

Guidelines for Rating Level 2 Environmental Attributes in Ecosystem Diagnosis and Treatment (EDT)

by

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Guidelines for Rating Level 2 Environmental Attributes in Ecosystem Diagnosis and Treatment

Introduction

This document provides guidelines for rating Level 2 Environmental Attributes used in Ecosystem Diagnosis and Treatment (EDT). It will begin with a short introduction to how information and data are organized within an EDT analysis is first provided, followed by descriptions and rating guidelines for the attributes. A more complete description of the EDT information structure and rules is found in Lestelle and others (2004).

Level 2 Environmental Attributes are a standardized set of attributes for characterizing the freshwater environment as it affects the performance of fish species. The attributes described here were selected to be applied to fish species, and in particular to salmonid species. Other attributes would likely need to be added to analyze performance for other aquatic species within freshwater.¹

Information used to derive biological performance parameters in EDT is organized through what is called the EDT Information Structure (Lestelle and others 2004). It structures information through three levels of organization. Together, these levels can be thought of as an information pyramid in which each builds on information from the lower level (Figure 1). As we move up through the three levels, we take an increasingly organism-centered view of the ecosystem.

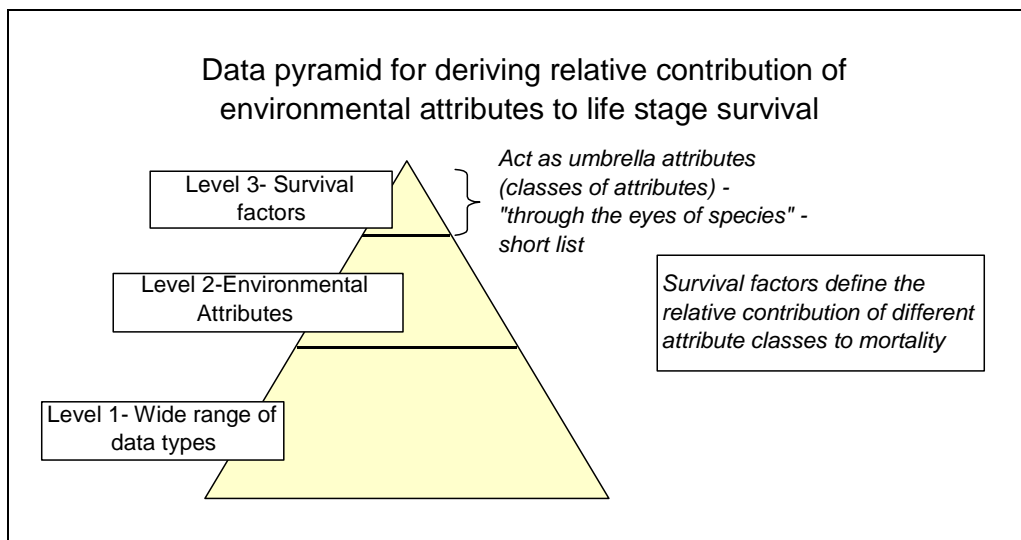


Figure 1. EDT Information Structure can be visualized as a “data pyramid.” Information begins as raw data and observations (Level 1), is organized into a species-neutral description of the environment (Level 2) and then characterized as performance of a particular species (Level 3).

¹ / The attributes described in this document were primarily formulated to address the riverine environment inhabited by salmonids. Other attributes have been formulated to characterize large lakes, like Lake Washington in western Washington.

Levels 1 and 2 together characterize the environment as it can be described by different types of data. Level 1 information is the raw data and observations that are available to describe a particular stream. This wide array of information is standardized and organized in terms of the Level 2 Environmental Attributes. A particular stream is characterized in terms of the Level 2 attributes using the Stream Reach Editor off-line tool (<http://www.Mobrand.com/EDT>). This creates the stream reach input data to the EDT model.

Level 2 Environmental Attributes are a set of measurable attributes that characterize a stream in terms of physical and biological aspects of the environment (Table 1). EDT Environmental Attributes are similar to the concept of Environmental Correlates used by Morrison and others (1998) to describe species-habitat relationships for terrestrial environments. The Level 2 Environmental Attributes in Table 1 are physical and biological characteristics of the environment relevant to a salmonid view of the stream. In concept though, a set of Level 2 Attributes can be described for analyzing the environment with respect to any species.

The EDT model estimates the biological potential of a stream based on the Level 2 characterization. Fish performance in an environment is estimated by linking the species-neutral Level 2 characterization to a species-specific Level 3 characterization of survival and capacity of the environment for the species. The Level 3 category is a characterization of the environment “through the eyes of the salmon” (Mobrand and others 1997). EDT uses a set of species-habitat relationships or “rules” to link the Level 2 Environmental Attributes to the Level 3 Survival Factors. The rules for chinook, coho and steelhead are described in Lestelle and others (2004).

The Level 2 characterization describes conditions in the watershed at specific locations (stream reaches), time within a year (months), and by scenario (historic, current, or a future scenario). These characterizations become operating hypotheses for these attributes under specific scenarios. Where Level 1 data are sufficient, Level 2 conclusions can be derived directly or through simple rules. However, in other cases, experts are needed to provide knowledge about geographic areas and attributes where Level 1 data are incomplete. Regardless of the means whereby Level 2 ratings are derived, the characterization can be ground-truthed and monitored through an adaptive process.

Most Level 2 Attributes are characterized using ratings on a scale of 0 to 4, spanning a spectrum of conditions. The descriptions below provide specific definitions for integer points on the scale. Generally, there is a consistent direction to the attribute ratings, where 0 or low values will tend to correspond with pristine environmental conditions and higher values tend toward more degraded conditions. In these cases, a 0 would correspond to a condition of no reduction of biological performance as a result of the attribute, whereas a value of 4 would generally be associated with a severe reduction in performance. This pattern is not followed for several attributes, however. For some attributes a rating of 2 represents a condition of no impairment of performance whereas 0 and 4 represent extreme increases or decreases in the condition as a result of anthropogenic factors. For other attributes, specific measurements are entered rather than categorical conclusions. These include reach length (miles), width (feet), gradient (proportion) and habitat types (percent of wetted area).

Table 2 gives examples of the index values for three Environmental Attributes, all addressing a different aspect of sediment load within the stream system. Integer values represent the midpoint

Table 1. Organization of Level 2 Environmental Attributes by categories of major stream corridor features. Salmonid Survival Factors (Level 3) are shown associated with groups of Level 2 attributes. Associations can differ by species and life stage.

Environmental Attributes (Level 2)		Related Survival Factors
1 Hydrologic Characteristics		
1.1 Flow variation	Flow - change in interannual variability in high flows	Flow Withdrawals (entrainment)
	Flow - changes in interannual variability in low flows	
	Flow - Intra daily (diel) variation	
	Flow - intra-annual flow pattern	
	Water withdrawals	
1.2 Hydrologic regime	Hydrologic regime - natural	
	Hydrologic regime - regulated	
2 Stream Corridor Structure		
2.1 Channel morphometry	Channel length	Channel length
	Channel width - month maximum width	Channel stability
	Channel width - month minimum width	Channel width
	Gradient	Habitat diversity
2.2 Confinement	Confinement - hydromodifications	Key habitat
	Confinement - natural	Obstructions
2.3 Habitat type	Habitat type - backwater pools	Sediment load
	Habitat type - beaver ponds	
	Habitat type - glides	
	Habitat type - large cobble/boulder riffles	
	Habitat type - off-channel habitat factor	
	Habitat type - pool tailouts	
	Habitat type - primary pools	
	Habitat type - small cobble/gravel riffles	
2.4 Obstruction	Obstructions to fish migration	
2.5 Riparian and channel integrity	Bed scour	
	Icing	
	Riparian function	
	Wood	
2.6 Sediment type	Embeddedness	
	Fine sediment (intragravel)	
	Turbidity (suspended sediment)	
3 Water Quality		
3.1 Chemistry	Alkalinity	Chemicals (toxic substances)
	Dissolved oxygen	Oxygen
	Metals - in water column	Temperature
	Metals/Pollutants - in sediments/soils	
	Miscellaneous toxic pollutants - water column	
	Nutrient enrichment	
3.2 Temperature variation	Temperature - daily maximum (by month)	
	Temperature - daily minimum (by month)	
	Temperature - spatial variation	
4 Biological Community		
4.1 Community effects	Fish community richness	Competition with hatchery fish
	Fish pathogens	Competition with other fish
	Fish species introductions	Food
	Harassment	Harassment
	Hatchery fish outplants	Pathogens
	Predation risk	Predation
	Salmonid carcasses	
4.2 Macroinvertebrates	Benthos diversity and production	

Table 2. Rating indexes used for three Level 2 Environmental Attributes that address different characteristics of sediment load in a stream system.

Embeddedness	
Rating	Rating definition
0	≤ 10% embedded
1	> 10% and ≤ 25% embedded
2	> 25% and ≤ 50% embedded
3	> 50% and ≤ 90% embedded
4	> 90% embedded
Fine sediment (intragravel)	
Rating	Rating definition
0	≤ 6% fines < 0.85 mm
1	> 6% and ≤ 11% fines < 0.85 mm
2	> 11% and ≤ 18% fines < 0.85 mm
3	> 18% and ≤ 30% fines < 0.85 mm
4	> 30% fines < 0.85 mm
Suspended sediment (from SEV index – after Newcombe and Jensen 1996)	
Rating	Rating definition
0	≤ 4.5 scale of severity (SEV)
1	> 4.5 and ≤ 7.5 scale of severity (SEV)
2	> 7.5 and ≤ 10.5 scale of severity (SEV)
3	> 10.5 and ≤ 12.5 scale of severity (SEV)
4	> 12.5 scale of severity (SEV)

of conditions for attributes when a range of conditions is associated with one value. The indexing system allows users to specify either continuous or integer values for the attributes, depending on the appropriate level of precision for particular stream reach given the available data.

The majority of Level 2 Attributes are entered in the Stream Reach Editor as single values representing a typical condition for the reach. For example, Large Woody Debris (LWD) is entered as a single value—variation in LWD across a typical year is minor and is not considered in the model. However, for other attributes, like flow, temperature and channel width, variation across the year, and how that pattern has been shifted by anthropogenic factors, is an important consideration. These attributes are shaped within EDT using patterns that are entered through the Stream Reach Editor. Patterns shape the value for an attribute for a month. Values for a month are computed as the overall attribute rating times the monthly shaping factor in the pattern. The discussion below deals with the overall attribute ratings for shaped and unshaped Level 2 Attributes. Whether an attribute is shaped or not is noted in each description; the Appendix provides a discussion of how patterns are devised for the shaped Level 2 Attributes.

The remainder of this document describes each of the Environmental Attributes used to characterize the freshwater environment. Each attribute is defined and described with regard to its ecological role, some of the factors affecting its condition, and its general importance to salmonid fishes of the Pacific Northwest. The attribute descriptions are listed in alphabetical order; however, they also include the Categories and Sub-Categories in Table 1 that are used to organize attributes within the Stream Reach Editor.

Alkalinity

Attribute Category

3. Water Quality

Attribute Sub-Category

3.1 Chemistry

Shaping

Alkalinity is a non-shaped attribute.

Definition/Usage

Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO_3 or CaCO_3 .

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Very low (average value typically would be 0-5 mg/l)	Moderately low (average value typically would be 5-10 mg/l)	Moderately high (average value typically would be 10-40 mg/l)	High (average value typically would be 40-100 mg/l)	High (average value typically would be 100-300 mg/l)

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Importance and Role

Alkalinity is broadly correlated with the productive capacity of streams, with respect to both primary production and fish production (McFadden and Cooper 1962, Ptolemy 1993, Bisson and Bilby 1998). Hard waters apparently tend to be more productivity, though reasons for this have not been clearly established (Hynes 1970, Allan 1995).

Factors Affecting Attribute/Guidelines

Because of the variability that can occur in alkalinity data and the incompleteness of available data for this correlate, a measure of alkalinity is sought for broad areas only. Alkalinity is highly correlated with water yield in watersheds, being lowest in high runoff areas.

In general, alkalinity on the west side of the Cascades will fall into Index Levels 1 and 2. Therefore, Index 1 or 2 should be prevalent for the west side unless evidence indicates otherwise. While alkalinity is generally higher on the east than the west side of the Cascades, it can vary widely in relation to runoff patterns, proximity to the Cascade crest, and local geology. In general, Index 3 and 4 should be prevalent in the mid and lower portions of subbasins on the east side of the Cascade crest but lower as the crest is approached.

Figure 2 shows data for selected streams on west and east sides of Cascades and in the vicinity of the Yellowstone National Park—data from USGS sampling stations.

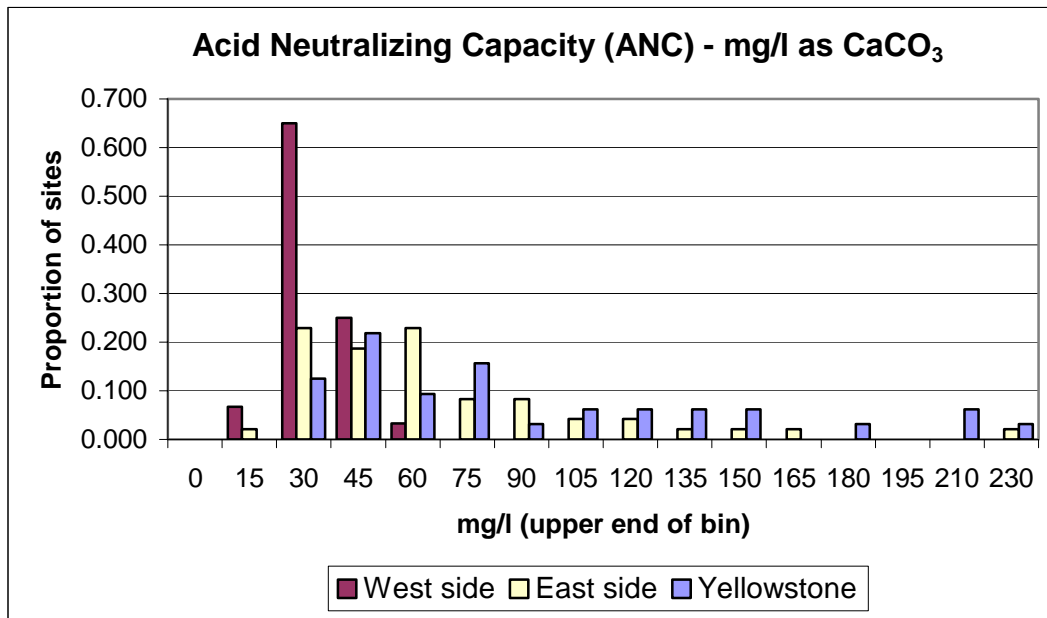


Figure 2. Patterns of alkalinity for selected streams on the west and east sides of the Cascade crest. Streams within Yellowstone Park are also shown for reference due to highly alkaline nature of many of those streams (data from USGS).

Special Instructions for New Input or Updates

In general, this attribute should be treated as a low priority meaning that default values premised on the pattern described above can be applied. When the attribute is explicitly addressed, all months should be rated the same. Conditions under moderate flows should be considered.

Effect on Level 3 Survival Factors

Alkalinity affects the Level 3 attributes Food and Competition (as a modifying attribute associated with food fish food production) and, in turn, affects 1) the maximum density that can be attained by the end of rearing life stages and 2) resultant species productivity.

References/Sources

Definition and Range of Values Within Pacific Northwest: Welch and others (1998).

Importance and Role: Allan (1995), Bisson and Bilby (1998), Hynes (1970), McFadden and Cooper (1964), Ptolemy (1993), Welch and others (1998).

Factors Affecting: Hynes (1970), Ptolemy (1993), Welch and others (1998).

Bed Scour

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.6 Riparian and channel integrity

Shaping

Bed Scour is a shaped attribute. Shaping can follow flow (Appendix 1), or an explicit shape can be used.

Definition/Usage

Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts and others (1983) based on information in Gordon and others (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Average depth of scour >0 cm and <2 cm	Average depth of scour >2 cm and <10 cm	Average depth of scour >10 cm and <18 cm	Average depth of scour >18 cm and <24 cm	Average depth of scour >24 cm and <40 cm

Importance and Role

The channel bed is a substrate used by aquatic organisms as a foothold, as a site to deposit or incubate eggs, and as a refuge from floods. The substrate can be extremely active biologically. The disruption of the particles comprising the upper layer of the substrate can therefore have a profound effect on survival and production of species that rely on this area of a stream. In particular, scour of bed materials during high flows can affect the survival of incubating salmonid eggs and overwintering juveniles located there. It can also affect the production of aquatic insects within streams.

Factors Affecting Attribute/Guidelines

Several studies have been conducted over the past decade that have greatly improved understanding on the nature and factors affecting the extent of bed scour in streams as it relates to salmonid egg incubation survival (Montgomery and others 1996, Montgomery and others 1999, DeVries 2000, Shellberg 2002, Schuett-Hames and Adams 2003).

In general, depth of bed scour in natural conditions is affected by discharge level and geomorphic conditions. Bed scour is generally assumed to occur when discharge reaches bankfull, which typically occurs every 1-2 years under pristine conditions. Some bed mobility occurs at stages below bankfull, but widespread bed mobility commonly occurs at a stage near bankfull. Steep and low-gradient channels, however, fundamentally differ in the extent of bed mobility and the depth of scour during typical bed-mobilizing events (Montgomery and others 1999).

Bankfull flows generally mobilize the streambed across the entire channel. The average thickness of the layer in active transport has generally been linked to the bedload transport rate, usually described in relation to the magnitude and duration of the peak discharge. Increased bedload transport rate in a stream reach may result from increases in peak flow or sediment supply—both of which may be caused by various land use activities. Channel straightening, diking, and closure of side channels can also increase bedload transport rate in a channel.

Bed scour within microhabitats of main channels may differ from surrounding areas due to localized conditions. For example, gravels impounded behind log jams may decrease local channel gradient enough to reduce bed scour. Elimination of such microhabitats may prevent fish from spawning at sites relatively protected from significant bed scour. Side channels may also experience less bed scour than main channel areas.

Anadromous salmonids typically bury their eggs 15-20+ cm below the channel bed, whereas smaller resident and anadromous trout bury eggs at shallower depths, typically 5-10 cm (DeVries 1997, Montgomery and others 1999). Larger females generally dig deeper redds than smaller fish do, and egg survival to emergence is inversely related to the depth of scour between time of spawning and fry emergence.

Montgomery and others (1996) reported that chum salmon bury their eggs just below scour depths during bankfull flow. This suggests that the average depth of scour in many rivers of the Pacific Northwest prior to watershed development must have been less than this depth.

The extent that depth of scour may be increased with watershed development, compared to the level that occurred in a stream's pristine state, can vary. DeVries (2000), in studying low gradient streams (<1%) in western Washington, concluded that depth of bed scour will often not be increased enough to adversely affect incubating salmon eggs, even when peak flows are increased due to land use. He noted that under some conditions, such as when pool spacing is increased (i.e., pool-riffle ratios are decreased), bed scour can be deepened.

Studies recently completed show that land use practices can have significant adverse effects on incubating eggs through increases in bed scour. Schuett-Hames and Adams (2003) found a strong negative relationship between annual peak flow level and scour depth at spring Chinook redd sites in the Greenwater River in western Washington (reach gradients of 0.8-1.4%) (Figure 3). They concluded that during their five year study that 26% of the redds in the study reaches had a poor likelihood for survival due to bed scour (76 redds monitored over the period). The Greenwater watershed has undergone extensive clearcutting, with associated loss of in-channel LWD, over the past 30 years.

In another recent study of bull trout redds in western Washington, Shellberg (2002) found a wide range of scour depth occurring at redd sites, ranging from deep scour to deep fill depending on the channel type and habitat unit. Scour depths at selected redd sites varied widely between side channel, protected main channel and unprotected main channel redd sites. This suggests that land use activities that reduce side channel and protected sites can have deleterious effects through bed scour.

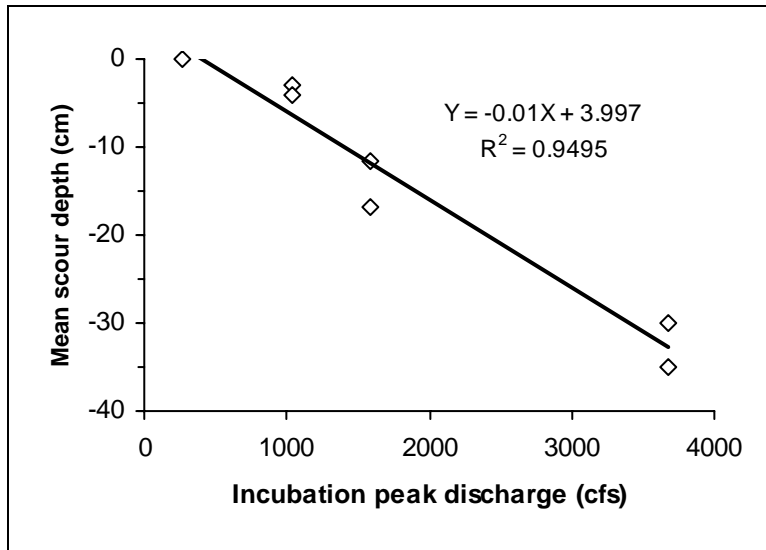


Figure 3. Relationship between mean scour depth at Chinook redd sites (by reach) and peak flow during incubation period in the Greenwater River, WA (from Schuett-Hames and Adams 2003).

Special Instructions for New Input or Updates

This attribute is considered as a high priority for rating.

It is necessary to rate only for the month when bed scour would likely be highest. Other months will be inferred by applying an appropriate flow pattern for the watershed of interest.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attribute Channel Stability and, in turn, affects resultant species productivity. The effects generally occur in the egg incubation and inactive life stages, though they can occur in the rearing life stages for certain species as well.

References/Sources

Platts and others (1983), DeVries (1997), Gordon and others (1992), Lisle (1989), Montgomery and Buffington (1993), Montgomery and others (1996), Montgomery and others (1999), DeVries (2000), Schuett-Hames and Adams (2003), Shellberg (2002).

Benthos Diversity and Production

Attribute Category

4. Biological Community

Attribute Sub-Category

4.2 Macroinvertebrates

Shaping

Benthos diversity and production is a non-shaped attribute.

Definition/Usage

Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): (1) a simple EPT count, (2) Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or (3) a multivariate approach using the BORIS (Benthic evaluation of ORegon RIVERs) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr and others (1986). BORIS score definitions based on ODEQ protocols, after Barbour and others (1994).

