification time), or;
- all available habitat in the assessment reach has been completely searched in less than 15 minutes. In dry stream channels with little bed/bank representation and little habitat diversity, a search may be completed in less than 15 minutes.

The 15 minute estimate for searching **does not** reflect time spent on identifying individuals, rather it is wholly focused on the searching and gathering effort. It is important to complete the search for macroinvertebrates, as described above, prior to identifying taxa necessary to evaluate the three indicators. The data sheet includes an area for noting observed macroinvertebrates.

Macroinvertebrate identification:

Macroinvertebrate Indicators of Streamflow Duration for the Pacific Northwest: Companion Field Guide (Blackburn and Mazzacano 2012) developed specifically for use with this method provides a useful, compact field guide for identification of aquatic macroinvertebrates, including as indicators of streamflow duration in Pacific Northwest streams. It is available at: http://www.epa.gov/region10/pdf/water/sdam/macroinvertebrate_field_guide

Notes:

These indicators do not differentiate between live organisms and shells, casings, and exuviae (i.e., the external coverings of larvae and nymphs). In other words, mussel shells are treated the same as live mussels, and caddisfly cases are treated the same as live caddisflies (Figure 3).

The assessment is based only on what is observed, not on what would be predicted to occur if the channel were wet, or in the absence of disturbances or modifications. Disturbances and modifications should be described in the "Notes" section of the data form and taken into account when drawing conclusions.

1. *Presence of Aquatic Macroinvertebrates*

Are there aquatic macroinvertebrates in the assessment reach? If at least one macroinvertebrate (or macroinvertebrate shell, casing, or exuviae) is present, the answer is "yes." *

This indicator includes the range of macroinvertebrates typically associated with stream habitats including: Coleoptera (aquatic beetles), Diptera (true flies), Ephemeroptera (mayflies), Megaloptera (dobsonflies and alderflies), Mollusca (snails and clams), Odonata (dragonflies and damselflies), Plecoptera (stoneflies), Trichoptera (caddisflies), and Astacoidea (crayfish).

*Exception: If the ONLY macroinvertebrate present is Culicidae (mosquito) larvae/pupae, which is an ephemeral indicator taxon (Mazzacano and Black 2008), the answer is "no."

2. *Presence of 6 or More Ephemeroptera*

Are 6 or more individuals of the Order Ephemeroptera present in the assessment reach? If at least six Ephemeroptera are present, the answer is "yes."

Ephemeroptera (mayflies) are present in many stream systems. Adults are short-lived and are commonly observed in swarms over streams. Immature mayflies are aquatic and have the following characteristics:

- Short and bristle-like antenna;
- Four to nine pairs of leaf-like or fan-like gills usually visible along the sides of the abdomen;
- Three (rarely two) long filaments at rear of abdomen.

3. *Presence of Perennial Indicator Taxa*

Are there perennial indicator taxa in the assessment reach? If at least one individual (or macroinvertebrate shell, casing, or exuviae) of such taxa is present, the answer is "yes."

Certain macroinvertebrate taxa are associated with the prolonged presence of water. Based on a literature review and synthesis completed by the Xerces Society for Invertebrate Conservation (Mazzacano and Black 2008; Blackburn and Mazzacano

2012)[6], several taxa and lifestages of macroinvertebrates occurring in Pacific Northwest streams have been identified as “Perennial Indicators” (Table 1).

6 Available at: http://www.xerces.org/macroinvertebrate-streamflow-indicators/

Table 1: Perennial Macroinvertebrate Indicator Taxa and Life Stages

Any life stage of:

- Pleuroceridae, Ancylidae, Hydrobiidae (Juga spp., freshwater limpets, pebble snails)
- Margaritiferidae, Unionidae (freshwater mussels)

Larvae/pupae of:

- Rhyacophilidae (freeliving caddisfly)
- Philopotamidae (finger-net caddisfly)
- Hydropsychidae (net-spinning caddisfly)
- Glossosomatidae (saddle case-maker caddisfly)

Nymphs of:

- Pteronarcyidae (giant stonefly)
- Perlidae (golden stonefly)
- Larvae of:
- Elmidae (riffle beetle)
- Psephenidae (water penny)
- Corydalidae (dobsonflies, fishflies)

Larvae/nymphs of:

- Gomphidae (clubtail dragonfly)
- Cordulegastridae (biddies)
- Calopterygidae (broad-winged damselflies)

Additional Indicators (4 and 5)

4. *Wetland Plants In or Near Streambed*

Within the assessment channel, and within one-half channel width of the stream on either bank, are there plants with a wetland indicator status of FACW or OBL, or is there submerged aquatic vegetation present? If so, the answer is “yes.”