Importance and Role

Benthic organisms in flowing waters comprise an important component of the diet of many fish species, particularly of juvenile salmonids. Food supply in turn can affect the survival of rearing fishes, as well as the maximum densities that can be achieved by these species within key habitats.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Simple EPT index Macroinvertebrates abundant; multiple species of families Ephemeroptera, Plecoptera, and Trichoptera are present.				
B-IBI (10 metrics) – definitions taken from Morley (2000) as modified from Karr and others (1986)				
B-IBI score ≥ 45 Comparable to least disturbed reference condition; overall high taxa diversity, particularly of mayflies, stoneflies, caddisflies, long-lived clinger, and intolerant taxa. Relative abundance of predators high.	B-IBI score ≥ 37 and < 45 . Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of mayflies, stoneflies, and caddisflies; proportion of tolerant taxa increases.	B-IBI score ≥ 27 and < 37 . Total taxa reduced—particularly intolerant, long-lived, stonefly, and clinger taxa. Relative abundance of predator declines; proportion of tolerant taxa continues to increase.	B-IBI score ≥ 17 and < 27 . Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few stoneflies or intolerant taxa present; dominance by three most abundant taxa often very high.	B-IBI score < 17 . Overall taxa diversity very low and dominated by a few highly tolerant taxa; mayfly, stonefly, caddisfly, clinger, long-lived and intolerant taxa largely absent. Relative abundance of predators very low.
BORIS score (based on ODEQ protocols, after Barbour and others 1994)				
Minimal impairment in benthic community— < 1 standard deviation from the reference mean AND considered "ideal or good watershed and stream condition for reference condition." ²	Minimal impairment in benthic community— < 1 standard deviation from the reference mean AND considered "marginal watershed and stream condition for reference condition." ¹	Moderate impairment in benthic community— > 1 and < 2 standard deviations from the reference mean.	Severe impairment in benthic community— > 2 and < 2.5 standard deviations from the reference mean.	Extremely severe impairment in benthic community— > 2.5 standard deviations from the reference mean.

Factors Affecting Attribute/Guidelines

The categorical conclusions employed for benthos diversity and production assume that biological impairment of the benthic community may be indicated by the absence of generally pollution-sensitive macroinvertebrate taxa such as Ephemeroptera, Plecoptera, and Trichoptera (EPT).

The EPT is highly sensitive to dissolved oxygen, resulting largely from the combination of temperature and nutrient loading. Benthos production and diversity will be at the lowest possible level under conditions of super enrichment and high temperature. Deleterious effects are assumed to drop sharply with reductions in enrichment levels. The EPT can generally be assumed to be highest possible under conditions of no nutrient loading because dissolved oxygen is normally at or near saturation in the absence of enrichment in the Pacific Northwest.

^{2/} See description of ODFW protocol presented in Mochan and Mrazik (2000).

A suggested guideline is given below that corresponds closely with that for dissolved oxygen (see guideline for *Dissolved Oxygen*); both guidelines are based on water temperature and nutrient enrichment (see guideline for *Nutrient Enrichment*).

Benthos Index Value Lookup Table

Nutrient enrichment index value	Mean monthly water temperature (°C)				
	≤10	>10 and ≤12	>10 and ≤12	>10 and ≤12	>20
0	0	0	0	0	0
1	0	0	1	1	1
2	0	0	2	2	2
3	2	2	2	3	3
4	2	2	3	3	4

Other attributes besides nutrient enrichment and water temperature are known to have significant effects on benthos production and diversity, such as fine sediment loading, riparian function, and toxic substances.

Quantitative metrics have been developed that can be used to more precisely describe the level of benthos diversity and production. The most widely used metric is the B-IBI (benthic indexes of biological integrity; Karr and Chu 1999). The B-IBI is a multimetric index that combines measures of the taxonomic diversity, trophic and age structures, and life histories of benthic macroinvertebrate assemblages. It ranges over a scale of 10 to 50 with higher scores indicating greater diversity of taxa, trophic and age structures, and life histories of macroinvertebrate assemblages. In Washington State, distinct regional patterns have been found among benthic macroinvertebrate communities in the Puget Lowlands, Cascade Mountains, and Columbia Basin (Plotnikoff and Wiseman 2001). Plotnikoff and Ehinger (1997) stressed the importance of reach-level variables (temperature, pH, conductivity, wetted width/bankfull width ratio, elevation) in shaping the macroinvertebrate communities. May and others (1997) found that B-IBI was strongly and inversely related to % total impervious area (TIA), showing a simple linear decline in B-IBI with increase in %TIA (Figure 4). Konrad (2000) reported that the decline in B-IBI with %TIA is likely related to persistent stream bed disturbance that occurs in urban streams due to altered hydrologic patterns. Karr and Chu (1999b) provide other examples of reduction in B-IBI with increasing watershed development.

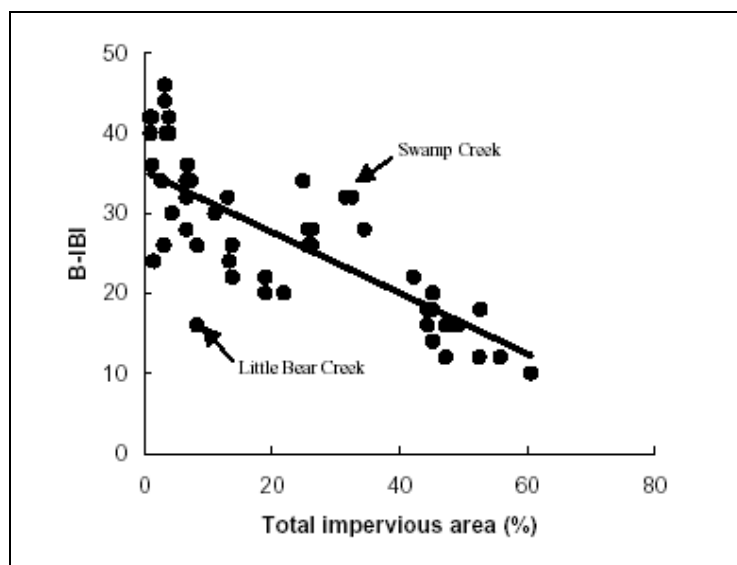


Figure 4. Relationship between percent total impervious surface area and B-IBI in Puget Sound lowland streams (from May and others 1997).

Special Instructions for New Input or Updates

Sampling using one of the protocols described for sampling benthos has increased dramatically in many areas of the Pacific Northwest in the past several years. Efforts should be made to incorporate this information as it is available. The importance of food warrants that this attribute is given high priority in rating. A previous edition of these guidelines suggested that this attribute could be treated as having a low priority for rating.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attribute Food, and in turn, affects 1) the maximum density that can be attained by the end of rearing life stages and 2) resultant species productivity.

References/Sources

Chapman (1966), Hynes (1970), Mason (1976), Karr and Chu (1999a), Canale (1999), Morley (2000), Karr and others (1986), Barbour and others 1994, Allan (1995), Hynes (1960), Plafkin and others (1989), May and others (1997), Plotnikoff and Wiseman (2001), Plotnikoff and Polayes (1999), Karr and Chu (1999b), Mochan and Mrazik (2000), McCubbing and Ward (2000).

Channel Width—Month Maximum Width (ft)

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.1 Channel Morphometry

Shaping

Channel width is a shaped attribute. Maximum width and minimum width use identical shapes that often follow the hydrograph. See Appendix.

Definition/Usage

Average width of the wetted channel during high flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels.

Importance and Role

The wetted width of the channel helps define the quantity of wetted area available as habitat for riverine species.

Categorical Conclusions

Categorical index levels are not to be used to describe channel width. The user must input Level 2 attribute values for this attribute as non-categorical estimates, i.e., point estimates of width in feet.

Factors Affecting Attribute/Guidelines

The width of the wetted channel, except in confined reaches, is normally related to discharge.

If empirical width data are not available for the reach of interest, reasonable conclusions can usually be based on personal knowledge of the area. In some cases, a better characterization of flow may exist than channel width. Here, an estimate of width (in feet) for larger streams might be obtained from flow (cfs) data using an equations from Johnson and others (1988) as follows:

For unconfined reaches,

$$Width = a * CFS^b$$

Where $a = 10.0342$ and $b = 0.4350$

For confined reaches,

$$Width = a * CFS^b$$

Where $a = 4.5789$ and $b = 0.5660$

The equation for unconfined reaches is based on data collected at 154 sites from a variety of rivers and tributaries in western Washington across a wide range of sizes. The equation for confined reaches was developed with data from sites in the Wenatchee River system; that system contains a high degree of semi- or fully confined reaches.

Special Instructions for New Input or Updates

Channel width – month maximum width (ft) is to be rated for the month when average flow tends to be highest. This month will typically be during some part of March–June east of the Cascade crest and during December or January on the westside. A pattern is applied by the EDT Stream Reach Editor to extrapolate from the high and low months to all remaining months (Appendix).

The attribute is to assigned point estimates of wetted channel width (not bankfull).

Effect on Level 3 Key Habitat

This attribute is used to estimate the wetted surface area of channel reaches in different months of the year. Percentages of key habitat for different life stages for the species of interest is then applied to wetted surface area to estimate quantities of key habitat at for each life stage.

References/Sources

Factors Affecting: Johnson and others (1988).

Channel Width—Month Minimum Width (ft)

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.1 Channel Morphometry

Shaping

Channel width is a shaped attribute. Maximum width and minimum width use identical shapes that often follow the hydrograph. See Appendix.

Definition/Usage

Average width of the wetted channel during low flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels.

Importance and Role

The wetted width of the channel helps define the quantity of wetted area available as habitat for riverine species.

Categorical Conclusions

Categorical index levels are not used to describe channel width. The user must input Level 2 attribute values for this attribute as non-categorical estimates, i.e., point estimates of width in feet.

Factors Affecting Attribute/Guidelines

The width of the wetted channel, except in confined reaches, is normally related to discharge.

If empirical width data are not available for the reach of interest, reasonable conclusions can usually be based on personal knowledge of the area. In some cases, a better characterization of flow may exist than channel width. Here, an estimate of width (in feet) for larger streams might be obtained from flow (cfs) data using an equation from Johnson and others (1988) as follows:

For unconfined reaches,

$$Width = a * CFS^b$$

Where $a = 10.0342$ and $b = 0.4350$

For confined reaches,

$$Width = a * CFS^b$$

Where $a = 4.5789$ and $b = 0.5660$

The equation for unconfined reaches is based on data collected at 154 sites from a variety of rivers and tributaries in western Washington across a wide range of sizes. The equation for confined reaches was developed with data from sites in the Wenatchee River system; that system contains a high degree of semi- or fully confined reaches.

Special Instructions for New Input or Updates

Channel width – month minimum width (ft) is to be rated for the month when average flow tends to be lowest. This month will typically be during late summer or early fall on both sides of the Cascade crest. A flow pattern is applied by the EDT Stream Reach Editor to extrapolate from the high and low months to all remaining months.

The attribute is to assigned point estimates of wetted channel width.

Effect on Level 3 Key Habitat

This attribute is used to estimate the wetted surface area of channel reaches in different months of the year. Percentages of key habitat for different life stages for the species of interest is then applied to wetted surface area to estimate quantities of key habitat at for each life stage.

References/Sources

Factors Affecting: Johnson and others (1988).

Confinement—Natural

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.2 Confinement

Shaping

Natural confinement is a non-shaped attribute.

Definition/Usage

The extent that the valley floodplain of the reach is confined by natural features—determined as the ratio between the width of the valley floodplain and the bankfull channel width. *Note: this attribute addresses the natural (pristine) state of valley confinement only. The extent that reaches are confined by hydromodifications (e.g., diking) is addressed under a separate attribute.*

Importance and Role

Channel confinement affects habitat-forming processes and, hence, the occurrence of different types of fish habitats within the stream network. Extent of confinement also affects water velocity and flood storage capacity of the floodplain, and, consequently it can strongly influence bed stability and potential for scour.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Reach mostly unconfined by natural features -- Average valley width > 4 channel widths.	Reach comprised approximately equally of unconfined and moderately confined sections.	Reach mostly moderately confined by natural features -- Average valley width 2 - 4 channel widths.	Reach comprised approximately equally of moderately confined and unconfined sections.	Reach mostly confined by natural features -- Average valley width < 2 channel widths.

Factors Affecting Attribute/Guidelines

Channel morphology and response to high flows are influenced by the degree of confinement by valley walls. Unconfined channels typically have relatively wide floodplains, relatively low gradients, and often are areas of alluvial aggradation. In this situation, sediment supply (of a wide range of sizes) exceeds transport capacity of the channel. Steep channels typically are confined by valley walls and shallow bedrock. These channels have relatively low sediment storage capacities and serve as transport reaches, with sediment loads being carried through the reach during high flow events.

Because confined channels have high transport capacities, their substrates containing small cobbles/gravel are typically subject to higher rates of bed scour than are unconfined reaches.

The extent of natural confinement can be determined from topography maps, though some ground truthing may be required. In western Washington, natural confinement has been determined for many river systems as part of the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP).

Special Instructions for New Input or Updates

All months are rated the same for this attribute.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attributes Flow and Habitat Diversity, which, in turn, affect productivity of certain life stages of salmonids.

References/Sources

Definition/Usage: Schuett-Hames and others (1994).

Importance and Role: Montgomery and Buffington (1993).

Factors Affecting: Montgomery and Buffington (1993).

Confinement—Hydromodifications

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.2 Confinement

Shaping

Artificial confinement (hydromodifications) is a non-shaped attribute.

Definition/Usage

The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cutoff due to channel incision. *Note: Setback levees are to be treated differently than narrow-channel or riverfront levees—consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in the reach to arrive at a rating conclusion. Reference condition for this attribute is the natural, undeveloped state.*

Importance and Role

Stream channels are modified to protect adjacent property from streambank erosion and flooding. This is accomplished by eliminating and/or reducing meanders to increase velocity, construction of levees and dikes, and armoring streambanks. These alterations reduce or eliminate (often by blocking access) fish habitat and typically reduce the quality of remaining habitat. Channel incision and channelization have similar effects on stream flow stage and stage hydrographs (Doyle and others 1998).

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
The stream channel within the reach is essentially fully connected to its floodplain. Very minor structures may exist in the reach that do not result in flow constriction or restriction. Note: this describes both a natural condition within a naturally unconfined channel as well as the natural condition within a canyon.	Some portion of the stream channel, though less than 10% (of the sum of lengths of both banks), is disconnected from its floodplain along one or both banks due to man-made structures or ditching.	More than 10% and less than 40% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.	More than 40% and less than 80% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.	Greater than 80% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.

Factors Affecting Attribute/Guidelines

The assignment of ratings to this attribute will likely be largely subjective, based on a determination of the extent that hydromodifications to the channel within a reach have occurred. Such determination may be wholly or partially a *judgment* based on information available. Types of alterations to the channel corridor that should be considered are dikes, bank armoring, closure of flood relief channels, channel straightening, and channelization.

Special Instructions for New Input or Updates

All months are rated the same for confinement—hydromodifications.

Effect on Level 3 Survival Factors

Confinement—hydromodifications affects the Level 3 attributes Flow and Habitat Diversity, which, in turn, affects productivity of certain life stages of salmonid fishes.

References/Sources

Beechie and others (1994), Federal Interagency Stream Restoration Working Group (1998), Doyle and Shields (1998).

Dissolved Oxygen

Attribute Category

3. Water Quality

Attribute Sub-Category

3.1 Chemistry

Shaping

Dissolved oxygen is a shaped attribute, often based on temperature. See Appendix.

Definition/Usage

Average dissolved oxygen within the water column for the specified time interval.

Importance and Role

Dissolved oxygen (DO) is a basic requirement for a healthy aquatic ecosystem. Fish and aquatic insects require DO to survive and carry on life giving functions.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
> 8 mg/L (allows for all biological functions for salmonids without impairment at temperatures ranging from 0-25 C)	> 6 mg/L and < 8 mg/L (causes initial stress symptoms for some salmonids at temperatures ranging from 0-25 C)	> 4 and < 6 mg/L (stress increased, biological function impaired)	> 3 and < 4 mg/L (growth, food conversion efficiency, swimming performance adversely affected)	< 3 mg/L

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

DO in unpolluted streams and rivers is usually near saturation; and, under these circumstances, it poses no risk to biological function to species of concern. *Hence index values should be set to 0 when nutrient enrichment is nil for all temperature levels.*

DO can be severely depleted as a result of human activities that introduce nutrients into surface waters. This occurs, for example, when runoff is enriched with fertilizers and animal wastes or from municipal discharges. Nutrient enrichment, consisting of elevated concentrations of phosphates or nitrates, can lead to oxygen depletion when the stream flora increases in biomass followed by death and decomposition of plant material. These conditions are made worse when water temperature increases, due to corresponding increases in rates of plant growth and subsequent decay. Further, oxygen solubility decreases with increasing water temperature. *Index values for DO should be set at 4 when mean monthly water temperatures are high (>20 °C) and*

super enrichment of nutrients occurs. Index values should be reduced corresponding to decreased temperatures or nutrient loading.

A guideline for the dissolved oxygen index value is given in the Dissolved Oxygen Index Value Lookup Table based on mean monthly water temperature and the Level 2 nutrient enrichment index value (see guideline for *Nutrient Enrichment*).

Dissolved Oxygen Index Value Lookup Table

Nutrient enrichment index value	Mean monthly water temperature (°C)				
	≤10	>10 and ≤12	>12 and ≤16	>16 and ≤20	>20
0	0	0	0	0	0
1	0	0	0	1	1
2	0	1	1	1	2
3	1	1	2	2	3
4	3	3	4	4	4

Special Instructions for New Input or Updates

Rate the month when DO is likely to be lowest, i.e., the month when temperature is highest. Rate only one month. Other months will be inferred from an appropriate seasonal pattern based on temperature.

Effect on Level 3 Survival Factors

The attribute, Dissolved Oxygen, affects the Level 3 attribute, Oxygen, which, in turn, can affect the productivity of any life stage of stream dwelling fishes.

References/Sources

Importance and Role: Hynes (1960).

Factors Affecting: Allan (1995), Federal Interagency Stream Restoration Working Group (1998), and Hynes (1960).

Embeddedness

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.6 Sediment Type

Shaping

Embeddedness is a non-shaped attribute.

Definition/Usage

The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

Importance and Role

Juvenile fish will hide in the interstitial spaces in stream substrates, particularly in winter, when the voids are accessible. When these spaces are filled by fine sediment (embedded), the quality of the substrate for hiding cover is diminished, and survival can be reduced. It can also effectively entomb pre-emergent fry within the substrate, blocking their emergence into the flowing stream. Embeddedness also affects the production of aquatic insects.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
< 10% of surface covered by fine sediment	> 10 and < 25 % covered by fine sediment	> 25 and < 50 % covered by fine sediment	> 50 and < 90 % covered by fine sediment	> 90% covered by fine sediment

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Responses to increases in fine sediment load depend on the ability of the channel to transport material relative to sediment supply. Responses can include aggradation, channel widening, bed fining, pool filling, or braiding where the amount of introduced sediment overwhelms local sediment transport capacity. Increased supply of fine sediment to a plane-bed channel is expected to result in either fining of the bed surface or channel aggradation. Pool-riffle channels will undergo aggradation and fining in response to increased sediment load. Increased sediment supply can also result in expansion of the zone of active sediment transport. Although bed scour

is expected to increase during high flow under this condition, the extent of embeddedness is expected to increase during lower flows. Hence, at the highest levels of sediment loading, reaches with the least transport capacity (typically lower gradient reaches with slowest water velocities) would result in the highest level of deposition and embeddedness.

It is important to note that embeddedness, as a measure of substrate characteristics, does not work well in all lithologic types. It is most suitable where sand size particles (< 6 mm) are the dominant fine sediment size (vs. particle sizes < 1 mm), such as in the Idaho Batholith. Embeddedness does not appear to work well as a measure of substrate characteristics in some areas with basalt parent materials. Fines in basalt areas often tend to consist of clays and silts easily moved by streams, hence armoring in those areas is more pronounced (Chapman and McLeod 1987).

It needs to also be recognized that embeddedness has a measure of substrate characteristics and is only appropriate where cobble and gravel substrates exist. The attribute is not pertinent to describe substrate quality in low gradient channels where silts and sands exist to a major extent.

Special Instructions for New Input or Updates

All months are to be rated the same for embeddedness. In reality, the extent of embeddedness likely varies in response to scour and fill and times when sediment inputs are greatest. A temporal pattern may need to be applied in a future application.

In channels where embeddedness is not a suitable measure of channel characteristics (see text above), embeddedness ratings of 0 should be assigned.

Effect on Level 3 Survival Factors

Embeddedness affects the Level 3 survival factor Sediment Load during the fry colonization and inactive life stages. While embeddedness might be considered to affect the incubation life stage (pre-emergent fry), sediment impact on incubation is handled by the Level 2 attribute Fine Sediment where particle size covers sand sizes (2-6 mm). Literature sometimes suggests that embeddedness also affects active rearing stages during summer, but these effects are most likely indirect due to losses in food organisms (Bjornn and Reiser 1991).

References/Sources

Importance and Role: Bjornn and others (1977), Bjornn and Reiser (1991), Chapman and Bjornn (1969), Cordone and Kelly (1961), Platts and others (1983), Chapman and McLeod 1987.

Factors Affecting: Chapman and McLeod 1987, Montgomery and Buffington (1993).

Effect on Level 3 Factors: Bjornn and Reiser 1991.

Fine Sediment (intra-gravel)

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.6 Sediment Type

Shaping

Fine Sediment is a non-shaped attribute.

Definition/Usage

Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the focus watershed. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles < 1mm (e.g., as measured by particles < 0.85 mm). Sand size particles (e.g., < 6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

Importance and Role

Fine sediment particles within the substrate of pool-tailouts, glides, and riffles can affect the survival of incubating salmonid eggs and alevins by altering oxygen exchange across the organisms and by entombment. Fine sediment can also affect the benthos, both species diversity and production (benthos is rated directly as another attribute, however).

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Particle sizes <0.85 mm: < 6% OR Particle sizes <6.3 mm: <10%	Particle sizes <0.85 mm: > 6% and < 11% OR Particle sizes <6.3 mm: >10% and <25%	Particle sizes <0.85 mm: > 11% and < 18% OR Particle sizes <6.3 mm: >25% and <40%	Particle sizes <0.85 mm: > 18% and < 30% OR Particle sizes <6.3 mm: >40% and <60%	Particle sizes <0.85 mm: > 30% fines OR Particle sizes <6.3 mm: >60%

Factors Affecting Attribute/Guidelines

Levels of fine sediment (< 0.85 mm) in salmon spawning areas of unmanaged streams of the Pacific Northwest, British Columbia, and Alaska have been reported to generally range between 6% and 11% (summarized in Peterson and others 1992). Basin geology and other geomorphic conditions (such as channel slope) can affect percent fines in unmanaged conditions. Some streams in such areas, however, do have fine sediment levels > 11%, and, presumably, such situations occur in low slope areas or those with particularly erosive geologic conditions.

All measures of watershed disturbance can affect the amount of intragravel fine sediment. These disturbances can be associated with agriculture (includes grazing), forestry, mining, or urban related. Each of these land use practices contributes major quantities of sediment to streams.

In forested areas, the road system can be a primary contributor; in other cases, slope failures and stream bank erosion are most influential.

On the west side of the Olympic Peninsula, Rittmueller (1986) reported that percent fines (< 0.85 mm) ranged from 0.7% in an unlogged basin to 29% in a stream with the highest sediment input coming from heavily used logging roads. Rittmueller found that percent fines increased by 0.15% as percent of watershed clearcut increased by 1%. As road density increased by 1 km/km^2 , intragravel fine sediment levels increased by 4.3%. In streams where logging has occurred, but road use and road building had ceased or been minimized in recent years, percent fines appeared to have returned to nearly background levels. *It should be noted that these streams would generally have channel slopes $> 0.5\%$, and many would have slopes $> 1\%$.*

In contrast to Rittmueller's findings, McHenry and others (1994) suggested that recovery to pre-management levels would be slow for streams draining to the west side of the Strait of Juan de Fuca on the Olympic Peninsula even with road closure. Geology of the area is comprised of sandstones, siltstones and mudstones. Only one of eighteen streams studied was found with percent fines (< 0.85 mm) $< 17\%$. All streams have been extensively logged over the past century.

Percent fines (< 0.85 mm) has been correlated with percent total impervious area (% TIA) in Puget Sound lowland streams, with 20% TIA having a high likelihood for % fines being $> 15\%$ (May and others 1997). In general, watersheds in heavily urbanized areas had high % fines. Watersheds with % TIA exceeding 45% had a high probability of having % fines between 20-30%.

In streams where embeddedness provides a useful measure of substrate characteristics, it has been found to be correlated with percent fines, both for fine sediment particles < 0.85 mm (as in Puget Sound lowland stream—May and others 1997) and for sand size particles < 6 mm (South Fork Salmon River—Burns 1984 cited in Chapman and McLeod 1987).

The effect of changes in the fine sediment load carried by a stream on the amount of sediment entrained within the upper layer of substrate is related to the ability of the channel to transport material relative to sediment supply. In general, the response of a channel to changes in sediment load are known to depend on sediment transport capacity. Sediment transport capacities are high in high gradient channels, making channel types associated with high slopes more resilient to increased sediment loads. Sediment transport capacity in lower gradient channels (e.g., those $< 4\%$) are more easily overwhelmed by increased sediment supply, causing aggradation, channel widening, bed fining, pool filling, or braiding. Thus increased sediment loading should show a much greater response in intragravel fines in low slope than in higher slope reaches.

For many streams, the intragravel fine sediment level may be considered roughly constant over an annual cycle despite periods of scour and fill due to high flows. It is known, however, that spawning salmonids can at least partially clean the substrate of fines during redd construction

(Chapman 1988). To assess percent fines within redd sites, which is the measure that this attribute is intended to represent, Kondolf (2000) recommends that an adjustment be made to reflect the extent of cleaning by spawners (see Figures 6 and 7 in that paper). Kondolf states that the longevity of this cleaning action (i.e., how clean the redd remains through the incubation period) will depend on the timing of sediment transport in relation to incubation of salmonid embryos. In many streams throughout the Pacific Northwest, at least in managed watersheds, fine sediment likely reinvades redds of fall spawning species so that % fines attain levels comparable to pre-spawning conditions. Two cases where this has been described are Kennedy Creek, a Puget Sound lowland stream (Peterson and others 1994) and Grande Ronde River in northeast Oregon (Rhodes and Purser 1998).

In rating this attribute, therefore, enter values that represent ambient conditions, i.e., not that would be found in egg pockets immediately following redd construction. Note: at the time that this document was written, the rules that translate fine sediment levels into survival response for the incubation life stage assume that all spawning sites would return to pre-spawning levels prior to emergence. This rule should be reviewed to account for situations when this is not the case, such as likely occurs in many streams for spring spawning species.

The reasons for considering whether particles < 0.85 mm or < 6 mm are the dominant size class of fine sediment in streams are outlined in Chapman and McLeod (1987) and Kondolf (2000). In general, where lithologic types contribute high volumes of sand size particles, the larger size class will be used (such as in the Idaho Batholith and in Northern California). Many other areas in the Pacific Northwest will best be characterized using the smaller particle size.

Special Instructions for New Input or Updates

All months should be rated the same for fine sediment load (intragravel).³

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attribute, Sediment Load and, in turn, affects resultant species productivity through the egg incubation life stage.

References/Sources

Importance and Role: Everest and others (1987), Bjornn and Reiser (1991), Peterson and others (1994).

Factors Affecting: Rittmueller (1986), Peterson and others (1992), Montgomery and Buffington (1993), Kondolf (2000), Chapman and McLeod (1987), Peterson and others (1994) Rhodes and Purser (1998), May and others (1997), McHenry and others (1994).

³ This does not necessarily mean that conditions with a salmon egg pocket would experience the same level of fine sediments, particularly over the entire period of incubation. Currently the biological rules assume that conditions remain constant in the redd over the entire period, but conditions may differ by hydrologic regime, particularly between some streams in the high desert (e.g., the John Day subbasin) and those on the west side of the Cascade crest. This matter is being addressed through the rules.

Fish Community Richness

Attribute Category

4. Biological Community

Attribute Sub-Category

4.1 Community Effects

Shaping

Fish Community Richness is a non-shaped attribute.

Definition/Usage

Measure of the richness of the fish community (no. of fish taxa, i.e., species).

Importance and Role

Fish community richness can influence the relative magnitude of interspecific interactions, including both competition and predation effects. Generally, the diversity of fish species increases from headwaters to downstream areas within a river system (Schlosser 1987, Li and others 1987). Hence the extent of interspecific interactions generally increases in a downstream direction within a river system. Predation, particularly on smaller individuals, such as juvenile salmonids, and competition are believed to be the dominant processes affecting community structure in downstream areas (Reeves and others 1998).

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
2 or fewer fish taxa	3-7 fish taxa	8-17 fish taxa	18-25 fish taxa	> 25 fish taxa

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Generally, fish species richness will increase in a downstream direction from headwaters to river mouth. All months should be rated the same for this attribute.

Special Instructions for New Input or Updates

This metric is to be determined by counting the number of fish species present within a drainage or subdrainage. Use taxonomically valid fish species definitions. Do not count multiple races of one species, i.e., spring and fall Chinook are to be counted as one species. Non-indigenous fish species are to be included in the count. Use a count of 35 species as an index value of exactly 4 (i.e., a rating of 3.5 would equate to 25 taxa).

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attributes of Competition and Predation, which, in turn, affect productivity of juvenile life stages of salmon and steelhead.

References/Sources

Importance and Role: Li and others (1987), Schlosser (1987), Reeves and others (1998)

Fish Pathogens

Attribute Category

4. Biological Community

Attribute Sub-Category

4.1 Community Effects

Shaping

Fish Pathogens is a non-shaped attribute.

Definition/Usage

The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

Importance and Role

Diseases may be controlling factors in the abundance of both cultured and wild fish and, therefore, should be an integral part of any assessment of these populations (Hedrick 1998). Diseases can directly influence performance, susceptibility to predation, success of reproduction, and other factors necessary for survival and propagation. These effects can be cumulative and have catastrophic consequences for wild fish populations (Nehring and Walker 1996). In the past, wild fish were generally viewed as relatively free of diseases. It is widely recognized, however, that disease micro-organisms and parasites are inherent in aquatic ecosystems. Wild fish are universally exposed. While exposure to pathogens may be a common contributor to their mortality, under certain circumstances, it may be a major factor in affecting wild population performance (Hedrick 1998).

The web of influences that determines effects of pathogens on wild fish is complex and not well understood. There are, however, certain issues that increase the risk of wild fish being adversely affected by pathogens, including:

- presence of sockeye in the immediate drainage; sockeye and kokanee may be "natural" hosts of IHNV (LaPatra 1998);
- proximity to a hatchery and/or frequency of hatchery fish releases (Hedrick 1998);
- presence of Whirling Disease or *Ceratomyxa shasta*, including their hosts, in the immediate drainage (Modin 1998, Bartholomew 1998).

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
No historic or recent fish stocking in drainage and no known incidences of whirling disease, C. shasta, IHN, or IPN. Fish stocking history is assumed to be an indicator of the potential for introductions of pathogens into the system in such manner to affect the relative abundance and species of pathogenic organisms.	Historic fish stocking, but no fish stocking records within the past decade, or sockeye population currently existing in drainage, or known incidents of viruses among kokanee populations within the watershed.	On-going periodic, frequent, or annual fish stocking in drainage or known viral incidents within sockeye, Chinook, or steelhead populations in the watershed.	Operating hatchery within the reach or in the reach immediately downstream or upstream	Known or strongly expected presence of whirling disease or C. shasta within the watershed, together with known or strongly expected presence of intermediate hosts for these species.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

This attribute is intended to capture the relative risk of wild fish being exposed to dangerous levels of pathogen concentrations, increasing the likelihood for infection. The attribute by necessity addresses only a few circumstances for exposure: presence of hatchery fish, presence of known host species to IHN, occurrence of known epizootics of virus in wild fish, and occurrence of two particularly virulent parasites, Whirling Disease and *C. shasta*.

The causative agent of Whirling Disease, *Myxobolus cerebralis*, an amoeba, has a complex life cycle, which involves two hosts, the fish (trout or salmon) and tiny aquatic worms called tubifex. The water-borne parasite may not directly kill salmonids, but fish heavily infested can become deformed or exhibit the erratic tail-chasing behavior from which the disease gets its name. Eventually, heavily infected young fish die. The parasite is believed to have originated in Europe.

Important note regarding Whirling Disease: This parasite has had significant effects on trout in some Western states, including Montana and Colorado, perhaps due to environmental conditions that favor large tubificid worms (Modin 1998). Although it was discovered in some drainages of the Grande Ronde basin approximately 20 years ago, no adverse effects on salmon or trout populations in that system have been found (ODFW 2001). It was recently discovered in the Clackamas River in Oregon. Again, no adverse effects have been reported. Population declines attributed to Whirling Disease have never been detected in any wild salmon, steelhead or trout in Oregon (ODFW 2001). Because of this, we expect that we will revise the rating definitions for this attribute to address the effects of this parasite more consistently with the pattern of effects seen in Western states. *Prior to that update, we advise that streams in Oregon where the parasite has been found be given a rating of 2, unless other conditions exist that warrant a higher rating.*

Ceratomyxa shasta is a myxosporean protozoan parasite that afflicts salmonid fish of the Pacific Northwest. It requires an intermediate host, a freshwater polychaete, before it can infect a fish. Infection occurs through contact with the infectious stage (actinospore), which occurs in the water column. It causes a severe infection of the intestinal tissues. Once infected, mortality is generally very high, often greater than 50% (Bartholomew 1998). The parasite and its intermediate host have been found (or the host is believed to be present) in the Cowlitz River, Deschutes River (Central Oregon), Willamette River, and Klamath River. Infection rates appear to be higher in or below reservoir environments than in mainstem rivers without reservoirs.

Special Instructions for New Input or Updates

As noted above, we expect to update the rating definitions used with this attribute. At this time we advise applying a rating of 2 to streams in Oregon where Whirling Disease has been discovered.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 survival factor Pathogens, which, in turn, affects productivity of juvenile life stages of salmon and steelhead.

References/Sources

Importance and Role: Nehring and Walker (1996), Bartholomew (1998), Hedrick (1998), LaPatra (1998), Modin (1998).

Factors Affecting: Bartholomew (1998), Modin (1998), ODFW (2001).

Fish Species Introductions

Attribute Category

4. Biological Community

Attribute Sub-Category

4.1 Community Effects

Shaping

Fish Species Introductions is a non-shaped attribute

Definition/Usage

Extent of introductions of exotic fish species in the vicinity of the stream reaches under consideration.

Importance and Role

Fish species introductions are a major contributor to the decline of native fishes in many areas of the Pacific Northwest (Li and others 1987, Reeves and others 1998). Some native fish communities have been significantly altered as a result of competition with, or predation from, various exotic species. Li and others (1987) describes a major restructuring of food webs in large mainstem rivers, such as the Columbia River and the lower portions of its larger tributaries, where smallmouth bass and walleye are now dominant predators. In smaller streams, introduced brook trout, brown trout, and rainbow trout have affected, perhaps displaced in some areas, native species through competition or hybridization (Rieman and McIntyre 1993).

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
No non-native species reported or known to be in the sub-drainage of interest.	1-2 non-native species reported or known to be in the sub-drainage of interest.	3-7 non-native species reported or known to be in the sub-drainage of interest.	8-14 non-native species reported or known to be in the sub-drainage of interest.	15 or more non-native species reported or known to be in the sub-drainage of interest.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Generally, the number of nonnative introductions will increase in a downstream direction from headwaters to river mouth. Upper areas may have introduced trout or charr, such as brook trout. Lower areas near the river mouth may include bass, walleye, and catfish, as well as other species.

We recognize that this attribute does not provide the specificity needed to address interactions resulting from specific exotic species. Bull trout, for example, can be strongly affected by the

presence of brook trout (Rieman and McIntyre 1993), while the effects of another introduced species, such as rainbow trout, would be expected to be much less. A future modification to address this attribute will include identification of each introduced species.

Special Instructions for New Input or Updates

This metric is to be determined by counting the number of introduced fish species within a drainage or subdrainage (such as in the upper reaches vs. lower reaches). Use taxonomically valid fish species definitions. Do not include introductions of nonnative subspecies as separate species (such as the introduction of coastal rainbow trout *O. mykiss irrideus* into areas inhabited by redband trout *O. mykiss gairdneri*). Do not count multiple races of one species, i.e., spring and fall Chinook are to be counted as one species. Use a count of 20 introduced as an index value of exactly 4 (i.e., a rating of 3.5 would equate to 15 species).

Rate all months the same for this attribute.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attributes of Predation, Competition, and Pathogens (depending on focus species) that, in turn, affect productivity of juvenile and adult life stages.

References/Sources

Importance and Role: Li and others (1987), Rieman and McIntyre (1993), Reeves and others (1998).

Factors Affecting: Rieman and McIntyre (1993).

Flow—Change in Inter-annual Variability in High Flows

Attribute Category

1. Hydrologic Characteristics

Attribute Sub-Category

1.1 Flow variation

Shaping

High Flow is a shaped attribute. See Appendix

Definition/Usage

The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as $T_{Q_{mean}}$, see Konrad 2000b), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q_{2yr}).

Importance and Role

Hydrologic patterns of ecologically healthy watersheds in the coastal ecoregion are strongly related to the timing and quantity of flow, characteristics of seasonal water storage, and dynamics of surface-subsurface exchanges.

Changes in the timing and quantity of flow, due to land uses and flow regulation, can affect responses of stream dwelling organisms like salmonids, leading to changes in overall performance of their populations.

Species adapted to disturbance events (such as floods) of intermediate intensity, as occurred in most pristine watersheds of the Pacific Northwest, can be negatively affected by increases in the frequency and magnitude of disturbance. Changes in flow runoff patterns associated with urbanization, channelization, and timber harvest can increase both magnitude and frequency of high flow events resulting in increased intensity of disturbance.

Moreover, hydrologic regimes that have been shifted to more stable patterns (i.e., less variation and reduced high flows) can result in loss of habitat quality if channel/habitat forming events occur much less frequently.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
<p>Peak annual flows expected to be strongly reduced relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >40% and <100% decrease in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known by regulated flow levels. This condition is associated with flow regulation or water diversion projects.</p>	<p>Peak annual flows expected to be moderately reduced relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >20% and <40% decrease in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known by regulated flow levels. This condition is associated with flow regulation or water diversion projects.</p>	<p>Peak annual flows expected to be comparable to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR <20% change in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state); OR <5% reduction in average T_{Qmean} compared to the undeveloped watershed state.</p>	<p>Peak annual flows expected to be moderately increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >20% and <40% increase in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state); OR >5% and <15% reduction in average T_{Qmean} compared to the undeveloped watershed state. This condition exemplified in some forested watersheds with high road density that experience significant rain on snow events, as the North Fork Stillaguamish River (Pess and others <i>in review</i>). Note: many managed forested watersheds in the Pacific Northwest exhibit slight, if any, increases in peak annual flows since logging commenced (see Ziemer and Lisle 1998).</p>	<p>Peak annual flows expected to be strongly increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >40% and <110%+ increase in Q_{2yr} based on a long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state); OR >15% and <45% reduction in average T_{Qmean} compared to the undeveloped watershed state. This condition exemplified in watersheds with significant urbanization (e.g., >20%).</p>

Factors Affecting Attribute/Guidelines

The attribute defines the relative extent of change in annual peak flow that has occurred over time as a result of watershed development.

Changes in vegetation cover and land use as a result of watershed development can alter the hydrograph shape, modifying inter-annual high flow variation and peak discharge. Because

vegetation cover affects infiltration rates, its removal can cause direct runoff to increase and hydrographs to become more peaked. This is most strongly seen in urban areas, where total runoff and peak discharges are increased relative to the pristine conditions. Depending on the degree of watershed impervious cover, as occurs in urban areas, the annual volume of storm water runoff can increase by 2 to 16 times its predevelopment rate (Booth 1991, Schueler 1995).

It should be noted that interannual variation in peak annual flow (measured as the coefficient of variation of the annual peak flow) will generally decrease as % impervious surfaces increases in a drainage (Konrad 2000a, Konrad 2000b). This pattern is due to a differential increase in the magnitude of smaller, frequent high flow events relative to larger floods. The result is that CV of the annual peak flow is likely to generally decrease with increasing impervious surface, but it has been shown that use of this metric to assess changes in a watershed requires a very long times series of data (Konrad 2000a, Konrad 2000b).

The index values for this attribute have been scaled to the pristine state, described by Index Value 2. Shifts toward higher peak discharge are represented by Index Value 3 and 4 and reduced peaks by values 0 and 1. The latter conditions would be characteristic of reaches subject to moderate or strong flood control or hydroregulation projects.

Three options are provided to assign index levels for this attribute. The first is based on generalized qualitative statements to describe expected changes in peak flow in relation to watershed development, the second is based on changes in the peak annual flow event expected on average once every two years (Q_{2yr}), and the third is inferred from changes in a metric that describes flow "flashiness" (T_{Qmean}).

The third option, which describes "flashiness", is also used to characterize the Level 2 attribute Flow-Intra-Annual Flow Variation. Generally, when flow "flashiness" increases, the annual peak flow is also expected to increase (Konrad 2000a). An advantage of using this metric to assess changes in flow characteristics in relation to land use changes is that it requires relatively short time series of data (approximately 10 years per land use state). See Flow-Intra-Annual Flow Variation for a further description of its properties.

The second option, use of Q_{2yr} , requires a sufficiently long time series to assess the change, which is not the case for some watersheds in the region. Many data sets do exist and can be obtained at the USGS web site. Computation of Q_{2yr} is based on the peak annual flow, not the highest mean daily flow for a year. Two useful web sites that describe the calculation of flood recurrence intervals are:

<http://dept.kent.edu/geology/rcraig/courses/Dynamics/flood%20recurrence%20interval.htm>

http://www.cs.umt.edu/GEOLOGY/classes/Comp_Geol/flood.htm

Eight examples that show patterns of change in peak annual flows for streams in the Pacific Northwest are given in Figure 5. In each example, the data record was divided approximately in half, considering that a comparison of the two periods would provide an approximation of change in peak flow that might be ascribed to watershed development that has occurred during the entire period of record (Table 3). These examples are provided for illustration—actual

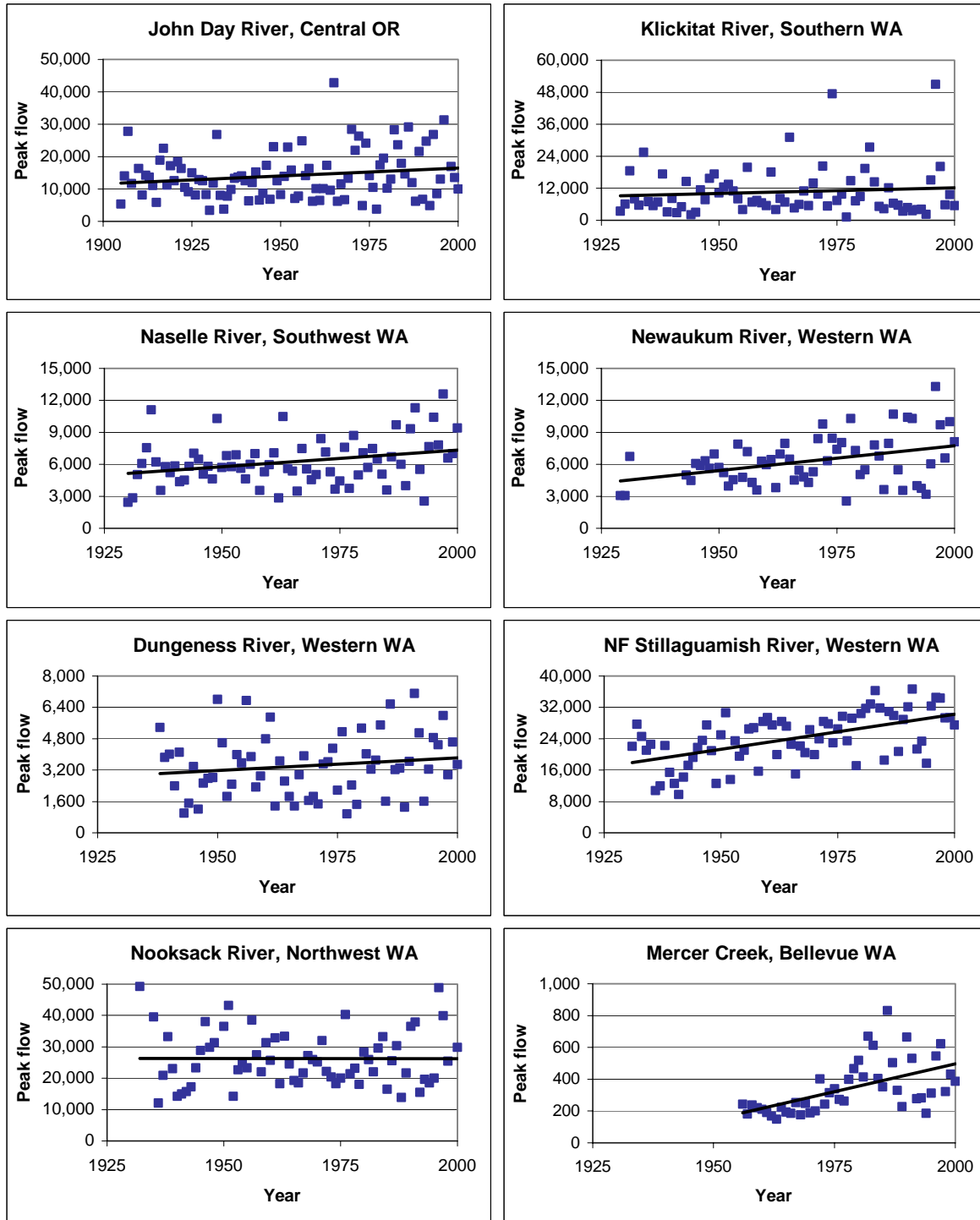


Figure 5. Patterns of annual peak flows seen in eight streams in the Pacific Northwest. No flow regulation occurs in any stream shown (data from USGS).