The U.S. Army Corps of Engineers (USACE) wetland delineation procedure[7] uses a plant species classification system which identifies hydrophytic plants. Likewise, the presence of hydrophytic plants can be used as an indicator of the duration of soil saturation in or near stream channels. Intermittent and perennial streams will often have obligate wetland (OBL) and facultative wetland (FACW) plants or submerged aquatic vegetation (SAV) growing in or immediately adjacent to the streambed. SAV grows completely underwater.

To determine the wetland indicator status of a plant, consult the National Wetland Plant List (NWPL). The NWPL, formerly called the National List of Plant Species that Occur in Wetlands, was revised by the USACE, U.S. Fish and Wildlife Service, USEPA, and the Natural Resource Conservation Service in 2013, and is available at: http://rsgisias.crrelusace.army.mil/NWPL/.

The wetland plant indicator is assessed based on the ***single*** most hydrophytic wetland plant found in or within one-half channel width of the assessed reach, even if that plant is not a dominant species.

7 http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf

Notes:

- Abundance and prevalence throughout the reach is not a factor in determining this indicator.
- While it is sometimes most convenient to take plant samples off-site for identification at a later date, please note that several aquatic plant species are protected by state and federal laws.

5. Slope

What is the 'straight line' slope, as measured with a clinometer, from the beginning of the reach to the end of the reach? Is it greater than or equal to 10.5%? To 16%?

Channel slope is measured as percent slope between the lower and upper extent of the assessment reach. This is most easily accomplished by a two-person team, with one individual standing in the thalweg at the downstream extent of the reach and, using a clinometer, sighting a location at eye-level at the upper extent of the reach. (e.g., if team members are of the same height, one individual standing in the thalweg at the lower end of the reach would 'site' the eyes of the crew member standing in the thalweg at the upper end of the reach).

This measurement requires direct line-of-site between the lower and upper ends of the reach. If direct line-of-site from the bottom to top of the reach is not possible, the slope of the longest representative portion of the reach should be 'line-of-site' evaluated.

Note: This measurement is not necessarily the same as the 'average water-surface slope' which is often evaluated as part of stream ecological assessments including U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) (Peck et al. 2006) and Oregon Department of Fish and Wildlife's Aquatic Inventory (Moore et al. 2006).

Ancillary Information

The presence of these features should be noted and briefly described, if applicable, as indicated on the assessment form.

Riparian Corridor: Is there a distinct change in vegetation between the surrounding uplands and the riparian zone, or corridor, along the stream channel?

Intermittent and perennial streams often support riparian areas that contrast markedly with adjacent upland plant communities. A distinct change in vegetation between the surrounding lands and the riparian area (top of bank and adjacent areas) may indicate the presence of seasonal moisture.

Erosion and Deposition: Does the channel show evidence of fluvial erosion in the form of undercut banks, scour marks, channel downcutting, or other features of channel incision? Are there depositional features such as bars or recent deposits of materials in the stream channel?

Undercut banks and scour marks are the most common signs of fluvial erosion for streams in a floodplain system. In steeper landscapes, channel downcutting and incision may occur. Alluvium may be deposited as sand, silt, gravel and cobble. Sometimes there may be depositional features along the side of the channel or on the lee side of obstructions in the channel (e.g., in the hydraulic shadow of logs, boulders, etc.). Erosion and deposition processes differ between bedrock and alluvial channels; note if the streambed consists primarily of bedrock.