Table 3. Estimated percent change in peak flow expected once every two years in eight streams between periods of record (see Figure 5).

Stream	Period 1	Period 2	% change in Q_{2yr}	Attribute rating
John Day	1905-1952	1953-2000	8%	2.2
Klickitat	1929-1964	1965-2000	-2%	2.0
Naselle	1930-1964	1965-2000	14%	2.4
Newaukum	1929-1969	1970-2000	33%	3.2
Dungeness	1938-1965	1966-2000	11%	2.3
NF Stillaguamish	1929-1964	1965-2000	30%	3.0
Nooksack	1932-1965	1966-2000	2%	2.0
Mercer	1956-1977	1978-2000	86%	3.8

application to a watershed might involve different divisions of the data record to represent various states of the watershed over time.

The eight examples show a wide range of change in peak flows over time, from essentially no change (Klickitat and Nooksack) to moderate change (NF Stillaguamish and Newaukum rivers) to severe change (Mercer Creek). The major land use in the Stillaguamish and Newaukum drainages is forest management. Mercer Creek is an urbanized stream that has undergone major development since the 1960s. Using the estimated change in Q_{2yr} between periods, ratings were assigned to each stream for purpose of illustration (Table 3).

It should be noted that not all of the change estimated in Q_{2yr} between periods for the eight examples is likely due to watershed development. Changes in precipitation patterns over the period of record have likely contributed—there is evidence that some areas have experienced an increase in precipitation in recent decades (e.g., Figure 6). This may explain why all but one watershed exhibits at least a small increasing trend in peak flow over the periods of record. It is probable, for example, that increased peak flows in the NF Stillaguamish River watershed are partially the result of higher precipitation levels (as seen at the Concrete station), though land use appears to be the primary cause. Increased peak flows are suspected of contributing to the decline of Chinook population abundance in the NF Stillaguamish River (Pess and others *in review*).

Care needs to be exercised in assigning ratings to watersheds that are in forest management. Many watersheds that are managed for timber production may not exhibit much (if any) increase in peak flow due to land use, though this appears to be controversial and open to debate (Ziemer and Lisle 1998).

Special Instructions for New Input or Updates

Rate the month when high flow variability (between years) will be greatest. Rate only one month. Other months will be computed on the basis of the flow pattern that is entered into the Stream Reach Editor by the user. See Appendix for guidelines in formulating the flow pattern to use.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 survival factor Flow, which captures the contribution of high flow in affecting productivity of several life stages, notably fry colonization and inactive stages of salmonids. Note: the magnitude and duration of high flow during a flood event affects bed scour, treated separately under the Level 2 attribute bed scour.

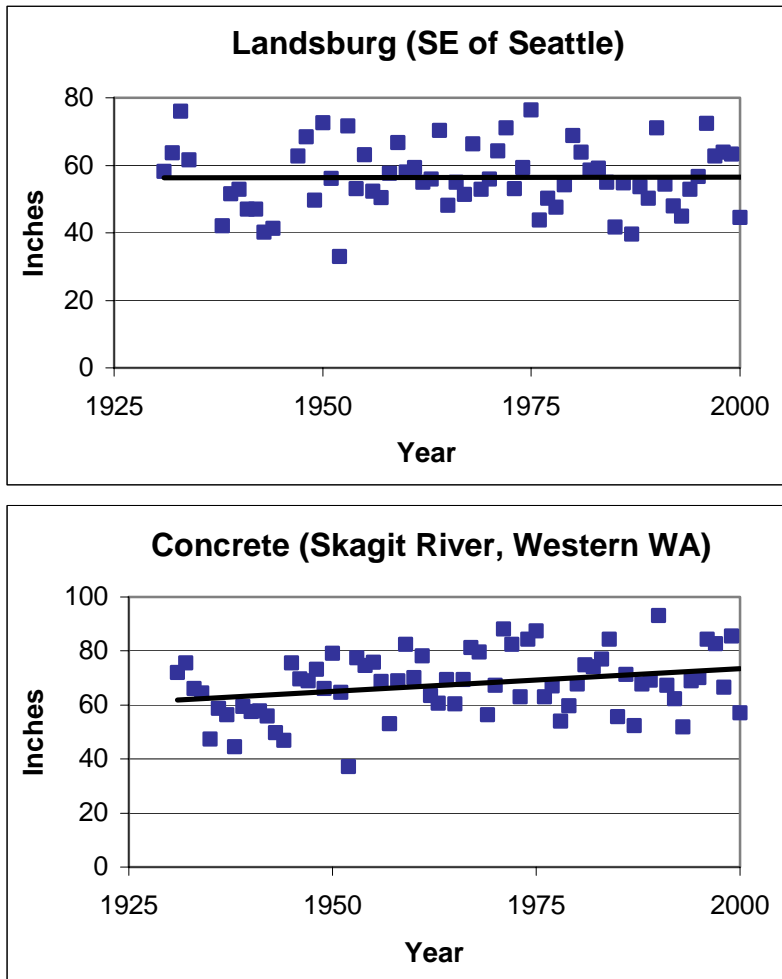


Figure 6. Annual precipitation at two stations in Western Washington. Landsburg is located in the Cascade foothills SE of Seattle. Concrete is located just north of the weather convergence zone north of Seattle in Western Washington. Some missing data were estimated from relationships with other stations; some data still missing due to lack of suitable relationships (data from Western Regional Climate Center, <http://www.wrcc.dri.edu/index.html>).

References/Sources

Importance and Role: Stanford and Ward (1992).

Factors Affecting: Federal Interagency Stream Restoration Working Group (1998), Gordon and others (1992), Schueler (1995), Pess and others (in review), Konrad (2000a), Konrad (2000b), Ziemer and Lisle (1998), Booth (1991).

Flow—Change in Inter-annual Variability in Low Flows

Attribute Category

1. Hydrologic Characteristics

Attribute Sub-Category

1.1 Flow Variation

Shaping

Low Flow is a shaped attribute. See Appendix.

Definition/Usage

The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000a). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

Importance and Role

Hydrologic patterns of ecologically healthy watersheds are strongly related to the timing and quantity of flow, characteristics of seasonal water storage, and dynamics of surface-subsurface exchanges.

Changes in the timing and quantity of flow due to land uses and flow regulation can affect responses of stream dwelling organisms like salmonids, leading to changes in overall performance of their populations. This attribute defines how low flow (e.g., during late summer) has changed relative to the undisturbed state. Reduced low flows can result in survival reduction due to increased exposure of rearing or adult fish or migration difficulties. Note: changes in quantity of flow are also expressed indirectly through the correlates describing wetted channel width (during high flow and low flow months). The low flow channel width correlate would correspond more closely with the empirical relationships reported between salmon abundance and summer low flow by various authors (e.g., for coho salmon by Smoker 1955 and Seiler 2001).

Categorical conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Average daily low flows expected to be strongly increased compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >75% increase in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.	Average daily low flows expected to be moderately increased compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >20% and <75% increase in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.	Average daily low flows expected to be comparable to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR <20% change in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state).	Average daily low flows expected to be moderately reduced compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >20% and <50% reduction in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.	Average daily low flows expected to be severely reduced compared to an undisturbed watershed of similar size, geology, and flow regime (or the pristine state for the watershed of interest); OR >50% and <=100% reduction in the 45 or 60-day consecutive lowest average daily flow on a sufficiently long time series (~40 yrs or longer with at least 20 yrs pertaining to a watershed development state) or as known through flow regulation.

Factors Affecting Attribute/Guidelines

Changes in vegetation cover and land use as a result of watershed development can alter the hydrograph shape in some streams, increasing inter-annual low flow variation or decreasing extreme low flow discharge. Changes in vegetation cover, reduction in the amounts of wetlands, and roads can alter the retention time and pattern of runoff in a watershed, resulting in reduced low flows. Urbanization can result in dramatic reductions in low flows compared to the predevelopment condition. Impervious cover prevents infiltration into the soil, reducing groundwater recharge. Consequently, during extended periods without rainfall, baseflow levels can be severely reduced in some streams (Simmons and Reynolds 1982). However, this apparently is not always the case, even in urbanized streams (Konrad 2000a). A strong rationale should exist in concluding that low flows have been reduced in a given watershed.

The index values for this attribute have been scaled to the pristine state, described by Index Value 2. Shifts toward more interannual variability or lower low flow discharge are represented by Index Value 3 and 4; less variability or increased low flows by values 0 and 1.

Rate as 2 the pristine state for all stream reaches. This index value states that inter-annual variation is equal to what would have occurred in the watershed's natural state.

Rate as 3 or 4 the reaches affected by land uses that increase between-year variation in low flow or reduce low flows. Rate as 0 or 1 the reaches subject to flow regulation that act to stabilize low flow or increase them. The latter conditions can lead to increased survival of salmonids in some life stages, at least in the short-term. Over the long-term, habitat-forming disturbance events may be reduced in frequency, leading to degradation of some Environmental Attributes.

Special Instructions for New Input or Updates

Rate the month when low flow variability (between years) will be greatest. Rate only one month. Other months will be inferred from an appropriate flow pattern for the watershed of interest.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attributes Flow and Predation⁴, which in turn affect productivity of certain life stages of salmonids.

References/Sources

Importance and Role: Stanford and Ward (1992), Smoker (1955), Seiler (2001).

Factors Affecting: Federal Interagency Stream Restoration Working Group (1998), Gordon and others (1992), Simmons and Reynolds (1982), Konrad (2000a).

⁴ The effect of Low Flow on predation is likely incorrect and will probably be adjusted.

Flow—Intra-daily (Diel) Variation

Attribute Category

1. Hydrologic Characteristics

Attribute Sub-Category

1.1 Flow Variation

Shaping

Diel Flow is a shaped attribute. See Appendix.

Definition/Usage

Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

Importance and Role

Sudden changes in flow associated with flow regulation or storm runoff can result in displacement of rearing juveniles or, in the case of loss of flow, in stranding. Such rapid flow changes can also affect other Environmental Attributes, like streambank erosion and riparian habitat.

Categorical conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Essentially no variation in discharge during an average 24-hr period during season or month. This characterizes conditions not influenced by flow ramping or accelerated storm runoff. This rating also would apply to small suburban-urbanized drainages with impervious surfaces of <10% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Slight to low variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) slight to low ramping condition associated with flow regulation, averaging <2 inches change in stage per hour. This condition has both slight to low rates of change in flow and high frequency with which it occurs. This rating also would apply to small suburban-urbanized drainages with impervious surfaces of ~10-25% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Low to moderate variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) low to moderate ramping condition associated with flow regulation, averaging >2 inches and <6 inches change in stage per hour. This condition has both moderate to high rates of change in flow and high frequency with which it occurs. This rating also would apply to small suburban-urbanized drainages with impervious surfaces of ~25-40% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Moderate to high variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) moderate to high ramping condition associated with flow regulation, averaging between 6 inches to 12 inches change in stage per hour. This condition has both moderate to high rates of change in flow and high frequency with which it occurs. This rating also would apply to small suburban to urbanized drainages with impervious surfaces of ~40-50% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.	Extreme variation in flow stage during an average 24-hr period during season or month. This pattern typical of routine (everyday) extreme ramping condition associated with flow regulation, averaging between 12 inches to 24 inches change in stage per hour. This condition is both extreme in the rate of change in flow and the frequency with which it occurs. This rating would apply to small, heavily urbanized drainages with impervious surfaces of 50-80% in high rainfall climates (e.g., Puget Lowlands) and with little or no flow detention systems in place.

Factors Affecting Attribute/Guidelines

Most, if not all, pristine basins should be assigned a rating of 0. This rating indicates that the average daily fluctuation in flow over a month is slight. *Note: under pristine conditions, some streams could experience much more variation over a single day, but the average value over a month would be minimal.*

The rating should be applied in consideration of the average expected variation over a month.

Special Instructions for New Input or Updates

Rate the month when diel variation will be greatest. Rate only one month. Other months will be inferred from an appropriate flow pattern for the watershed of interest. In this case, the month will likely occur during power peaking. Any unusual pattern should be noted in the comments.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attribute Flow, which, in turn, affects survival of free-swimming fish (including emergent fry) or the survival of eggs due to stranding.

References/Sources

Importance and Role: Federal Interagency Stream Restoration Working Group (1998), Gordon and others (1992).

Factors Affecting: Federal Interagency Stream Restoration Working Group (1998), Gordon and others (1992).

Flow—Intra-annual Flow Pattern

Attribute Category

1. Hydrologic Characteristics

Attribute Sub-Category

1.1 Flow Variation

Shaping

Intra-Annual Flow is a shaped attribute. See Appendix.

Definition/Usage

The average extent of intra-annual flow variation during the primary runoff season – in other words, the attribute is a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with percent total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric T_{Qmean} , see Konrad 2000a and b), or inferred from patterns corresponding to watershed development.

Importance and Role

Frequent, significant changes in flow over a relatively short time-period like a month associated with flow regulation or storm runoff can result in displacement of rearing juveniles during high flows, or, in the case of loss of flow, in stranding.

Categorical conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Storm runoff response (rates of change in flow) expected to be slowed greatly relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >15% increase in average T_{Qmean} compared to the undeveloped watershed state or as known by regulated flow levels. This condition is associated with flow regulation.	Storm runoff response (rates of change in flow) expected to be moderately slower relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >5% and <15% increase in average T_{Qmean} compared to the undeveloped watershed state or as known by regulated flow levels. This condition is associated with flow regulation.	Storm runoff response (rates of change in flow) comparable to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR <5% reduction in average T_{Qmean} compared to the undeveloped watershed state.	Storm runoff response (rates of change in flow) expected to be moderately increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >5% and <15% reduction in average T_{Qmean} compared to the undeveloped watershed state. This condition exemplified in some managed forested watersheds with high road density, likely most evident in small drainages.	Storm runoff response (rates of change in flow) expected to be strongly increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (or the pristine state for the watershed of interest); OR >15% and <45% reduction in average T_{Qmean} compared to the undeveloped watershed state. This condition exemplified in watersheds with significant urbanization.

Factors Affecting Attribute/Guidelines

This attribute is similar to the one that describes diel variation in flow, only it acts on a slightly longer time scale. The extreme on the high end in this attribute would be seen in heavily urbanized watersheds. Less extreme conditions would be found in watersheds with a high amount of vegetation cover removed (e.g., high degree of clearcutting) or high road densities. In heavily urbanized streams, the annual volume of storm water runoff can increase by 2 to 16 times the predevelopment rate; essentially every rainfall event can produce a sharp spike in the hydrograph, resulting in a high degree of flashiness (Schueler 1995).

Rate as 2 the pristine state for all stream reaches. This index value states that within-year variation is equal to what would have occurred in the watershed's natural state.

Rate as 3 or 4 the reaches affected by land uses that increase within-year variation daily flow. Rate as 0 or 1 the reaches that are subject to flow regulation that acts to reduce within-year variation.

Lower values of T_{Qmean} indicate more rapid recession rates in storm flow and shortened durations of intermediate to high flows (Konrad 2000a, page 36). Short duration flows may be insufficient to exhaust the local supply of small and unconstrained particles from a gravel streambed and, thus, will fail to form a stable armor layer.

The effects of storm-scale hydrologic changes on the biological conditions of streams can be difficult to deduce because biological conditions in streams quickly re-establish, often within months, after hydrologic disturbances such as floods. But, over multiple-year time scales, changes in stream flow patterns may have a persistent influence on the biological conditions of streams (Poff and others 1997).

In a stream with stable land use, T_{Qmean} varies little from year to year. Since T_{Qmean} does not display high inter-annual variability, it can be estimated reliably from a relatively short (e.g., ~10 years) stream flow record. In Mercer Creek, Bellevue, WA, where urbanization has steadily progressed over the past several decades, T_{Qmean} shows a steady decline from 1960-1998.

T_{Qmean} will be affected by basin size because runoff patterns are attenuated as basin size increases.

Konrad (2000a): "Once a stream basin has been developed and land use is relatively stable, the stream channel can be expected to attain a new equilibrium with the urban stream flow patterns (Henshaw and Booth in prep)." Konrad continues "Thus, bed disturbance in gravel-bed streams will be more frequent and extensive than it was prior to development as a result of hydrologic changes provided sediment continues to be available for transport in the stream."

Special Instructions for New Input or Updates

Rate the month when intra-annual flow variation is greatest. It is assumed that this variation will be greatest during high runoff months. Rate only one month. Other months will be inferred from an appropriate flow pattern for the watershed of interest.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attribute Flow and, in turn, principally affects survival of fingerlings during overwintering. It can affect other free-swimming stages also. In addition, it can affect survival from egg to emergence due to redd stranding.

References/Sources

Definition: Konrad (2000a and b).

Importance and Role: Gordon and others (1992), Konrad (2000a and b).

Factors Affecting: Federal Interagency Stream Restoration Working Group (1998), Gordon and others (1992), Poff and others (1997), Schueler (1995), Konrad (2000a and b).

Gradient

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.1 Channel Morphometry

Shaping

Gradient is a non-shaped attribute.

Definition/Usage

Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

Importance and Role

Channel gradient (or slope) describes how the channel's elevation changes over distance. It is an important determinant of flow velocity and sediment transport within a reach. It is a controlling factor in channel shape and pattern, and therefore in determining the types and stability of habitat within a reach. Hence it can be an important factor in controlling the overall suitability of a reach for salmonid utilization and survival.

Categorical conclusions

Gradient is entered as a point estimate (percentage).

Factors Affecting Attribute/Guidelines

Channel gradient has a key role in driving geomorphic processes of erosion, sediment transport, and sediment deposition. It is determinant of a stream's power to affect these processes. As gradient increases, flow velocity increases and so does stream power, providing the energy to rework channel materials.

Channel straightening and clearing will generally increase gradient within a reach compared to the pre-altered state. This in turn increases the amount of energy available for bank erosion and sediment transport, including bedload movement. Channel entrenchment or incision also generally increases channel slope during the period of channel headcutting. In contrast, channel degradation associated with sediment deposition results in a lower gradient in the reach of deposition compared to the pre-altered state, though the channel may then become unstable as it moves back toward its earlier state.

Special Instructions for New Input or Updates

Estimates of stream channel gradient are required to be input, i.e., as point estimates.

Effect on Level 3 Survival Factors

This attribute is used to define the effect of two Level 3 survival factors: Habitat Diversity and Flow on several salmonid life stages. In the former, gradient serves as the primary determinant of how other attributes, such as wood and riparian condition combine to define the factor Habitat Diversity. In the latter, it serves as a modifying correlate, to control the overall severity of the effect of high flow on fry colonization and inactive life stages of salmonids.

References/Sources

Importance and Role: Gordon and others (1992).

Factors Affecting: Federal Interagency Stream Restoration Working Group (1998), Gordon and others (1992).

Habitat Type—Backwater Pools

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

Percentage of the wetted channel surface area comprising backwater pools. Backwater pools are habitat units located along the channel margins but are otherwise enclosed—though still connected to the main channel (or side channel). *Note: backwater pools as defined here include "alcoves" as described by Nickleson and others (1992).*

Importance and Role

Backwater pools are located along channel margins, resulting in low water velocities through these habitat units. They often are relatively shallow with fine-grained substrates. Backwater pools are particularly important as nursery areas for fry of some salmonid species (e.g., coho and Chinook), as well as for continued rearing during summer. They also serve as refuge areas during winter, particularly within deeper backwater pools.

Bisson and others (1982) and Nickelson and others (1992) reported a strong preference for this habitat type by coho emergent fry and juveniles during both summer and winter. Hayman and others (1996) reported high use of this habitat type by 0-age juvenile Chinook in the Skagit River, Western Washington.

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) slow water habitat types (after Hawkins and others 1994) are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel fast water habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the Off-Channel Habitat Factor.

Backwater pools typically comprise no more than a small portion (< 15%) of the wetted surface area of unconfined channels. Diking, channel straightening and loss of large wood (or jams)

reduces the amount of backwater pools. The relative quantity of backwater pools declines with increasing gradient, as well as with increasing extent of channel confinement.

Many data sets exist on the quantities of habitat types for different types of streams in the Pacific Northwest. Any person doing an EDT assessment should learn whether such data exist for the watershed of interest. For example, excellent data sets exist for streams in the National Forest, and the state of Oregon (<http://rainbow.dfw.state.or.us/nrimp/information/index.htm>). Other sources include the Northwest Indian Fish Commission and fish and wildlife agencies for individual tribes. Also, EDT stream reach datasets for many watersheds in the region are currently available online at <http://www.mobrand.com/edt/>). These can be examined for how streams were characterized on the west and east sides of the Cascades, under historic conditions, and in urban areas (such as for the lower areas of the Puyallup-White River, Chambers-Clover Creek, and Hylebos Creek in the Puget Sound region).

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of Key Habitat used by juvenile salmonids at different life stages.

References/Sources

Importance and Role: Bisson and others (1982), Hayman and others (1996), Hawkins and others (1994), Nickelson and others (1992).

Factors Affecting: Bisson and others (1982), Federal Interagency Stream Restoration Working Group (1998), Hayman and others (1996); see also <http://rainbow.dfw.state.or.us/nrimp/information/index.htm> for Oregon's data and <http://www.mobrand.com/edt> for existing EDT datasets.

Habitat Type—Beaver Ponds

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

Percentage of the wetted channel surface area comprising beaver ponds. *Note: this includes only those sites associated with the main channel or its side channels. Off-channel sites are addressed through the Off-Channel Habitat Factor.*

Importance and Role

Beaver ponds provide important ecological functions in riverine systems inhabited by salmonids. These functions include nutrient retention, sediment trapping, and amelioration of flow and temperature extremes. Beaver ponds provide habitat to salmonids, notably during juvenile life stages. Low velocities associated with this habitat type make these sites particularly preferable by some salmonid species for rearing or overwintering.

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) slow water habitat types (after Hawkins and others 1994) are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel fast water habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the Off-Channel Habitat Factor.

Beaver activity occurs most frequently in relatively low gradient, unconfined reaches. Land uses of various kinds, particularly urbanization can reduce beaver abundance and the amount of beaver ponds. Disruption of riparian function and stream channel alterations, such as channelization and straightening, typically reduce beaver activity.

For this application, do not include beaver ponds found in off-channel areas. Those habitat units are estimated through the Off-Channel Habitat Factor.

Many data sets exist on the quantities of habitat types for different types of streams in the Pacific Northwest. Any person doing an EDT assessment should learn whether such data exist for the watershed of interest. For example, excellent data sets exist for streams in the National Forest, and the state of Oregon (<http://rainbow.dfw.state.or.us/nrimp/information/index.htm>). Other sources include the Northwest Indian Fish Commission and fish and wildlife agencies for individual tribes. Also, EDT stream reach data sets for many watersheds in the region are currently available online at <http://www.mobrand.com/edt/>). These can be examined for how streams were characterized on the west and east sides of the Cascades, under historic conditions, and in urban areas (such as for the lower areas of the Puyallup-White River, Chambers-Clover Creek, and Hylebos Creek in the Puget Sound region).

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of Key Habitat used by salmonids at different life stages. The attribute also affects the Level 3 attributes Flow, which, in turn, affects productivity of certain life stages of salmonids.

References/Sources

Importance and Role: Bisson and others (1982), Cederholm and others (2000).

Factors Affecting: Bisson and others (1982), Federal Interagency Stream Restoration Working Group (1998), Maser and Sedell (1994); see also <http://rainbow.dfw.state.or.us/nrimp/information/index.htm> for Oregon's data and <http://www.mobrand.com/edt> for existing EDT datasets.

Habitat Type—Large Cobble/Boulder Riffles

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

Percentage of the wetted channel surface area comprising large cobble/boulder riffles. Particle sizes of substrate modified from Platts and others (1983) based on information in Gordon and others (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (> 11.9 inch diameter).

Importance and Role

Riffles tend to support higher densities of benthic invertebrates than pools, and are thus important food-producing areas for fish. The most productive streams typically are composed of the pool-riffle sequence, providing a diversity of habitats and food-producing areas. In terms of physical habitat, the pool-riffle structure provides a great diversity of bedforms, substrate materials and local velocities. Brussock and others (1985), cited in Gordon and others (1992), proposed that the reason biotic diversity is greatest in the mid reaches of a river system is because they usually possess a pool-riffle morphology.

Bisson and others (1982) reported that relatively low gradient riffles are selectively occupied by subyearling steelhead and cutthroat; these areas are not preferentially used by older age classes of these species. These riffles can be comprised of both small cobble/gravel and large cobble/boulder substrates. Utilization of rapids and cascades (comprised of large cobble/boulder riffles) by juvenile salmonids is generally limited to yearling and older steelhead and rainbow. Chapman and Bjornn (1969) reported that steelhead occupy swifter water as they grow larger, suggesting to these authors that preference for faster water was associated with increased exposure to food organisms by this species.⁵

Substrate size associated with this habitat type is unsuited for spawning by salmonids, except that small pockets of small cobble/gravel can be interspersed within this habitat type enabling successful redd construction by salmonids. *Note: those pockets containing small cobble/gravel substrates should be considered as part of the habitat type associated with that substrate size.*

⁵ Juvenile steelhead utilize all habitat types, though maximum rearing densities tend to increase with increasing gradient, to some limit, perhaps in the range 4-8% (see Johnson 1985 and Johnson and others 1988).

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) slow water habitat types (after Hawkins and others 1994) are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel fast water habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the Off-Channel Habitat Factor.

In general, the percent of the wetted channel comprised of this channel type will increase as gradient increases, although it will be affected by wood loading, stream size, channel type, and land use. In small to moderate sized streams and rivers, abundance of large wood can force morphologies on the channel by creating pools and small cobble/gravel riffles. Streams of similar sizes and features, but containing little or no large wood, would have a higher proportion of large cobble/boulder riffles, except within very low gradient channels (e.g., $< 1\%$). In larger rivers, the effect of large wood pool formation will be considerably less, except as associated with side channels, which are created by large wood.

The relative proportion of the wetted channel comprised of large cobble/boulder riffles can be affected by land use practices. As noted above, loss of wood load, especially in small to moderate sized streams with slopes $> 1\%$ can reduce relative proportions of pools and small cobble/gravel riffles, increasing the percent of wetted channel in large cobble/boulder riffles (glide type habitat units can also be increased).

The response of channels to increased sediment loads can be different in different portions of a drainage network. Generally, scour will increase in the steeper portions accompanied by aggradation in the lower portions of the network. Thus an increase in area of large cobble/boulder riffles may occur in the steeper areas with an increase in area of small cobble/gravel riffles downstream.

Diking and channel straightening can result in increased bed scour within the main channel, increasing channel roughness, and hence the relative amount of large cobble riffles.

Many data sets exist on the quantities of habitat types for different types of streams in the Pacific Northwest. Any person doing an EDT assessment should learn whether such data exist for the watershed of interest. For example, excellent datasets exist for streams in the National Forest, and the state of Oregon (<http://rainbow.dfw.state.or.us/nrimp/information/index.htm>). Other sources include the Northwest Indian Fish Commission and fish and wildlife agencies for individual tribes. Also, EDT stream reach data sets for many watersheds in the region are currently available online at <http://www.mobrand.com/edt/>). These can be examined for how streams were characterized on the west and east sides of the Cascades, under historic conditions, and in urban areas (such as for the lower areas of the Puyallup-White River, Chambers-Clover Creek, and Hylebos Creek in the Puget Sound region).

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of Key Habitat used by salmonids at different life stages.

References/Sources

Importance and Role: Bisson and others (1982), Brussock and others (1985), Chapman and Bjornn (1969), Gordon and others (1992), Mundie (1974).

Factors Affecting: Federal Interagency Stream Restoration Working Group (1998), Montgomery and Buffington (1993).

Habitat Type—Off-channel Habitat Factor

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat. Off-channel habitat consists of oxbows, back swamps, riverine ponds, and the channels that connect them to the main channel or its side channels.

Importance and Role

The channels of natural riverine systems tend to meander across their floodplains over time. This movement of channels results in a variety of topographic features along a floodplain. Some of these features form and maintain wetlands, marshes, and ponds. The aquatic sites comprising these areas are considered off-channel habitats.

Off-channel areas are an extremely important component of natural riverine systems. They store water, nutrients, and sediments, creating a mosaic of seasonal habitats for riverine-riparian biodiversity. They serve to slow water velocity during floods, creating refuges for aquatic animals during these events. These areas sometimes provide thermal refuge, because of the influence of groundwater, in areas where extreme water temperatures occur in the main channel during summer or winter. Because of these functions, off-channel habitats sometimes act as biological hotspots, supporting key biological functions to various species.

Off-channel habitat is particularly important for rearing for some salmonid species, notably coho salmon and cutthroat trout (Peterson and Reid 1984).

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) non-turbulent habitat types are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel turbulent habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the off-channel habitat factor.

Alluvial floodplains in the natural condition frequently support a high amount of off-channel habitat. Land-use activities of various kinds reduce the quantity of these areas, most severely in heavily urbanized areas where off-channel sites are usually eliminated. Diking, channelization, agricultural land use, roads and railroads normally result in severe losses to off-channel habitat.

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of key habitat used by juvenile salmonids at different life stages.

References/Sources

Importance and Role: Doppelt and others (1993), Federal Interagency Stream Restoration Working Group (1998), Peterson and Reid (1984).

Factors Affecting: Doppelt and others (1993), Federal Interagency Stream Restoration Working Group (1998).

Habitat Type—Pool Tailouts

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

Percentage of the wetted channel surface area comprising pool tailouts.

Importance and Role

Pool-tailouts are a primary spawning habitat of nearly all salmonids.

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) non-turbulent habitat types are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel turbulent habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the off-channel habitat factor.

The proportion of the wetted channel comprised of pool-tailouts will be a function of the amount of surface area comprised of in-channel pools. Care should be taken in interpreting habitat type data. In most cases, older data will not have tailouts split out. In these cases, pool-tailouts were likely included partially with the pool quantity and partially with riffle data. Generally the quantity of tailouts will be approximately 15-20% of the amount of pool habitat, though it will be less in very low gradient streams. If tailouts are not included in the habitat inventory data available, estimate the amount of tailouts based on pool quantity, then reduce the pool quantity by half the amount of the estimated tailouts and riffle quantity by the same amount.

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of key habitat used by juvenile salmonids at different life stages.

References/Sources

Importance and Role: Bisson and others (1982).

Factors Affecting: Bisson and others (1982), Federal Interagency Stream Restoration Working Group (1998).

Habitat Type—Glides

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

Percentage of the wetted channel surface area comprising glides. *Note: There is a general lack of consensus regarding the definition of glides (Hawkins and others 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore and others 1999): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of < 1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.*

Importance and Role

Glides are used for spawning and rearing by different salmonid species.

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) non-turbulent habitat types are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel turbulent habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the off-channel habitat factor.

The quantity of glide habitat will often be affected by land use. In general, streams in the Pacific Northwest, particularly in areas with abundant wood, are assumed to have had less glide habitat under historic conditions than they have under intensive land use. Land use has generally resulted in dramatic reductions in wood and increased sediment loads, resulting in fewer and shallow pool habitat. These conditions typically result in an increased amount of glide habitat.

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of key habitat used by juvenile salmonids at different life stages.

References/Sources

Definition: Hawkins and others (1993) Moore and others (1999).

Importance and Role: Bisson and others (1982).

Factors Affecting: Bisson and others (1982), Federal Interagency Stream Restoration Working Group (1998).

Habitat Type—Primary Pools

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

Percentage of the wetted channel surface area comprising pools, excluding beaver ponds

Importance and Role

Bisson and others (1982) and Nickelson and others (1992) reported a strong preference for this habitat type by coho emergent fry and juveniles during both summer and winter. Hayman and others (1996) reported high use of this habitat type by 0-age juvenile Chinook in the Skagit River, Western Washington. Pools serve as key habitat for some life stages of virtually all salmonids.

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) non-turbulent habitat types are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel turbulent habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the off-channel habitat factor.

In lower gradient, unconfined to moderately confined reaches, the percentage of the channel surface area comprised of pools will normally be related to land use. Removal of LWD and increased sediment loading usually will result in a conversion of pool habitat to glides and riffles. Large woody debris is a primary determinant of pool spacing, pool depth, and quantity in small to medium sized streams. It has less effect on channel form in larger streams (Bisson and Bilby 1998, Montgomery and Buffington 1998).

May and others (1997) reported that cumulative upstream development (percent total impervious surface) significantly decreased the percentage of a channel's wetted surface area comprised of pool habitat (see Figure 36 in that document).

Many data sets exist on the quantities of habitat types for different types of streams in the Pacific Northwest. Any person doing an EDT assessment should learn whether such data exist for the watershed of interest. For example, excellent data sets exist for streams in the National Forest, and the state of Oregon (<http://rainbow.dfw.state.or.us/nrimp/information/index.htm>). Other sources include the Northwest Indian Fish Commission and fish and wildlife agencies for individual tribes. Also, EDT stream reach datasets for many watersheds in the region are currently available online at <http://www.mobrand.com/edt/>). These can be examined for how streams were characterized on the west and east sides of the Cascades, under historic conditions, and in urban areas (such as for the lower areas of the Puyallup-White River, Chambers-Clover Creek, and Hylebos Creek in the Puget Sound region).

Another source of information on historic pool amounts is contained in Peterson and others (1992)

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of key habitat used by juvenile salmonids at different life stages.

References/Sources

Importance and Role: Bisson and others (1982), Hayman and others (1996), Nickelson and others (1992).

Factors Affecting: Bilby and Bisson (1998), Bisson and others (1982), Federal Interagency Stream Restoration Working Group (1998), Montgomery and Buffington (1998), Peterson and others (1992).

Habitat Type—Small Cobble/Gravel Riffles

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.3 Habitat Type

Shaping

Habitat Types are non-shaped attributes.

Definition/Usage

Percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts and others (1983) based on information in Gordon and others (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (> 11.9 inch diameter).

Importance and Role

Riffles tend to support higher densities of benthic invertebrates than pools, and are thus important food-producing areas for fish. The most productive streams typically are composed of the pool-riffle sequence, providing a diversity of habitats and food-producing areas. In terms of physical habitat, the pool-riffle structure provides a great diversity of bedforms, substrate materials and local velocities. Brussock and others (1985), cited in Gordon and others (1992), proposed that the reason biotic diversity is greatest in the mid reaches of a river system is because they usually possess a pool-riffle morphology.

Bisson and others (1982) reported that relatively low gradient riffles are selectively occupied by subyearling steelhead and cutthroat; these areas are not preferentially used by older age classes of these species. These riffles can be comprised of both small cobble/gravel and large cobble/boulder substrates. Utilization of rapids and cascades (comprised of large cobble/boulder riffles) by juvenile salmonids is generally limited to yearling and older steelhead and rainbow. Chapman and Bjornn (1969) reported that steelhead occupy swifter water as they grow larger, suggesting to these authors that preference for faster water was associated with increased exposure to food organisms by this species.⁶

Substrate size associated with this habitat type is unsuited for spawning by salmonids, except that small pockets of small cobble/gravel can be interspersed within this habitat type enabling successful redd construction by salmonids. Note: those pockets containing small cobble/gravel substrates should be considered as part of the habitat type associated with that substrate size.

⁶ Juvenile steelhead utilize all habitat types, though maximum rearing densities tend to increase with increasing gradient, to some limit, perhaps in the range 4-8% (see Johnson 1985 and Johnson and others 1988).

Many data sets exist on the quantities of habitat types for different types of streams in the Pacific Northwest. Any person doing an EDT assessment should learn whether such data exist for the watershed of interest. For example, excellent data sets exist for streams in the National Forest, and the state of Oregon (<http://rainbow.dfw.state.or.us/nrimp/information/index.htm>). Other sources include the Northwest Indian Fish Commission and fish and wildlife agencies for individual tribes. Also, EDT stream reach datasets for many watersheds in the region are currently available online at <http://www.mobrand.com/edt/>). These can be examined for how streams were characterized on the west and east sides of the Cascades, under historic conditions, and in urban areas (such as for the lower areas of the Puyallup-White River, Chambers-Clover Creek, and Hylebos Creek in the Puget Sound region).

Categorical Conclusions

Habitat types are entered as a point estimate of the percentage of the stream reach wetted width in this particular habitat type.

Factors Affecting Attribute/Guidelines

Main channel (includes side channels) non-turbulent habitat types are defined for this application as primary pools, pool-tailouts/glides, beaver ponds, and backwater pools. Main channel turbulent habitat types are defined as small cobble/gravel riffles and large cobble/boulder riffles (includes units usually referred to as cascades). Off-channel habitat is addressed through the off-channel habitat factor.

Special Instructions for New Input or Updates

All months are rated the same for this attribute, although it is recognized that the relative amount of this habitat type can change over a wide range of flow levels. When rating this attribute, a moderate flow level should be assumed.

Effect on Level 3 Key Habitat

This attribute is a determinant of the amount of key habitat used by juvenile salmonids at different life stages.

References/Sources

Importance and Role: Bisson and others (1982), Chapman and Bjornn (1969), Gordon and others (1992).

Factors Affecting: Bisson and others (1982), Federal Interagency Stream Restoration Working Group (1998).

Harassment

Attribute Category

4. Biological Community

Attribute Sub-Category

4.1 Community Effects

Shaping

Harassment is a non-shaped attribute.

Definition/Usage

The relative extent of poaching and/or harassment of fish within the stream reach.

Importance and Role

Salmonids, particularly adults, can be highly vulnerable to poaching or harassment. They are especially susceptible when they congregate in certain areas prior to, during, or after spawning migrations or during spawning. Some watersheds appear to be more subjected to poaching activity than others, even with similar levels of access, depending on local societal patterns and history. Long (1997), for example, reported that the extent of poaching in an area is related to family and community traditions and norms. His study, based on interviews with convicted poachers, showed that family instruction in poaching is an accepted norm in some communities. Harassment of spawners can also occur near campgrounds or other areas where recreational activity concentrates. This can be especially troublesome at times and places where spring Chinook spawn, which typically occurs during August and early September.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Reach is distant from human population centers, no road access or no local concentration of human activity.	Reach is distant from human population centers, but with partial road access or little local concentration of human activity.	Reach is near human population center, but has limited public access (through roads or boat launching sites).	Extensive road and/or boat access to the reach with localized concentrations of human activity.	Reach is near human population center or has extensive recreational activities, and has extensive road access and/or opportunities for boat access.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

This attribute was designed so that it could be rated entirely based on locations of campgrounds, road crossing, road traffic, and other human activity where harassment or poaching can occur. It

does not utilize a computed metric, however. The rating requires some subjectivity. If possible, it is best rated by someone familiar with a watershed who is aware of where poaching is most likely to occur and other activities that might disrupt fish behavior. Reaches known to be used by poachers should be rated 4.

Special Instructions for New Input or Updates

Apply the rating definitions as given but, in addition, assign known areas of poaching activity a rating of 4. Assign all months the same rating.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 survival factor Harassment, which in turn affects the productivity of certain life stages, primarily adult life stages.

References/Sources

Importance and Role: Long (1997).

Hatchery Fish Outplants

Attribute Category

4. Biological Community

Attribute Sub-Category

4.1 Community Effects

Shaping

Hatchery Fish Outplants is a non-shaped attributes.

Definition/Usage

The magnitude of hatchery fish outplants made into the drainage over the past 10 years. "Drainage" here is meant to include the portion of a watershed where *juvenile* hatchery fish are likely to be found as a result of hatchery releases—it does not include any area of the watershed where stray hatchery adults might be found. This attribute is intended to only be used for describing releases of juvenile hatchery fish, not adult hatchery fish.

Importance and Role

Hatchery fish released into streams can effect the performance of co-mingled wild fish through competition for limited resources and predation (recent reviews by Flagg and others 2000 and HSRG 2004). Adverse effects through such interactions can occur during juvenile rearing, smolt, spawning, and incubation life stages.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
No stocking records in the past decade.	No more than two instances of fish releases in the past decade in the drainage.	Fish releases made into the drainage every 1-3 years at isolated locations within the drainage.	Fish releases made at multiple sites in the drainage, but only in 1-3 years during the past decade.	Fish releases made every 1-3 years and at multiple sites in the drainage

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

This single attribute is intended to characterize in very general terms the frequency and distribution of hatchery juveniles releases in the drainage. It does not address the magnitude, fish size, or species of the releases. It is used in the modeling process as a crude way to assess the risk that wild fish would be impacted by hatchery fish through competitive interactions or predation during juvenile life stages.

Important Note: The procedure for characterizing hatchery fish releases in a watershed is soon to be updated using Level 2 attributes. The attribute as it is described above included both supplementation and on-station releases, making it difficult to appropriately describe a continuum of hatchery releases. Prior to the expected update in attribute definitions, the ratings should be interpreted so that a 4 is associated with the reach where releases occur annually from on-station releases and to reaches downstream. For example, if a hatchery is located at river mile 20 on a river, assign a 4 to the reach associated with the release site and to reaches located downstream. For off-station releases, use the definitions as written but also retaining the ratings downstream of the release points.

Special Instructions for New Input or Updates

Care should be exercised in assigning ratings > 0 to only those reaches where hatchery fish are released and to reaches downstream of release points.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 survival factors Competition with hatchery fish and Predation, both of which, in turn, affect productivity of juvenile life stages of salmon and steelhead.

References/Sources

Importance and Role: Flagg and others (2000), HSRG (2004).

Hydrologic Regime—Natural

Attribute Category

1. Hydrologic Characteristics

Attribute Sub-Category

1.2 Hydrologic Regime

Shaping

Hydrologic Regime is a non-shaped attribute.

Definition/Usage

The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This attribute applies to an unregulated river or to the pre-regulation state of a regulated river. *Note: Only a categorical rating is acceptable for this attribute (e.g., 0, 1, 2, 3, or 4).*

Importance and Role

The hydrologic or flow regime was described by Hynes (1970) as having important influences on stream biota. Regimes differ by their seasonal timing and duration of high and low flows. Flow patterns can be classified on the basis of the source of most of the water. Haines and others (1988), as summarized in Gordon and others (1992), developed 15 regime classes for perennial streams, though these are often combined into relatively few groups (Hynes 1970), as done here.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Groundwater-source-dominated; strongly buffered peak flows (as in a springbrook or in river like the Metolius in central Oregon)	Spring snowmelt dominated, non-glacial; temporally consistent and moderate peak and low flows	Rain-on-snow transitional; consistent spring peak and low flows with inconsistent and flashy winter or early spring rain-on-snow peaks	Rainfall-dominated; flashy winter and early spring peaks, consistently low summer flows and variable spring and fall flows.	Glacial runoff system; high, turbid low flows, generally buffered peak flows except with occasional outburst floods and infrequent rain-on-snow events

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

The flow regime is defined by the primary source of water in a stream. This attribute defines five classes of natural regimes according to the major source of water affecting the reach.

Special attention needs to be given to recognizing regimes dominated by groundwater. Streams that are considered springs, springbrooks, and wall-base channel streams are to be assigned a rating of 0. Springbrooks and wall-base channels refer to the same general type of stream (Stanford and Ward 1992). These are streams, or channels on river's floodplain, fed by shallow groundwater. They are the result of effluent groundwaters re-emerging within a channel on the floodplain from stream water that downwelled into the upstream end of floodplain segment. Springbrooks usually occur in abandoned meander channels blocked at the upstream end by natural deposition of alluvium and woody debris. They are referred to as wall-base channels in locations where they erupt from the substratum of old channels originally constrained by contact with the terrace or canyon walls (Peterson and Reid 1984).

The flow regime for a stream can affect the method used during the EDT stream reach characterization procedure to define flow patterns, see Appendix.

Special Instructions for New Input or Updates

Special care needs to be given to recognizing groundwater fed streams.

Effect on Level 3 Survival Factors

This attribute is used to delineate how certain attributes affect some Level 3 survival factors. A rule for a given species, life stage, and survival factor can differ in its effect on survival based on stream size (width) and hydrologic regime.

References/Sources

Definition: Gordon and others (1992).

Importance and Role: Hynes (1970), Montgomery and Bolton (2003), Stanford and Ward (1992).

Factors Affecting: Peterson and Reid (1984), Stanford and Ward (1992).

Hydrologic Regime—Regulated

Attribute Category

1. Hydrologic Characteristics

Attribute Sub-Category

1.2 Hydrologic Regime

Shaping

Hydrologic Regime is a non-shaped attribute.

Definition/Usage

The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. *Note: Definition does not take into account daily flow fluctuations (see Flow—Intra-daily variation attribute).*

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
No artificial flow regulation occurs upstream to affect hydrograph.	Project operations have not changed median flows between months or season as the project is operated as a run-of-river facility, or project storage is < 15 days of the annual mean daily flow of the river.	Project operations have not changed median flows between months or season as the project is operated as a run-of-river facility, or project storage is > 15 and < 30-days of the annual mean daily flow of the river.	Project operations have resulted in a measurable shift in median flows between months or seasons. The project provides limited flood control during periods of high run-off (winter or spring). The project's reservoir is operated each year to store more than 30 but less than 60-days of the annual mean daily flow of the river.	Project operations have resulted in a major shift in median flows between months or seasons. The project is operated to provide significant flood control during high run-off periods (winter or spring). The project's reservoir is operated each year to store more than 60-days of the annual mean daily flow of the river.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Importance and Role

Regulation of river flow associated with a dam or diversion can dramatically alter the flow regime of a river, changing seasonal timing, duration of high flows and low flows, and rate of change in flow (Gordon and others 1992). Reservoirs associated with regulation can alter sediment movement, stream temperatures, and water quality. Changes in flow regime and sediment supply can lead to changes in downstream channel dimensions. All of these alterations can affect the biota.

Factors Affecting Attribute/Guidelines

This attribute is currently used as documentation of how flow regime has been altered due to regulation. When ratings are > 0 , indicating regulation, the flow and width patterns that are used to specify how the flow and width attributes are shaped temporally need to be adjusted to reflect the extent of regulation.