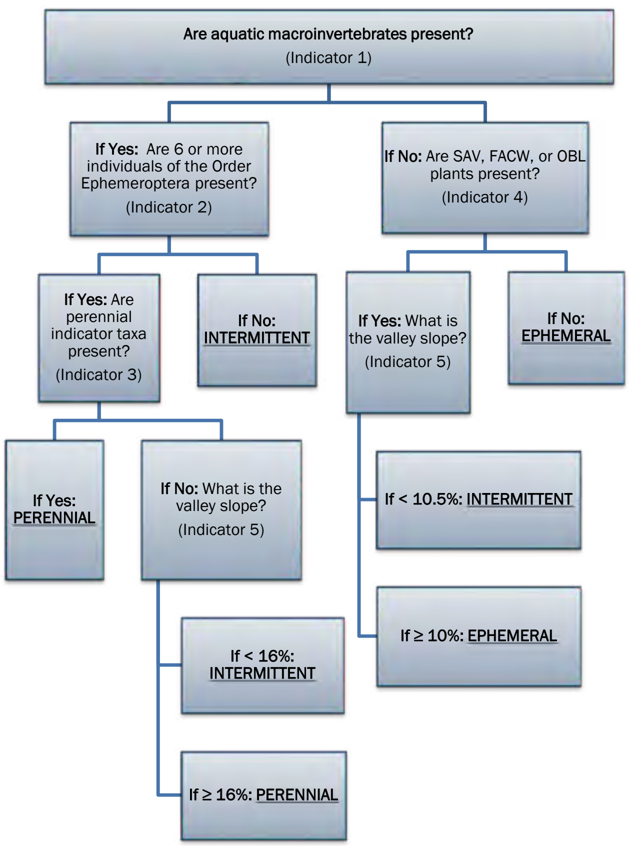
Floodplain connectivity: Is there an active floodplain at the bankfull elevation?

A floodplain is a level area near a stream channel, constructed by the stream and overflowed during moderate flow events if there is still connectivity. An active floodplain (at current bankfull elevation, such that it is inundated on an approximate 2-year recurrence interval) shows characteristics such as drift lines, sediment and debris deposits on the surface or surrounding plants, or flattening of vegetation. The floodplain of incised streams may be restricted to within the channel itself and the previous floodplain (now a terrace) may be inundated rarely or infrequently, if at all.

Section 3: Drawing Conclusions

Results of the field evaluation, applied to the assessment decision-tree (Figure 4; also included on the field assessment form), are used to determine whether the assessed stream has perennial, intermittent, or ephemeral streamflow.

Figure 4: Decision tree for drawing conclusions from assessed indicators



In addition, the method indicates a stream is at least intermittent when either of the two following criteria, for the presence of fish or for the presence of specific herpetological species, is met:

1. One or more fish are found in the assessment reach.*

Fish are an obvious indicator of flow presence and duration. Fluctuating water levels of intermittent and ephemeral streams provide unstable and stressful habitat conditions for some fish communities. However, the strongly seasonal precipitation pattern in the Pacific Northwest means intermittent streams may flow continuously for several months; thus, some native fish species have evolved to use intermittent streams for significant portions of their lifespan (e.g., Wigington et al. 2006).

When looking for fish, all available habitats should be searched, including pools, riffles, root clumps, and other obstructions. In small streams, the majority of fish species usually inhabit pools and runs. Also, fish will seek cover if disturbed, so we recommend checking several areas along the sampling reach, especially underneath undercut banks and other places likely to provide cover.

***Exception:** Non-native fish, with the exception of mosquito fish (*Gambusia spp.*) that has been placed as a vector control, are also included in the assessment. If *Gambusia spp.* is encountered as the only fish species present, its placement as a vector control at the site must be documented, along with an explanation of why the single indicator ('presence of fish') conclusion does not apply.

2. One or more individuals of an amphibian or snake life stage (adult, juvenile, larva, or eggs) identified as obligate or facultative wet (Table 2) are present in the assessment reach.