Effect on Level 3 Survival Factors

This attribute is currently not used to directly compute Level 3 survival factors. It is used as documentation.

References/Sources

Importance and Role: Gordon and others (1992).

Icing

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.5. Riparian and Channel Integrity

Shaping

Icing is a shaped attribute.

Definition/Usage

Average extent (magnitude and frequency) of icing events over a ten-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

Importance and Role

Ice formation in streams can severely destabilize habitat features in streams in the more northern latitudes and at higher elevations in the interior snow dominated ecoregions (Swanston 1991). Such conditions can adversely affect the quality of habitat to stream-rearing salmonids. Benthic fauna can also be impacted.

Ice formation can destabilize habitat features when anchor ice forms and in cases where the channel freezes over. Anchor ice forms along the channel bottom from the accumulation of frazil ice along the substrate. During formation, it frequently breaks loose from the bottom, carrying gravel still attached to the surface and downstream. This action can be disruptive to incubating eggs and to overwintering salmonids. When channels freeze over, subsequent melting and ice breakup can cause extensive flooding and bank and channel erosion through the gouging action of moving ice. These conditions are believed to be adverse to the survival of alevins within the substrate and to overwintering small fish.

It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

Categorical conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Anchor ice and icing events do not occur.	Some anchor ice may occur infrequently, having little or no impact to physical structure of stream, in-stream structure, and stream banks/bed.	Likelihood for some anchor ice and/or icing events is moderate to high each year and effects on stream, in-stream structure, and stream banks/beds is considered low to moderate.	Likelihood for anchor ice and/or icing events is high each year, having effects on stream, in-stream structure, and stream banks/beds that differ widely within the reach--from low to high across the reach.	Likelihood of severe anchor ice or overbank ice jams is high each year, having major and extensive effects on stream, in-stream structure, and stream banks across the reach.

Factors Affecting Attribute/Guidelines

The conditions that promote ice formation appear to more readily occur in reaches where riparian vegetation is limited (Platts 1991, Swanston 1991). Riparian vegetation cover apparently reduces the intensity of radioactive heat loss from the stream during winter, lessening the likelihood for severe ice formation. As ice formation occurs, stream water is supercooled. Wide, shallow streams are more susceptible to anchor ice formation than are deep, narrow ones because supercooling takes place more rapidly under such conditions. Severe grazing or other land use practices can lead to these conditions. Susceptibility to severe icing can be offset, however, if sufficient snow accumulates to insulate the stream before water temperatures are supercooled. In those cases, channel icing tends to be less than in canopied reaches with less snow (Swanston 1991).

Special Instructions for New Input or Updates

Rate the month when icing is likely to be worst. Rate only one month. Other months will be inferred from an expected pattern that coincides with cold temperature.

Effect on Level 3 Survival Factors

This attribute affects the two Level 3 survival factors: Channel Stability and Habitat Diversity. For both factors, icing combines with other attributes to result in the overall effects attributed to these factors. In the case of Channel Stability, icing is assumed to act directly in reducing survival of either incubating eggs or overwintering fish. For Habitat Diversity, icing is assumed to act in reducing the overall quality of habitat features in the reach, both for active and inactive life stages.

References/Sources

Importance and Role: Swanston (1991), Naiman and others (2000).

Factors Affecting: Platts (1991), Swanston (1991).

Metals—in Water Column

Attribute Category

3. Water Quality

Attribute Sub-Category

3.1 Chemistry

Shaping

Metals are non-shaped attributes

Definition/Usage

The extent of dissolved heavy metals within the water column.

Importance and Role

Substances that can contaminate aquatic ecosystems are as varied as the human activities that produce them (Hynes 1960). These contaminants have been classified in a wide variety of ways. For the sake of simplicity, we group them into three classes for addressing effects on the fish species: metals in the water column, metals/pollutants within sediments, and miscellaneous toxic substances in the water column. All of these have the potential to severely impact aquatic communities, including fish species.

Heavy metals are common inorganic chemical pollutants. They include lead, copper, zinc, cadmium, and mercury, in addition to others. Although toxicities of metals can vary greatly with pH, water hardness, temperature and other conditions, they can have lethal or sub-lethal effects on stream fish at very low concentrations (USEPA 1987). Sub-lethal effects include behavioral modification such as avoidance of stream sections contaminated by dissolved metals (Giattina and Garton 1983). Sources of heavy metal contaminants include mining, industrial processing, and non-point urban stormwater.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
No toxicity expected due to dissolved heavy metals to salmonids under prolonged exposure (1 month exposure assumed).	May exert some low level chronic toxicity to salmonids (1 month exposure assumed).	Consistently chronic toxicity expected to salmonids (1 month exposure assumed).	Usually acutely toxic to salmonids (1 month exposure assumed).	Always acutely toxic to salmonids (1 month exposure assumed).

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Toxic substances, other than when they occur naturally, which is quite rare, originate primarily from urbanization (residential, commercial, industrial activities), mining, and agricultural activities.

The extent of toxic substances coming from mining activity varies greatly depending on the ore being mined, the type of mine, processing, and remedial measures taken. Where mining activities exist data should be adequate to rate this attribute directly on knowledge about the activity.

Runoff from agricultural activities and urbanization will likely be the greatest concern in rating this attribute. Pesticides will be the primary substance coming from agricultural activities. We advise that information be obtained from local soil conservation services on these substances or other local agencies.

Pollutants associated with urbanization will likely correspond closely to the amount of impervious surface in the drainage upstream each reach of interest or to what is known about specific activities in the drainage (Pitt and others 1995). In general, the more intense the level of urbanization, the higher will be the pollutant loading. Also, the greater the diversity of land-use activities, the more diverse will be the mixture of pollutants found in stormwater runoff (Herricks 1995). Table 4 lists constituents of urban runoff.

Table 4. Pollutants commonly found in stormwater and their sources (from Brandenberger 2003).

Pollutant	Potential sources
Hydrocarbons (oil and grease)	Automobiles - industrial machinery
Copper (Cu)	Building materials, paints and preservatives, algicides, brake pads
Zinc (Zn)	Galvanized metals, paints and preservatives, roofing and gutters, tires
Lead (Pb)	Gasoline, paint, batteries
Chromium (Cr)	Electro-plating, paints and preservatives
Cadmium (Cd)	Electro-plating, paints and preservatives
Pesticides	Agriculture and grazing, residential and commercial use
Herbicides	Agriculture and grazing, residential and commercial use, roadside vegetation maintenance
Organic compounds	Industrial processes, power generation

Klein (1979), studying storm runoff in Maryland, found that stream life problems were first identified with watersheds having impervious areas comprising at least 12% of the watershed. Severe problems were noted when impervious surfaces reached 30%.

May and others (1997), studying a variety of small lowland streams in the Puget Sound region, found that metal concentrations were relatively insignificant, even during large storms, unless impervious percentage exceeded 45%. It should be noted, however, that the nature of urban stormwater runoff is that it is sporadic.

Tremendous variability can exist in pollutant concentrations from storm to storm and by local area. Higher levels of urban pollutants such as metals and hydrocarbons are typically found during "first flush" storm events (Pitt and others 1995). It is frequently difficult to detect problem substances. In the Puget Sound region, high levels of mortality on prespawning coho adults have been found to be occurring in a number of urban streams (> 50% mortality) during the first or second major storm event (Greg Blair, personal communications). To date, agencies have not been able to discover the causal agent.

The rating that is input for this attribute is currently applied to the entire year. An update to the EDT procedure is expected soon to allow for differences across the calendar year. This change will address the matter of the first flush more effectively.

Special Instructions for New Input or Updates

Only one rating is applied for the calendar year.

Effect on Level 3 Biological Metrics

This attribute affects the Level 3 survival factor Toxic Substances (chemicals), and, in turn, affects productivity of various life stages.

References/Sources

Importance and Role: Hynes (1960), USEPA (1987), Giattina and Garton (1983), Goldstein and others (1999), Burton and Pitt (2002).

Factors Affecting: May and others (1997), Pitt and others (1995), Herricks (1995), Brandenberger and others (2003).

Metals/Pollutants—in Sediments/Soils

Attribute Category

3. Water Quality

Attribute Sub-Category

3.1 Chemistry

Shaping

Metals are non-shaped attributes

Definition/Usage

The extent of heavy metals and other toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

Importance and Role

Substances that can contaminate aquatic ecosystems are as varied as the human activities that produce them (Hynes 1960). These contaminants have been classified in a wide variety of ways. For the sake of simplicity, we group them into three classes for addressing effects on the fish species: metals in the water column, metals/pollutants within sediments, and miscellaneous toxic substances in the water column. All of these have the potential to severely impact aquatic communities, including fish species.

Heavy metals and many other pollutants are adsorbed by fine sediments, which serve to remove them from solution, but they are then deposited and concentrated in bottom sediments within the aquatic environment. Heavy metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), pesticides and other toxic substances can accumulate and remain present for an extended period. Within the sediment, these contaminants can periodically be resuspended or dissolved again and enter the water column where they can continue to affect aquatic organisms. In addition, microbial activity within the sediments can transform inorganic substances into more toxic organic forms (Herrick 1995). Major sources of heavy metal and other contaminants are industrial processing

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Metals/pollutants at natural (background) levels with no or negligible effects on benthic dwelling organisms or riparian vegetation (under continual exposure).	Deposition of metals/pollutants in low concentrations such that some stress symptoms occur to benthic dwelling organisms or riparian vegetation root/shoot growth is impaired (under continual exposure).	Stress symptoms increased or biological functions moderately impaired to benthic dwelling organisms; or few areas within the riparian zone present where no vegetation exists (slickens); ecotonal to these areas occupied only by tolerant species; horizons containing metals/pollutant concentrations influencing root growth and composition are common within the riparian corridor.	Growth, food conversion, reproduction, or mobility of benthic organisms severely affected; or large areas of the riparian zone devoid of vegetation; ecotonal areas occupied only by metals/pollutant-tolerant species; few areas in the riparian zones which are unaffected.	Metals/pollutant concentrations in sediments/soils are lethal to large numbers of the benthic species and/or riparian zone is practically devoid of vegetation.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Toxic substances, other than when they occur naturally, which is quite rare, originate primarily from urbanization (residential, commercial, industrial activities), mining, and agricultural activities.

The extent of toxic substances coming from mining activity varies greatly depending on the ore being mined, the type of mine, processing, and remedial measures taken. Where mining activities exist data should be adequate to rate this attribute directly on knowledge about the activity.

Runoff from agricultural activities and urbanization will likely be the greatest concern in rating this attribute. Pesticides will be the primary substance coming from agricultural activities. We advise that information be obtained from local soil conservation services on these substances or other local agencies.

Pollutants associated with urbanization will likely correspond closely to the amount of impervious surface in the drainage upstream each reach of interest or to what is known about specific activities in the drainage (Pitt and others 1995). In general, the more intense the level of urbanization, the higher will be the pollutant loading. Also, the greater the diversity of land-use activities, the more diverse will be the mixture of pollutants found in stormwater runoff (Herricks 1995). Table 5 lists constituents of urban runoff.

Table 5. Pollutants commonly found in stormwater and their sources (from Brandenberger 2003).

Pollutant	Potential sources
Hydrocarbons (oil and grease)	Automobiles - industrial machinery
Copper (Cu)	Building materials, paints and preservatives, algicides, brake pads
Zinc (Zn)	Galvanized metals, paints and preservatives, roofing and gutters, tires
Lead (Pb)	Gasoline, paint, batteries
Chromium (Cr)	Electro-plating, paints and preservatives
Cadmium (Cd)	Electro-plating, paints and preservatives
Pesticides	Agriculture and grazing, residential and commercial use
Herbicides	Agriculture and grazing, residential and commercial use, roadside vegetation maintenance
Organic compounds	Industrial processes, power generation

Klein (1979), studying storm runoff in Maryland, found that stream life problems were first identified with watersheds having impervious areas comprising at least 12% of the watershed. Severe problems were noted when impervious surfaces reached 30%.

May and others (1997), studying a variety of small lowland streams in the Puget Sound region, found that metal concentrations were relatively insignificant, even during large storms, unless impervious percentage exceeded 45%. It should be noted, however, that the nature of urban stormwater runoff is that it is sporadic.

Tremendous variability can exist in pollutant concentrations from storm to storm and by local area. Higher levels of urban pollutants such as metals and hydrocarbons are typically found during "first flush" storm events (Pitt and others 1995). It is frequently difficult to detect problem substances. In the Puget Sound region, high levels of mortality on prespawning coho adults have been found to be occurring in a number of urban streams (> 50% mortality) during the first or second major storm event (Greg Blair, personal communications). To date, agencies have not been able to discover the causal agent.

The rating that is input for this attribute is currently applied to the entire year. An update to the EDT procedure is expected soon to allow for differences across the calendar year. This change will address the matter of the first flush more effectively.

Special Instructions for New Input or Updates

Only one rating is applied for the calendar year.

Effect on Level 3 Biological Metrics

This attribute affects the Level 3 survival factor Toxic Substances (chemicals), and, in turn, affects productivity of various life stages.

References/Sources

Importance and Role: Hynes (1960), USEPA (1987), Giattina and Garton (1983), Goldstein and others (1999), Burton and Pitt (2002).

Factors Affecting: May and others (1997), Pitt and others (1995), Herricks (1995), Brandenberger and others (2003).

Miscellaneous Toxic Pollutants—in Water Column

Attribute Category

3. Water Quality

Attribute Sub-Category

3.1 Chemistry

Shaping

Metals are non-shaped attributes

Definition/Usage

The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

Importance and Role

Substances that can contaminate aquatic ecosystems are as varied as the human activities that produce them (Hynes 1960). These contaminants have been classified in a wide variety of ways. For the sake of simplicity, we group them into three classes for addressing effects on the fish species: metals in the water column, metals/pollutants within sediments, and miscellaneous toxic substances in the water column. All of these have the potential to severely impact aquatic communities, including fish species.

Among the most common pollutants found in contaminated streams are petroleum hydrocarbon compounds, pesticides, herbicides and industrial chemicals. Storm runoff is a major source of contamination from agricultural land and lands being urbanized (residential, commercial, and industrial). Toxicity of these substances on fish species varies greatly from sub-lethal to lethal. Potential effects are reasonably well established (Burton and Pitt 2002).

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
No substances present that may periodically be at or near chronic toxicity levels to salmonids.	One substance present that may only periodically rise to near chronic toxicity levels (may exert some chronic toxicity) to salmonids.	More than one substance present that may periodically rise to near chronic toxicity levels or one substance present > chronic threshold and < acute threshold (consistently chronic toxicity) to salmonids.	One or more substances present > acute toxicity threshold but < 3X acute toxicity threshold (usually acutely toxic) to salmonids.	One or more substances present with > 3X acute toxicity (always acutely toxic) to salmonids.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Toxic substances, other than when they occur naturally, which is quite rare, originate primarily from urbanization (residential, commercial, industrial activities), mining, and agricultural activities.

The extent of toxic substances coming from mining activity varies greatly depending on the ore being mined, the type of mine, processing, and remedial measures taken. Where mining activities exist data should be adequate to rate this attribute directly on knowledge about the activity.

Runoff from agricultural activities and urbanization will likely be the greatest concern in rating this attribute. Pesticides will be the primary substance coming from agricultural activities. We advise that information be obtained from local soil conservation services on these substances or other local agencies.

Pollutants associated with urbanization will likely correspond closely to the amount of impervious surface in the drainage upstream each reach of interest or to what is known about specific activities in the drainage (Pitt and others 1995). In general, the more intense the level of urbanization, the higher will be the pollutant loading. Also, the greater the diversity of land-use activities, the more diverse will be the mixture of pollutants found in stormwater runoff (Herrick 1995). Table 6 lists constituents of urban runoff.

Table 6. Pollutants commonly found in stormwater and their sources (from Brandenberger 2003).

Pollutant	Potential sources
Hydrocarbons (oil and grease)	Automobiles - industrial machinery
Copper (Cu)	Building materials, paints and preservatives, algicides, brake pads
Zinc (Zn)	Galvanized metals, paints and preservatives, roofing and gutters, tires
Lead (Pb)	Gasoline, paint, batteries
Chromium (Cr)	Electro-plating, paints and preservatives
Cadmium (Cd)	Electro-plating, paints and preservatives
Pesticides	Agriculture and grazing, residential and commercial use
Herbicides	Agriculture and grazing, residential and commercial use, roadside vegetation maintenance
Organic compounds	Industrial processes, power generation

Klein (1979), studying storm runoff in Maryland, found that stream life problems were first identified with watersheds having impervious areas comprising at least 12% of the watershed. Severe problems were noted when impervious surfaces reached 30%.

May and others (1997), studying a variety of small lowland streams in the Puget Sound region, found that metal concentrations were relatively insignificant, even during large storms, unless impervious percentage exceeded 45%. It should be noted, however, that the nature of urban stormwater runoff is that it is sporadic.

Tremendous variability can exist in pollutant concentrations from storm to storm and by local area. Higher levels of urban pollutants such as metals and hydrocarbons are typically found during "first flush" storm events (Pitt and others 1995). It is frequently difficult to detect problem substances. In the Puget Sound region, high levels of mortality on prespawning coho adults have been found to be occurring in a number of urban streams (> 50% mortality) during the first or second major storm event (Greg Blair, personal communications). To date, agencies have not been able to discover the causal agent.

The rating that is input for this attribute is currently applied to the entire year. An update to the EDT procedure is expected soon to allow for differences across the calendar year. This change will address the matter of the first flush more effectively.

Special Instructions for New Input or Updates

Only one rating is applied for the calendar year.

Effect on Level 3 Biological Metrics

This attribute affects the Level 3 survival factor Toxic Substances (chemicals), and, in turn, affects productivity of various life stages.

References/Sources

Importance and Role: Hynes (1960), Burton and Pitt (2002).

Factors Affecting: May and others (1997), Pitt and others (1995), Herricks (1995), Brandenberger and others (2003).

Nutrient Enrichment

Attribute Category

3. Water Quality

Attribute Sub-Category

3.1 Chemistry

Shaping

Nutrient enrichment is a shaped attribute, often based on temperature.

Definition/Usage

The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids.

Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

Importance and Role

Nitrogen or phosphorus, and sometimes both, usually limit primary production in freshwaters. In the Pacific Northwest, the relative importance of each often differs between streams on the west and east sides of the Cascade crest. In Pacific coastal streams and lakes, P is typically in much shorter supply than N because the parent bedrock yields low amounts of P (Welch et al. 1998). In contrast, the basaltic parent material on the eastside contains abundant and relatively easily weathered forms of inorganic phosphorus (Spence et al. 1996).

Enrichment of limiting nutrients in streams can cause significant periphyton growth, resulting in what is called nuisance levels. Nuisance periphyton usually occurs as dense mats or long strands of green filamentous algae. Blue-green algae, which poses problems principally in lakes, are not common in streams of the Pacific coastal region, though it can occur there. It should be noted that significant periphyton growth can occur in Pacific coastal streams even in their oligotrophic state when stream canopies are opened.

The primary response variable used typically to assess nutrient loading is algal biomass, measured as benthic chlorophyll *a* per unit area of stream substrate in fast flowing rivers with cobble or gravel substrates. Nutrient cycling through the biota makes direct measures of nutrient loading difficult, though use of chlorophyll *a* can also be problematic because of effects of insect grazing on the periphyton. Biggs (2000) provides examples of visual characterization of periphyton levels in streams.

Nuisance levels of periphyton can result in degraded water quality and changes to micro habitat used by some species. Associated changes to water quality can be oxygen depletion, pH

elevation, and increased turbidity. These changes can in turn result in further degradation of water quality, including increased availability of ammonia and hydrogen sulfide. Changes in micro habitats can be due to restriction of intragravel water flow and substrate structure used by benthic fauna. These changes can affect the performance of various species. (It should be noted that many of these changes related to salmonid or benthos performance are captured by other Level 2 correlates, such as dissolved oxygen and benthos diversity.)

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Unenriched streams (corresponding to benthic chlorophyll <i>a</i> values 0.5-3 mg/m ²). Nutrient levels typical of oligotrophic conditions (small supply of nutrients, low production of organic matter, low rates of decomposition, and high DO). No enrichment is occurring nor is suspected. Green filamentous algae may be present at certain times of year, particularly in unshaded areas.	Very small amount of enrichment suspected to be occurring through land use activities (corresponding to benthic chlorophyll <i>a</i> values 3-20 mg/m ²). Green filamentous algae present in summer months in unshaded reaches.	Nutrient levels typical of oligotrophic conditions (small supply of nutrients, low production of organic matter, low rates of decomposition, and high DO). Some enrichment known to be occurring (corresponding to benthic chlorophyll <i>a</i> values 20-60 mg/m ²), often associated with failing septic tanks or runoff from areas of heavy fertilizer usage. Dense mats of green or brown filamentous algae present in summer months.	Eutrophic (abundant nutrients associated with high level of primary production, frequently resulting in oxygen depletion). Very obvious enrichment of reach is occurring from point sources or numerous non-point sources (corresponding to benthic chlorophyll <i>a</i> values 60-600 mg/m ²). Large, dense mats of green or brown filamentous algae will be present during summer months.	Super enrichment of reach is strongly evident. Known, major point sources of organic waste inputs, such as runoff from large feedlot operation, wash water from farm products processing, or significant sewage facilities with inadequate treatment (corresponding to benthic chlorophyll <i>a</i> values 600-1200 mg/m ²). In most severe cases, filamentous bacteria abundant, associated with low D.O. and hydrogen sulfide. In less severe cases, large dense mats of green or brown filamentous algae generally cover the substrate.

Factors Affecting Attribute/Guidelines

Nutrient loading is commonly associated with agriculture and urbanization. It is produced by agricultural runoff, failing septic tanks, wastewater discharges, and stormwater runoff. Omernik (1977), in a nationwide analysis of 928 catchments, found that streams draining agricultural areas had mean concentrations of total phosphorus and total nitrogen 900 percent greater than those in streams draining forested lands.

Total phosphorus (TP) is related to the total percentage impervious surface in urbanized areas (Welch et al. 1998). Despite elevated TP in Puget Sound streams affected by urbanization, May et al. (1997) did not find nuisance periphyton levels in any study stream., though such conditions were reported earlier by Welch et al. (1998). Nuisance levels of periphyton are sometimes found in streams heavily impacted by agricultural runoff in western Washington.

Special Instructions for New Input or Updates

The effects of this attribute are largely captured through other attributes. Rating of this attribute should be considered a low priority.

Effect on Level 3 Biological Metrics

The current version of biological rules incorporates effects of this attribute on performance through only one Level 3 survival factor, Pathogens. It is assumed that nutrient loading can result in conditions that promote the abundance and diversity of pathogenic organisms. The rating can also help in rating benthic community richness and dissolved oxygen (this volume).

References/Sources

Importance and Role: Welch et al (1998), Biggs (2000), EPA (2000)

Factors Affecting: Welch et al. (1998), Biggs (2000), EPA (2000), Spence et al. (1996), May et al. (1996), Omernick (1977)

Obstructions to Fish Migration

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.4 Obstructions

Shaping

Impedance to fish passage is shaped across months and between life stages.

Definition/Usage

Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen). *Note: Rating here is used as a flag in the database. The nature of the obstruction is required to be defined more rigorously in a follow-up form.*

Categorical Conclusions

Categorical index levels are not used to describe fish passage effectiveness at potential barriers. In the Stream Reach Editor, the user is directed through a set of forms to describe the nature of passage the reach in question having a potential barrier. Obstructions are rated by life stage as a monthly survival rate (0-1). A rating of 0 is a complete impediment and a rating of 1 means the obstruction poses no impediment to the passage of that life stage.

Importance and Role

Fish passage effectiveness at potential barriers is a critical issue affecting population performance in a river system.

Factors Affecting Attribute/Guidelines

Passage effectiveness will vary by species and life stage. Vertical height of the barrier, water velocity, and configuration will affect passage.

This attribute should be rated by someone familiar with the barrier reach in question or using data that describe the nature of the barrier. The Washington Department of Fish and Wildlife maintains a database on thousands of potential barriers in the state (SSHEARS database).

Predation Risk

Attribute Category

4. Biological Community

Attribute Sub-Category

4.1 Community Effects

Shaping

Predation is a shaped attribute, usually based on water temperature. See Appendix.

Definition/Usage

Small fish—Level of predation risk on small-bodied fish (< 10 inches in length) due to presence of unusual concentrations of fish eating species or the concentration of the prey species by a man-made structure. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant).

Large fish—Level of predation risk on large-bodied fish (> 10 inches in length) due to presence of unusual concentrations of fish eating species or the concentration of the prey species by a man-made structure. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant).

Importance and Role

Human activities can affect concentrations of fish-eating predators relative to conditions that existed prior to Euro-American settlement. In some cases, predator risk has been reduced as some fish-eating species have declined sharply due to human activity. Other activities, such as construction of dams, have concentrated some fish-eating species, like northern pikeminnow, at critical fish passage sites in the Columbia River. These changes in relative concentrations (or effectiveness) may have altered predation risk on salmon species compared to historic levels in some areas.

Categorical Conclusions

Describe for small and large bodied fish:

Index 0	Index 1	Index 2	Index 3	Index 4
Many or most native predators are depressed or rare, none are greatly increased over natural levels, and there is expected a significant numerical survival advantage to fish as a result compared to historical predator abundance.	Some native predators are moderately depressed, none are greatly increased over natural levels, and there is expected some small to moderate numerical survival advantage to fish as a result compared to historical predator abundance.	Diversity and per-capita abundance of predators exists so that predation risk is at near-natural level and distribution.	Moderate increase in population density or moderately concentrated population of predator species exists due to artifacts of human alteration of the environment (e.g., top-down food web effects, habitat manipulations) compared to historical condition.	Excessive population density or concentrated population of predator species exists due to artifacts of human alteration of the environment (e.g., top-down food web effects, habitat manipulations) compared to historic condition.

Factors Affecting Attribute/Guidelines

This factor is meant to cover a fairly broad range of types of predation risk, though it largely addresses the *relative concentration or dispersal* of fish-eating predators compared to the pristine state associated with dispersed predators. Situations that are meant to be covered by this attribute are concentrations of birds or piscivores below dams or near juvenile migrant bypasses, and artificially enhanced, concentrations of fish eating species associated with the creation of new habitat (as on Rice Island in the Columbia River), or large concentrations of hatchery smolts at or near release sites. The natural concentrations of piscivores that occurs at the outlet of sockeye producing streams under pristine conditions would also be addressed here.

A rating of 2 is assumed to be the historic condition. In areas where human activity acts to concentrate fish-eating predators, or to increase their effectiveness at prey capture, ratings will increase to 3 or 4. A value of 4 would represent highly unusual conditions likely to result in a dramatic per capita predation risk on salmon species, as might occur below fish bypass facilities associated with some dams.

In areas where human activity has dispersed fish-eating species abundance or reduced their overall population abundance (e.g., where bull trout or Dolly Varden are listed through the ESA), ratings will be reduced to values < 2.

It is recognized that the per capita risk of some fish-eating species may be increased over historic levels, while risk associated with other species may be reduced. The assigned ratings should represent an average condition across all species.

Special Instructions for New Input or Updates

A rating of 2 is assumed to be the historic condition. Rationale to be given for assigned ratings should note the fish-eating species that are assumed in the ratings. Consideration should be given to species that prey either on small or large fish (i.e., juvenile or adult salmon).

Rate the month when per capita predation risk is believed to be highest.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attribute, Predation, and in turn affects resultant species productivity.

References/Sources

Importance and Role: Beamesderfer and others (1996), Roby and others (1998).

Factors Affecting: Beamesderfer and others (1996), Roby and others (1998).

Riparian Function

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.5. Riparian and Channel Integrity

Shaping

Riparian Function is a non-shaped attribute.

Definition/Usage

A measure of riparian function that has been altered within the reach.

Importance and Role

The riparian zone is characterized by its vegetation—trees, brush, grass, and sedges. This zone and the stream channel are interdependent. The zone comprises those areas near the stream channel that affect the channel and are affected by it. Riparian areas constitute the interface between aquatic and terrestrial ecosystems.

Many of the functional and structural attributes of stream habitat are created and maintained through interaction with the riparian vegetation. Healthy riparian areas dissipate flood energy, moderate drought, store surface waters, recharge groundwater supplies, moderate water temperatures by providing shade, regulate energy inputs, and reduce erosion. These areas also provide large-sized wood structure, which is critical in creating structural diversity and habitat complexity in streams.⁷

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Strong linkages with no anthropogenic influences.	>75-90% of functional attributes present (overbank flows, vegetated streambanks, groundwater interactions typically present).	50-75% functional attribute rating- significant loss of riparian functioning- minor channel incision, diminished riparian vegetation structure and inputs etc.	25-50% similarity to natural conditions in functional attributes- many linkages between the stream and its floodplain are severed.	< 25% functional attribute rating: complete severing of floodplain-stream linkages

⁷ Historically large wood was not available in all streams east of the Cascade crest, particularly in the high desert. In those streams, other types of vegetation served some of the same purposes as those afforded by large wood, see text under "Factors Affecting Attribute/Guidelines."

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Valley form and channel confinement, including the extent that the channel has been artificially modified, strongly affect the extent and maintenance of the riparian zone. Unconfined channels tend to flood relatively frequently, promoting riparian development. Tightly confined channels, particularly within canyons, have much less opportunity for such development and support much smaller riparian zones.

Riparian wetlands are an important component of riparian zones. A wetland is a system that depends on recurrent or constant inundation or saturation at or near the surface of the substrate. Besides providing habitat for fish and wildlife, wetlands provide water storage, sediment trapping, flood damage reduction, water quality improvement/pollution control, and groundwater recharge.

Drawing from the Bureau of Land Management's (BLM) use of the concept, Proper Functioning Condition (PFC), the riparian-wetland area is considered to be proper functioning when adequate vegetation, landform, or large woody debris is present to:

- dissipate stream energy associated with high water flow, thereby reducing erosion and improving water quality;
- filter sediment, capture bedload, and aid floodplain development;
- improve flood-water retention and ground-water recharge;
- develop root masses that stabilize streambanks against cutting action;
- develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses;
- support greater biodiversity.

The reason the definition of proper function here includes "adequate vegetation, landform, *or* large woody debris" is that not all riparian-wetland areas are created equally. For example, in many areas west of the Cascade crest, large wood must be present to dissipate energy, capture bedload, and aid floodplain development. However, many streams in the high desert do not have the potential or require large wood to dissipate stream energy associated with high streamflows. These streams can dissipate energy through the presence of vegetation such as willows, sedges, and rushes (Prichard 1998).

The BLM's definition of function emphasizes the aspect of stream stability. Other elements of function are also worth noting, however, including: shading and inputs and regulation of energy sources (e.g., litter input) (Spence and others 1996).

The assignment of ratings to this attribute is subjective, to be based on a *judgment* of the extent that the elements defined above have been diminished by land use. Conclusions are to be based on personal knowledge of the reaches or inferences based on land use. Riparian function within urban areas and agricultural valleys will typically be extremely modified. Grazing practices are also known to severely impair riparian function. Forestry operations, especially using current standards, can result in impaired function, though usually not to the level seen with the other land uses.

Special Instructions for New Input or Updates

All months are rated the same for Riparian Function.

Effect on Level 3 Survival Factors

Riparian Function can affect the Level 3 attributes channel stability, habitat diversity, flow, and harassment, which in turn affects species productivity at certain life stages. Riparian function also affects other environmental conditions like temperature or habitat types. In these cases, however, the linkage is already accounted for in assessing the condition of the Level 3 attribute (here, temperature and key habitat).

References/Sources

Importance and Role: Cederholm and others (2000), Federal Interagency Stream Restoration Working Group (1998), Leopold (1997), Spence and others (1996).

Factors Affecting: Federal Interagency Stream Restoration Working Group (1998), Prichard (1998), Spence and others (1996).

Salmon Carcasses

Attribute Category

4. Biological Community

Attribute Sub-Category

4.1. Community Effects

Shaping

Salmon Carcasses is a non-shaped attribute.

Definition/Usage

Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

Importance and Role

Salmon act as an ecological process vector, important in the transport of energy and nutrients between the ocean, estuaries, and freshwater environments (Cederholm and others 2000). Salmon serve to cycle nutrients between these environments, most notably from the ocean to freshwater, where the carcasses can be the source of large amounts of nutrients to the riparian-stream system. The carcasses provide food to numerous wildlife species, macroinvertebrates, and fish species, including juvenile salmonids.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Super abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >800.	Very abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >400 and < 800.	Moderately abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >200 and < 400.	Not abundant -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) >25 and <200.	Very few or none -- average number of carcasses per mile of main channel habitat (within an appropriately designated area) <25.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper end.

Factors Affecting Attribute/Guidelines

The attribute, Salmon Carcasses, is intended to describe the relative number of salmon carcasses available for nutrient input. It is meant only to be a very rough approximation of an average annual number of carcasses that becomes available to the system. All species of salmon that

spawn naturally (including those of hatchery origin) in the system should be considered. The density of carcasses is to represent potential availability only to the system.⁸

Special Instructions for New Input or Updates

All months are to be rated the same for Salmon Carcasses.

Effect on Level 3 Survival Factors

The attribute, Salmon Carcasses, affects the Level 3 attributes Food and Competition.

References/Sources

Importance and Role: Cederholm and others (2000).

⁸ The effectiveness that carcasses can be utilized as food is likely related to channel structure (e.g., as provided by wood), flow patterns, and riparian condition. These may need to be incorporated in the biological rules that translate the Salmon Carcass attribute into the Level 3 attribute Food.

Temperature—Daily Maximum (by month)

Attribute Category

3. Water Quality

Attribute Sub-Category

3.2 Temperature Variation

Shaping

Temperature attributes are shaped. See Appendix.

Definition/Usage

Maximum water temperatures within the stream reach during a month.

Importance and Role

Water temperature is a crucial factor in many ecological processes within aquatic environments. It has a key role in shaping ecological structure and function along the river continuum.

Many aquatic species can tolerate only a limited range of temperature (Bjornn and Reiser 1991). Shifts in maximum and minimum temperatures within the stream can have profound effects on species composition of both vertebrates and invertebrates. Cold-water fishes cannot survive water above 25° C for very long; effects vary significantly among species.

Salmonids have definite ranges of tolerance and optimal temperatures at different life stages. For example, most salmon spawn in autumn when seasonal temperatures are decreasing from about 13° C to 5° C. Egg mortality or delayed inhibition of alevin development can occur when ripe females or newly deposited eggs are exposed to temperatures above 12.5° C. Survival of salmon eggs from adults exposed to temperatures of 16° C just prior to spawning can be assumed to be 50% if eggs are exposed to water temperatures of 16° C during incubation (Cuenco and McCullough 1996). At 18° C egg survival will approach zero.

During rearing life stages, salmonids can survive at temperatures near the extremes of suitable range, but growth and subsequent survival can be reduced at low temperatures (< 4° C)—because all metabolic processes are slowed—and at high temperatures (> 20° C)—because most or all food must be used for maintenance. High water temperatures can also inhibit salmon migrations and cause stress and mortality of holding adults. Excellent reviews of temperature effects, with ranges of tolerance described for many life stages of salmonids, are provided in the references listed at the end of this attribute.

In addition to direct effects on fish, water temperature affects dissolved oxygen solubility, decreasing with increasing water temperature. Temperature also governs many biochemical and physiological processes in cold-blooded aquatic organisms—increased water temperature generally increases metabolic rates throughout the food chain, resulting in higher rates of food consumption, and predation on salmonid species.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Warmest day < 10 C	Warmest day > 10 C and < 16 C	> 1 d with warmest day 22-25 C or 1-12 d with > 16 C	> 1 d with warmest day 25-27.5 C or > 4 d (non-consecutive) with warmest day 22-25 C or > 12 d with > 16 C	> 1 d with warmest day 27.5 C or 3 d (consecutive) > 25 C or > 24 d with > 21 C

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Water temperature within a stream reach is affected by the temperature of water coming from upstream, processes within the stream reach, and the temperature of other sources of water entering the reach (influent water). Each of these contributions is affected by solar radiation, ambient air temperature, vegetation cover, and the balance between water arriving via surface and groundwater pathways. Hence heavily shaded streams or those with significant groundwater inputs will normally be cooler than those without these elements.

Land use activities can have a pronounced effect both on the temperature of water entering streams, as well as on its rate of change as stream water moves downstream. Stream temperatures can be altered by removal of streambank vegetation, filling and drying of wetlands, interception and rerouting of groundwater inputs, withdrawal and return of water for agricultural irrigation, and release of water from reservoirs (warm water from a surface release and cold water from a deep release).

Increased exposure of streams to solar radiation due to the removal of streamside vegetation has altered the natural temperature regime of streams throughout the Pacific Northwest. Studies in the Coast Range and the Cascade Mountains of Oregon have shown increases in mean monthly maximum temperatures of about 3 to 8° C following clearcut logging (Beschta and others 1987). In warmer climates, such as occurs at lower elevations on the eastside of the Cascade crest, increased exposure to solar radiation by removal of streamside shading could be expected to result in a greater increase in maximum water temperatures.

The effect of buffer strips left along streams following logging or land clearing depends on a range of factors, such as vegetation species composition, age of stand, and density of vegetation. In forested areas within the Coast Range and Cascade Mountains of Oregon, buffer strips with widths of 30 m or more generally provide the same level of shading as that of an old-growth stand (Beschta and others 1987).

Special Instructions for New Input or Updates

This attribute is considered as a high priority for rating.

It is necessary to rate only the month when water temperature would likely be highest. Other months will be inferred using modeling techniques within the database by applying an appropriate temperature pattern for the watershed of interest.

Effect on Level 3 Survival Factors

This attribute is the primary factor affecting the Level 3 attribute Temperature during most life stages, which in turn, affects resultant species productivity in these life stages. It also is used as modifying factor affecting the Level 3 attributes Predation, Pathogens, and Sediment during some life stages, thereby also affecting species productivity.

References/Sources

Importance and Role: Beschta and others (1987), Bjornn and Reiser (1991), Cuenco and McCullough (1996), McCullough (1999).

Factors Affecting: Beschta and others (1987), Bjornn and Reiser (1991), Federal Interagency Stream Restoration Working Group (1998).

Temperature—Daily Minimum (by month)

Attribute Category

3. Water Quality

Attribute Sub-Category

3.2 Temperature Variation

Shaping

Temperature attributes are shaped. See Appendix.

Definition/Usage

Minimum water temperatures within the stream reach during a month.

Importance and Role

Water temperature is a crucial factor in many ecological processes within aquatic environments. It has a key role in shaping ecological structure and function along the river continuum.

Many aquatic species can tolerate only a limited range of temperature (Bjornn and Reiser 1991). Shifts in maximum and minimum temperatures within the stream can have profound effects on species composition of both vertebrates and invertebrates. Stream-dwelling salmonids can survive at temperatures near the extremes of suitable range, but growth and subsequent survival can be reduced at low temperatures ($< 4^{\circ}\text{C}$)—because all metabolic processes are slowed—and at high temperatures ($> 20^{\circ}\text{C}$)—because most or all food must be used for maintenance.

Extremely cold water temperatures during winter can cause stress, poor growth, and death among many fish species, including cold-water species. In juvenile life stages of salmonids, it is believed that a reduced metabolism during early winter can result in declining body condition and depletion of lipid reserves. A sharp metabolic deficit is difficult to offset by net energy intake, forcing individuals to use lipid reserves to maintain metabolic functions. Depletion of lipid reserves can lower body condition and result in overwinter mortality.

Incubation success of salmonid eggs is also reduced at cold water temperatures, when egg deposition occurs at such temperatures. The threshold for this effect appears to be in the range of $3\text{--}4^{\circ}\text{C}$. When egg deposition occurs at higher temperatures, followed by a reduction to very low temperatures, there is little or no effect of low temperature on survival.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Coldest day $>4^{\circ}\text{C}$	< 7 d with $<4^{\circ}\text{C}$ and minimum $>1^{\circ}\text{C}$	1 to 7 d $< 1^{\circ}\text{C}$	8 to 15 days $< 1^{\circ}\text{C}$	> 15 winter days $< 1^{\circ}\text{C}$

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Water temperature within a stream reach is affected by the temperature of water coming from upstream, processes within the stream reach, and the temperature of other sources of water entering the reach (influent water). Each of these contributions is affected by solar radiation, ambient air temperature, vegetation cover, and the balance between water arriving via surface and groundwater pathways.

Land use activities can have a pronounced effect both on the temperature of water entering streams, as well as on its rate of change as stream water moves downstream. Stream temperatures can be altered by removal of streambank vegetation, filling and drying of wetlands, interception and rerouting of groundwater inputs, withdrawal and return of water for agricultural irrigation, and release of water from reservoirs (warm water from a surface release and cold water from a deep release).

Increased exposure of streams to solar radiation due to the removal of streamside vegetation has altered the natural temperature regime of streams throughout the Pacific Northwest. While this has been most pronounced during summer months, natural temperature regimes have likely also been altered during winter in many streams. Exposed streams during winter can experience lower temperatures because canopy cover can inhibit energy losses by reducing evaporation, convection, or long-wave radiation from the stream. Long-wave losses are greatest when clear skies prevail, particularly at night (Beschta and others 1987). This phenomenon is typically not important in coastal streams of Oregon and Washington, where nighttime cloud cover and relatively warm air temperatures are common. However, it can be significant in streams at high elevations and farther east, or at northerly latitudes where snow accumulations are insufficient to cover and insulate the channel from energy losses.

Special Instructions for New Input or Updates

This attribute is considered as a high priority for rating.

It is necessary to rate only the month when water temperature would likely be lowest, such as January. Other months will be inferred using modeling techniques within the database by applying an appropriate temperature pattern for the watershed of interest.

Effect on Level 3 Survival Factors

This attribute is the primary factor affecting the Level 3 attribute Temperature during the inactive life stages, which in turn, affects resultant species productivity in these life stages.

References/Sources

Importance and Role: Beschta and others (1987), Bjornn and Reiser (1991), McCullough (1999), Smith and Griffith (1994).

Factors Affecting: Beschta and others (1987), Bjornn and Reiser (1991), Federal Interagency Stream Restoration Working Group (1998).

Temperature—Spatial Variation

Attribute Category

3. Water Quality

Attribute Sub-Category

3.2 Temperature Variation

Shaping

Temperature attributes are shaped. See Appendix.

Definition/Usage

The extent of water temperature variation (cool or warm water depending upon season) within the reach as influenced by inputs of groundwater or tributary streams, or the presence of thermally stratified deep pools.

Importance and Role

Spatial variation in water temperature within a stream reach can be created by the inputs of groundwater along the reach. In regions with extreme seasonal air temperatures, as occurs throughout extensive areas east of the Cascade crest, the spatial variation in water temperature provided by groundwater inputs can be important to the life histories and survival of many aquatic species. Sites with substantial inputs of groundwater also tend to have stable water flow, providing refugia from high or low water extremes for fish species—on both sides of the Cascade crest.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
Super abundant sites of groundwater discharge into surface waters (primary source of stream flow), tributaries entering reach, or deep pools that provide abundant temperature variation in reach.	Abundant sites of groundwater discharge into surface waters, tributaries entering reach, or deep pools that provide abundant temperature variation in reach.	Occasional sites of groundwater discharge into surface waters, tributaries entering reach or deep pools that provide intermittent temperature variation in reach.	Infrequent sites of groundwater discharge into surface waters, tributaries entering reach or deep pools that provide infrequent temperature variation in reach.	No evidence of temperature variation in reach.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

The most important factor for temperature of influent water within a stream is the balance between water arriving via surface and groundwater pathways (Federal Interagency Stream Restoration Working Group 1998). Water flowing over the land surface has opportunity to gain heat (or lose heat in winter). In contrast, groundwater generally maintains a stable temperature regime year round, averaging the annual ambient air temperature in the watershed. Hence groundwater is typically cooler than surface water during summer and warmer during winter. *Water flow via shallow groundwater pathways may lie between the average annual air temperature and ambient temperatures during runoff events.*

Land uses may change the natural balance of surface vs. groundwater supplies within an area. For example, both the fraction of runoff arriving via surface pathways and the temperature of surface runoff are strongly affected by the amount of impervious surfaces within a watershed. Hot paved surfaces in a watershed can heat surface runoff and significantly increase the temperature of streams that receive the runoff. Geographic areas with a high amount of impervious surfaces typically will also have reduced quantities of wetlands and interrupted groundwater routing, further altering the overall temperature regime within the stream.

Special Instructions for New Input or Updates

This attribute is considered as a high priority for rating.

Effect on Level 3 Survival Factors

This attribute is a modifier of the Level 3 attribute Temperature during most life stages, which in turn, affects resultant species productivity in these life stages.

References/Sources

Importance and Role: Stanford and Ward (1992), Federal Interagency Stream Restoration Working Group (1998), Ebersole and others (2003).

Factors Affecting: Stanford and Ward (1992), Federal Interagency Stream Restoration Working Group (1998), Ebersole and others (2003).

Turbidity (or suspended sediment)

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.6 Sediment Type

Shaping

Turbidity is a shaped attribute, often based on high flow. See Appendix.

Definition/Usage

The severity of suspended sediment (SS) episodes within the stream reach. *Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as Suspended Sediment, which affects turbidity.*

Suspended sediment is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not suspended sediment, but the two are usually well correlated. If only NTUs are available, an approximation of suspended sediment (SS) can be obtained through relationships that correlate the two.

The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$, where, X = duration in hours, Y = mg/l, $a = 1.0642$, $b = 0.6068$, and $c = 0.7384$. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS (see rating guidelines).