Amphibians, by definition, are associated with aquatic habitats, and some amphibians require aquatic habitat for much or all of their lives. In the Pacific Northwest, there are likewise three snake species that require aquatic habitat for significant portions of their life cycle. This indicator focuses on the life history stages of salamanders, frogs, toads, and snake species that require aquatic habitat by indicating life history stages for these species as facultative (FAC), facultative wet (FACW), or obligate (OBL).[8]

This indicator is assessed using a minimum 20 minute search time, within one channel width from the top of both stream banks, to sample the range of habitats present This search can be conducted concurrently with the macroinvertebrate search (Indicators 1 – 3) for greatest efficiency. Various life stages of frogs and salamanders can be found under rocks, on stream banks and on the bottom of the stream channel. They may also appear in benthic samples. Using kicknets or smaller nets and light colored tubs for

8 The designations "FAC", "FACW", and "OBL" are based on a review of the scientific literature and current understanding of the life history stages of these herpetological species.

Table 2: Water-dependent life stages of amphibians and snakes of the Pacific Northwest. OBL - obligate, requires surface or hyporheic water; FACW – facultative wet, strong preference for surface or hyporheic water; FAC – facultative, uses but does not depend on surface or hyporheic water. These designations are based on a review of the scientific literature and current understanding of the life history stages of these herpetological species.

Species	Common Name	Water-Dependent Life Stages			
		Eggs	Larva / Tadpole	Juvenile	Adult
Aquatic Salamanders					
Ambystoma gracile	Northwest Salamander	OBL	OBL	FACW	FACW
Ambystoma macrodactylum	Long-toed Salamander	OBL	OBL	FACW	FACW
Ambystoma tigrinum	Tiger Salamander (rare)	OBL	OBL	FACW	FACW
Taricha granulosa	Roughskin Newt	OBL	OBL	FAC	FAC
Dicamptodon copei	Cope's Giant Salamander	OBL	OBL	OBL	OBL
Dicamptodon tenebrosus	Pacific Giant Salamander	OBL	OBL	OBL	FACW
Rhyacotriton spp.	Torrent Salamanders (rare)	OBL	OBL	OBL	OBL
Frogs and Toads					
Ascaphus truei	Tailed Frog	OBL	OBL	OBL	OBL
Spea intermontana	Great Basin Spadefoot	OBL	OBL	FAC	FAC
Bufo boreas	Western Toad	OBL	OBL	FAC	FAC
Bufo woodhousii	Woodhouse's Toad	OBL	OBL	FAC	FAC
Pseudacris regilla	Pacific Treefrog	OBL	OBL	FACW	FAC
Rana aurora	Red-Legged Frog	OBL	OBL	FACW	FACW
Rana boylii	Foothill Yellow-Legged Frog	OBL	OBL	OBL	OBL
Rana cascadae	Cascades Frog	OBL	OBL	FACW	FACW
Rana catesbeiana	Bullfrog	OBL	OBL	FACW	FACW
Rana pretiosa	Oregon Spotted Frog	OBL	OBL	OBL	OBL
Rana luteiventris	Columbia Spotted Frog	OBL	OBL	OBL	OBL
Snakes					
Thamnophis atratus	Western Aquatic Garter Snake (SW Oregon)			OBL	OBL
Thamnophis elegans	Wandering Garter Snake			FACW	FACW
Thamnophis sirtalis	Common Garter Snake			FACW	FACW

specimen collection and identification is recommended. Certain frogs and tadpoles, as well as adult and larval salamanders, typically inhabit the shallow, slower moving waters of stream pools and near the sides of banks.

Amphibians of Oregon, Washington, and British Columbia (Corkran and Thoms 1996) and *A Field Guide to Western Reptiles and Amphibians* (Stebbins 2003) are useful field guides for identifying amphibians of the Pacific Northwest.

Note: Vertebrates must be identified at the assessment site, and left at the site following identification. We recommend that a series of photographs be taken of any species in question to allow further identification to be done off-site, if necessary. Please note that several animal species, including fish and amphibian species, are protected by state and federal laws.

Additional considerations

If the stream does not have a bed and banks, is covered with wetland plant species, and/or indicators cannot be assessed, it may be more appropriate to consider the reach as a swale, wetland, or upland.

As discussed in the introductory sections, if the channel does not meet the decision-tree or single indicator criteria and the evaluator believes the channel to be perennial or intermittent, the evidence supporting this assertion should be clearly described on the assessment form. This may occur in highly polluted or recently manipulated streams; in those cases, the indicators that could potentially be there were it not for the pollution/manipulation should be described in the “Additional Notes” section of the field form.

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Appendix B: Streamflow Duration Field Assessment Form

Project # / Name	Assessor
Address	Date
Waterway Name	Coordinates at downstream end (ddd.mm.ss) Lat. N
Reach Boundaries	Long. W

Precipitation w/in 48 hours (cm)	Channel Width (m)	☐ Disturbed Site / Difficult Situation (Describe in “Notes”)

Observed Hydrology

% of reach w/observed surface flow_______

% of reach w/any flow (surface or hyporheic) _______

# of pools observed_______

Observations

Observed Wetland Plants (and indicator status):

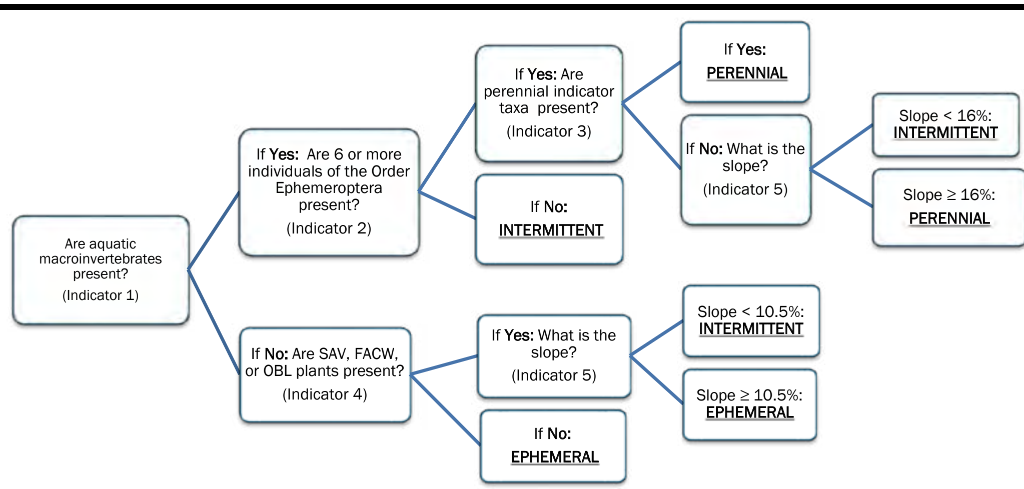
Observed Macroinvertebrates:

Taxon	Indicator Status	Ephemeroptera?	# of Individuals

Indicators

1. Are aquatic macroinvertebrates present?	☐ Yes	☐ No
2. Are 6 or more individuals of the Order Ephemeroptera present?	☐ Yes	☐ No
3. Are perennial indicator taxa present? (refer to Table 1)	☐ Yes	☐ No
4. Are FACW, OBL, or SAV plants present? (Within ½ channel width)	☐ Yes	☐ No
5. What is the slope? (In percent, measured for the valley, not the stream)	_______ %	

Conclusions



Single Indicators:
☐ Fish
☐ Amphibians

Finding: ☐ Ephemeral ☐ Intermittent ☐ Perennial

Notes: (explanation of any single indicator conclusions, description of disturbances or modifications that may interfere with indicators, etc.)

Difficult Situation:

Describe situation. For disturbed streams, note extent, type, and history of disturbance.

☐ Prolonged Abnormal Rainfall / Snowpack

- ☐ Below Average
- ☐ Above Average

☐ Natural or Anthropogenic Disturbance

☐ Other: ______________________________

Additional Notes: (sketch of site, description of photos, comments on hydrological observations, etc.) Attach additional sheets as necessary.

Ancillary Information:

☐ Riparian Corridor

☐ Erosion and Deposition

☐ Floodplain Connectivity

Observed Amphibians, Snake, and Fish:

Taxa	Life History Stage	Location Observed	Number of Individuals Observed



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