Importance and Role

Effects of suspended sediment (SS), either as turbidity or suspended solids⁹, on fish are well documented (summarized in Bash and others 2001). Suspended sediment can affect fish behavior and physiology and result in stress and reduced survival. The severity of effect of suspended

⁹ / The correlate suspended sediment is described either as turbidity or suspended solids, though the latter is preferred. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not normally considered as SS, but we treat them together since they are usually well correlated.

sediment increases as a function of both sediment concentration and exposure time, or dose (Newcombe and Jensen 1996). Newcombe and Jensen (1996) performed a meta-analysis of data contained in 80 published and documented reported to assess the effects of dose on fish responses, including numerous studies involving salmonids. The analysis yielded empirical equations that relate biological response to duration of exposure and suspended sediment (SS), including two that specifically address salmonids.

Equation 1, presented in that paper, applicable to all life stages, is used here to derive their scale of severity (SEV) for estimating effects on salmonid life stages (adapted in Table 7). The Level 2 index values 0-4 scale) were then aligned to their scale to cover the full range of effects of this attribute consistent with how the biological rule was constructed (Table 8).

Table 7. Scale of Severity (SEV) Index for suspended sediment (adapted from Newcombe and Jensen 1996). Boundaries shown encompass corresponding Level 2 index values, e.g., index value 0 corresponds to SEV values ≤ 4.5 ; index value 1 corresponds to SEV values > 4.5 and ≤ 7.5 , etc.

Duration (hrs)	Suspended sediment concentration (mg/l)														
	1	2	4	6	8	10	25	50	150	300	1,000	5,000	10,000	15,000	20,000
1	0.6	1.6	2.1	2.4	2.6	2.8	3.4	4.0	4.8	5.3	6.2	7.4	7.9	8.2	8.4
24	2.5	3.5	4.0	4.3	4.5	4.7	5.4	5.9	6.7	7.2	8.1	9.3	9.8	10.1	10.3
48	2.9	3.9	4.4	4.7	4.9	5.1	5.8	6.3	7.1	7.6	8.5	9.7	10.2	10.5	10.7
72	3.1	4.2	4.7	5.0	5.2	5.4	6.0	6.5	7.4	7.9	8.8	9.9	10.5	10.8	11.0
96	3.3	4.3	4.9	5.2	5.4	5.5	6.2	6.7	7.5	8.0	8.9	10.1	10.6	10.9	11.1
120	3.5	4.5	5.0	5.3	5.5	5.7	6.3	6.9	7.7	8.2	9.1	10.3	10.8	11.1	11.3
144	3.6	4.6	5.1	5.4	5.6	5.8	6.5	7.0	7.8	8.3	9.2	10.4	10.9	11.2	11.4
168	3.7	4.7	5.2	5.5	5.7	5.9	6.6	7.1	7.9	8.4	9.3	10.5	11.0	11.3	11.5
336	4.1	5.1	5.6	5.9	6.1	6.3	7.0	7.5	8.3	8.8	9.7	10.9	11.4	11.7	11.9
504	4.3	5.4	5.9	6.2	6.4	6.5	7.2	7.7	8.5	9.1	9.9	11.1	11.6	11.9	12.2
672	4.5	5.5	6.0	6.3	6.6	6.7	7.4	7.9	8.7	9.2	10.1	11.3	11.8	12.1	12.3
840	4.6	5.7	6.2	6.5	6.7	6.9	7.5	8.0	8.8	9.4	10.3	11.4	12.0	12.3	12.5
1,008	4.7	5.8	6.3	6.6	6.8	7.0	7.6	8.1	9.0	9.5	10.4	11.5	12.1	12.4	12.6
1,176	4.8	5.9	6.4	6.7	6.9	7.1	7.7	8.2	9.1	9.6	10.5	11.6	12.2	12.5	12.7
1,344	4.9	5.9	6.5	6.8	7.0	7.1	7.8	8.3	9.1	9.6	10.5	11.7	12.2	12.5	12.7
1,512	5.0	6.0	6.5	6.8	7.0	7.2	7.9	8.4	9.2	9.7	10.6	11.8	12.3	12.6	12.8
1,680	5.1	6.1	6.6	6.9	7.1	7.3	7.9	8.5	9.3	9.8	10.7	11.9	12.4	12.7	12.9
1,848	5.1	6.1	6.7	7.0	7.2	7.3	8.0	8.5	9.3	9.8	10.7	11.9	12.4	12.7	12.9
2,016	5.2	6.2	6.7	7.0	7.2	7.4	8.1	8.6	9.4	9.9	10.8	12.0	12.5	12.8	13.0
2,184	5.2	6.2	6.8	7.1	7.3	7.4	8.1	8.6	9.4	9.9	10.8	12.0	12.5	12.8	13.0
2,352	5.3	6.3	6.8	7.1	7.3	7.5	8.2	8.7	9.5	10.0	10.9	12.1	12.6	12.9	13.1
2,520	5.3	6.3	6.8	7.1	7.4	7.5	8.2	8.7	9.5	10.0	10.9	12.1	12.6	12.9	13.1

Table 8. Scale of Severity (SEV) index of ill effects associated with suspended sediment (adapted from Newcombe and Jensen 1996) and corresponding Level 2 Turbidity (suspended sediment) ratings used in rule formulation.

SEV	Description of effect	Level 2 SS rating
Nil effect		0
0	No behavioral effects	
Behavioral effects		
1	Alarm reaction	
2	Abandonment of cover	
3	Avoidance response	1
Sublethal effects		
4	Short-term reduction in feeding rates; short term reduction in feeding success	
5	Minor physiological stress; increase in rate of coughing;	
6	Moderate physiological stress	
7	Impaired homing	2
8	Indications of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition	
Lethal and para-lethal effects		
9	Reduced growth rate; reduced fish density	
10	0-20% mortality; increased predation	
11	>20 – 40% mortality	3
12	>40 – 60% mortality	
13	>60 – 80% mortality	4
14	>80 – 100% mortality	

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
SEV Index <= 4.5 Clear with infrequent (short duration--several days per year) concentrations of low concentrations (< 50 mg/l) of suspended sediment. No adverse effects on biota of these low doses.	SEV Index >4.5 and <= 7.5 Occasional episodes (days) of low to moderate concentrations (<500 mg/L), though very short duration episodes (hours) may occur with of higher concentrations (500 to 1000). These concentrations are always sublethal to juvenile and adult salmonids-though some behavioral modification may occur.	SEV Index >7.5 and <= 10.5 Occasional episodes of moderate to relatively high concentrations (>500 and <1000 mg/L), though shorter duration episodes (<1 week) may occur with higher concentrations (1000-5000 mg/L). The higher concentrations stated can be expected to result in major behavioral modification, severe stress, severely reduced forage success and direct mortality.	SEV Index >10.5 and <= 12.5 On-going or occasional episodes (periodic events annually lasting weeks at a time) of high concentrations of suspended sediment (>5000 and <10000 mg/L), or shorter duration episodes lasting hours or days of higher concentrations. These conditions result in direct, high mortality rates.	SEV Index >12.5 Extended periods (month) of very high concentrations (>10000 mg/L). These represent the most extreme severe conditions encountered and result in very high mortality of fish species.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

Suspended sediment loads in non-glacial streams are generally related to the intensity of land use. Logging, grazing, agriculture, mining, road building, urbanization, and construction activities result in periodic or chronic levels of suspended sediment in streams.

Glacial streams, such as the Puyallup and Nooksack in the Puget Sound region and Sandy, Hood, and White in Oregon, carry naturally high suspended sediment loads during hot summer months. Suspended sediment levels characteristic of such streams are described in Lloyd (1987). The paper discusses Alaskan rivers but sediment loads in those streams are likely similar to many glacial rivers in the Pacific Northwest.

Turbidity or suspended sediment measurements of some type exist for most watersheds in the Pacific Northwest. USGS records of measurements can be accessed at its web site. Washington Department of Ecology maintains a user-friendly database of SSC and turbidity for many sites around the state; the data provide a useful characterization of levels of SSC for the streams posted (http://www.ecy.wa.gov/programs/eap/fw_riv/wa_rvlks.html).

Special Instructions for New Input or Updates

Rate the month when suspended sediment is likely to be highest. Rate only one month. Other months will be inferred by application of a temporal pattern referenced to the one month that is rated. The pattern will be based on the hydrologic regime identified for the reach. Provide suitable comments if the seasonal turbidity pattern is different from what might be inferred from the flow pattern. This will be especially needed for glacial systems, where the worst SS month may be July or August. In this case, a note on the severity of turbidity during winter freshets would be helpful.

The rating procedure for this attribute requires that two aspects of suspended sediment load be applied: concentration (mg/l) and duration (in hours). Most rivers do not have extensive sampling programs to profile maximum SS concentrations across many years at multiple sites. Fewer have had detailed studies of SS to learn how concentrations vary daily during periods of runoff. Generally the best information that will be available will be for grab samples taken periodically by USGS or other governmental agencies. Use the average of concentrations for the season of runoff for the time series available, applied to the focus month as described above. Apply the data available to reaches that are likely to have similar levels of SS, then assume greater or lesser values for reaches and streams expected to differ based on local knowledge of the watershed. Duration is to be approximated as the number of hours in the focus month when that SS concentration is likely to occur or be exceeded. Compute the SEV index by the following: $SEV = a + b(\ln X) + c(\ln Y)$, where X = duration in hours in month (not necessary to be consecutive), Y = mg/l, $a = 1.0642$, $b = 0.6068$, and $c = 0.7384$.

If only turbidity measurements are available (in NTUs) and not SS, then SS concentrations can be approximated using a relationship between the two. Relationships can differ between watersheds, however, depending on the prevailing type of sediment within the watershed. For example, the relationships are likely to differ markedly between non-glacial and glacial streams. Example relationships for four areas are given in Figure 7 and Table 9. Relationships for other types of streams and areas can be constructed using data found at the USGS or WDOE web sites.

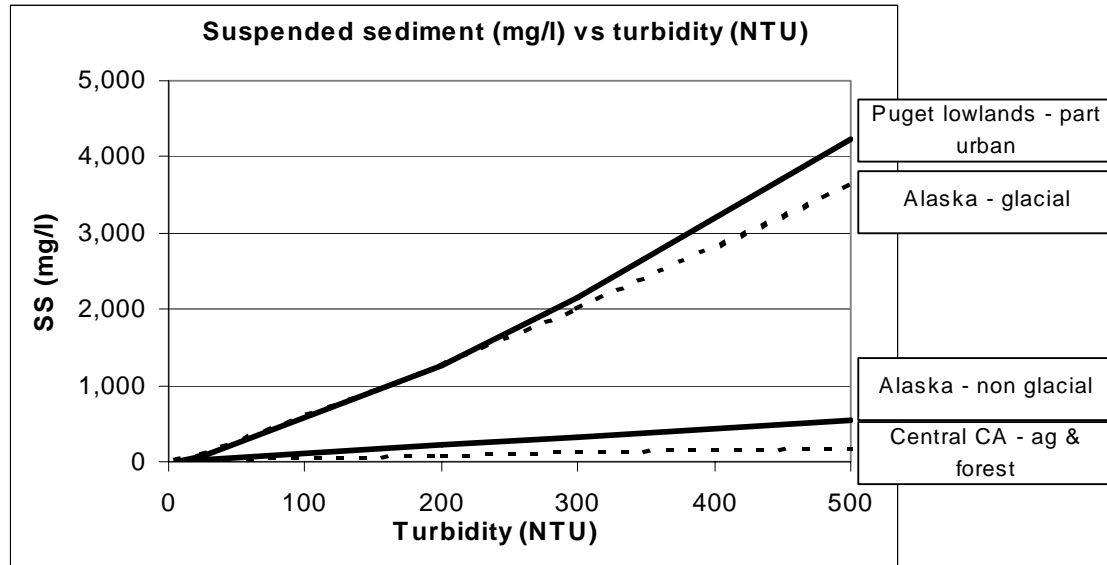


Figure 7. Relationship between suspended sediment and turbidity measured in NTU for selected streams in Puget Sound, Alaska, and California (relationships from Lloyd 1987, Packman and others 2000, Environmental Science Associates 2001).

Table 9. Parameters for relationships between suspended sediment (SS in mg/l) and turbidity (Turb in NTUs) for four categories of streams. Each relationship is described by the following: $SS = a \times \text{Turb}$

Geographic area – stream type	a	b	Source
Alaska - glacial	2.604	1.165	Lloyd and others 1987
Alaska – non glacial	0.904	1.033	Lloyd and others 1987
Puget lowlands – part urbanized	1.162	1.320	Packman and others 2000
Central Calif. – ag and forest lands	1.187	0.806	Environmental Science Associates 2001

Effect on Level 3 Survival Factors

This attribute affects all free swimming salmonid life stages. It is used to capture the effects on survival as described through the Level 3 survival factor Sediment Load.

References/Sources

Definition/Usage: Newcombe and Jensen (1996).

Importance and Role: Bash and others (2001), Newcombe and Jensen (1996).

Factors Affecting: Bash and others (2001).

Special Instructions for New Input or Updates: Lloyd and others (1987), Packman and others (2000), Environmental Science Associates (2001).

Water Withdrawals

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.4 Obstructions

Shaping

Water Withdrawal is a shaped attribute. See Appendix.

Definition/Usage

The number and relative size of water withdrawals in the stream reach.

Importance and Role

This attribute identifies risk of fish species being entrained or injured by screening or other structures associated with withdrawals of water from stream courses. *Note: Risk of a fish being stranded within a main channel when water is withdrawn from a reach is not to be addressed by this attribute. In that case, flow is the attribute of concern. Similarly, the effect of withdrawals on flow is assessed through the flow attributes.*

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
No withdrawals.	Very minor water withdrawals with or without screening (entrainment probability considered very low).	Several sites of significant water withdrawals along reach. All sites known or believed to be screened with effective screening devices. (Note: one site that withdraws substantial portion of flow with screening falls into this category.)	Several sites of significant water withdrawals along reach without screening or screening believed to be ineffective. (Note: one site that withdraws substantial portion of flow without screening falls into this category.)	Frequent sites of significant water withdrawals along reach without screening or screening believed to be ineffective.

* Where an index value is associated with a range, the integer value is assumed for modeling to be the midpoint. Index values can be identified as non-integers to represent the lower or upper ends of a range.

Factors Affecting Attribute/Guidelines

This attribute is to be applied only where this entrainment or screen impingement associated with water withdrawals. Factors affecting this attribute are presence of diversions where entrainment can occur or where fish can be injured at screening facilities.

Special Instructions for New Input or Updates

Rate the month when water withdrawals are greatest. Rate only one month. Other months will be inferred from an appropriate seasonal pattern based on an assumption that irrigation is the purpose for the withdrawal. If a more suitable temporal pattern should be applied, note this in the comments.

Effect on Level 3 Survival Factors

This attribute affects the Level 3 attribute Water Withdrawals (entrainment and injury related only).

References/Sources

Importance and Role: Bjornn and Reiser (1991).

Factors Affecting: See local information on presence of diversion and status of screening facilities.

Wood

Attribute Category

2. Stream Corridor Structure

Attribute Sub-Category

2.5. Riparian and Channel Integrity

Shaping

Wood is not a shaped attribute.

Definition/Usage

The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces > 0.1 m diameter and > 2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson and others (1992), May and others (1997), Hyatt and Naiman (2001), and Collins and others (2002). *Note: channel widths here refer to average wetted width during the high flow month ($< \text{bank full}$), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.*

Importance and Role

Large woody debris is an important structural component of many riverine ecosystems in the Pacific Northwest. It has key functions in forming channel type and habitat units, particularly in the creation and maintenance of pools, side channels, and backwaters. It provides structural complexity and cover for fish habitat. It regulates the transport of sediment, gravel, and organic matter, influencing their effects within physical and biological processes. The ability of large wood to perform these functions depends in part on its abundance, size, and type of wood, and on the size and geomorphology of the stream system.

Over the past century, the dramatic and steady loss of wood from river systems has contributed to significant changes in their form and function. Abundance, size, and stability of pools have declined. Distribution and abundance of side channels, backwaters, and off-channel habitats have diminished. Quantity and stability of spawning beds have been reduced. Nutrient cycling, including retention rates of critical constituents like salmon carcasses, has been altered. The effect of these changes has been an overall loss in both environmental quality and habitat quantity for salmonid species.

Categorical Conclusions

Index 0	Index 1	Index 2	Index 3	Index 4
A complex mixture of single large pieces and accumulations consisting of all sizes, decay classes, and species origins; cross-channel jams are present where appropriate vegetation and channel conditions facilitate their existence; large wood pieces are a dominant influence on channel diversity (e.g., pools, gravel bars, and mid-channel islands) where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 3-10 pieces/CW, 25-50 ft -- 3-10 pieces/CW, 50-150 ft -- 7-30 pieces/CW, 150-400 ft -- 20-50 pieces/CW in conjunction with large jams in areas where accumulations might occur, >400 ft -- 15-37 pieces/CW in conjunction with large jams in areas where accumulations might occur.	Complex array of large wood pieces but fewer cross channel bars and fewer pieces of sound large wood due to less recruitment than index level 1; influences of large wood and jams are a prevalent influence on channel morphology where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 2-3 pieces/CW, 25-50 ft -- 2-4 pieces/CW, 50-150 ft -- 3-7 pieces/CW, 150-400 ft -- 10-20 pieces/CW (excluding large jams) in conjunction with large jams in areas where accumulations might occur, >400 ft -- 8-15 pieces/CW (excluding large jams) in conjunction with large jams in areas where accumulations might occur.	Few pieces of large wood and their lengths are reduced and decay classes older due to less recruitment than in index level 1; small debris jams poorly anchored in place; large wood habitat and channel features of large wood origin are uncommon where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 1-2 pieces/CW, 25-50 ft -- 1-2 pieces/CW, 50-150 ft -- 1-3 pieces/CW, 150-400 ft -- 10-20 pieces/CW without large jams in areas where accumulations might occur, >400 ft -- 8-15 pieces/CW without large jams in areas where accumulations might occur.	Large pieces of wood rare and the natural function of wood pieces limited due to diminished quantities, sizes, decay classes and the capacity of the riparian streambank vegetation to retain pieces where channel gradient and flow allow such influences. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- 0.33-1 pieces/CW, 25-50 ft -- 0.33-1 pieces/CW, 50-150 ft -- 0.33-1 pieces/CW, 150-400 ft -- 3-10 pieces/CW without large jams in areas where accumulations might occur, >400 ft -- 2-8 pieces/CW without large jams in areas where accumulations might occur.	Pieces of LWD rare. Density of LWD (pieces per channel width CW) consistent with the following: channel width <25 ft -- <0.33 pieces/CW, 25-50 ft -- <0.33 pieces/CW, 50-150 ft -- <0.33 pieces/CW, 150-400 ft -- <3 pieces/CW with accumulations where they might occur, >400 ft -- <2 pieces/CW with no accumulations where they might occur.

* Note that two size class of LWD are applied: LWD by definition is anything > 0.1 m diameter and > 2 m in length while a "large piece" or "large wood" is defined as a piece > 50 cm diameter at its midpoint (based on standard Timber-Fish-Wildlife definitions).

Factors Affecting Attribute/Guidelines

The abundance of wood within stream channels is related to riparian tree species composition, soil stability, valley form, climate, lateral channel mobility, and channel and streamside management history. The operation of natural processes regulating wood input and stability in streams vary greatly across the Pacific Northwest, depending upon these factors.

Inputs of especially large wood (> 50 cm diameter) are most common in maturing and old growth forests. However, input rates of smaller pieces from young stands can sometimes equal or exceed those from old-growth forests, resulting in differently sized wood compositions between forested streams. Often, the majority of trees entering streams in second-growth stands tend to be dominated by deciduous species, with longevities within streams much less than those of coniferous species. These patterns generally result in smaller, less abundant, and less stable wood loads within channels of second-growth stands than in maturing and old growth forests.

Not all streams in the Pacific Northwest historically contained substantial amounts of wood. Riparian vegetation is usually the primary source of wood loading in channels. Streams flowing through forests typically have higher wood loading than those flowing through shrublands and grasslands, of which extensive areas exist east of the Cascade crest. Part of the function of large wood in forested streams can be served by riparian willows, sedges, and rushes in some eastside streams, as those in the high desert. There, these vegetation types can effectively dissipate stream energy and provide abundant fish habitat.

Wood loading in large rivers, at least on the eastside, can come mainly from areas well upstream in the stream system. In systems where the headwaters are the main source of wood, high flows can transport large quantities of wood into the lower reaches. Frequency of high flows, gradient, and physical complexity are important factors in determining where wood is deposited and when it becomes mobilized. Large rivers commonly have scattered pieces and aggregations of large in-channel wood on the upstream ends of islands and on river bends.

Any land use that diminishes riparian function or decreases riparian vegetation can affect wood loading into streams. Wood loads have been diminished through direct removal over the years (channel clearing), alterations of riparian vegetation species composition and age structure, and simplification of stream channels (e.g., straightening and diking), thereby reducing the ability of channels to retain wood.

Care needs to be taken to adjust for differences in wood sizes that may have been utilized in collecting data that are used to rate this attribute. For example, wood count surveys conducted by the Oregon Department of Fish and Wildlife use a larger minimum size of wood. That agency uses a minimum of approximately 6-inch diameter and 9 feet length (Moore and others 1999) whereas our definition uses approximately a 4-inch diameter and 6 feet in length (Peterson and others 1992).

Care also needs to be taken to convert all wood counts to units used in the definition of LWD applied here. EDT uses pieces per channel width (in meters) as described in Peterson and others (1992). The density of wood is often reported as the number of pieces per 100 meters of channel width (ODFW reports its wood counts like this) or pieces/100 m. Sometimes density is reported as pieces per mile. Other units have been used as well. It is critical to know what units are being used.

Pieces per channel width is computed by first by calculating the density for a *one* meter length of channel, then multiplying by the channel width in meters. The formula is:

$$\text{Pieces/channel width} = (\text{Pieces/meter channel length}) \times (\text{max channel width in meters})$$

The maximum monthly width used as part of the EDT width rating should be used. Technically, the number of pieces per channel width is to be computed with bankfull width but we have adjusted our rating metric to use the EDT maximum width for ease of calculation and comparison. Table 10 provides a lookup table to obtain categorical ratings for a range of data.

IMPORTANT NOTE: The ratings involve two size classes of wood, pieces > 0.1 m in diameter (4 inches) and large pieces > 50 cm in diameter (20 inches). Ratings of 2 or less indicate that some pieces of "large" wood are present though there may be few. Wood counts are to include those located in large jams.

Table 10. Conversion of wood counts expressed in pieces per 100 meters of stream to pieces per channel width (based on Peterson and others 1992).

Scale	Channel width (maximum width rating during high flow month)								
ft	3.3	6.6	9.8	16.4	25.0	32.8	49.2	65.6	147.6
m	1.0	2.0	3.0	5.0	7.6	10.0	15.0	20.0	45.0

Pieces per 100 m	Pieces per m	Pieces per channel width (corresponding to widths above)								
0.1	0.001	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.05
0.5	0.005	0.01	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.23
1	0.01	0.01	0.02	0.03	0.05	0.08	0.10	0.15	0.20	0.45
2	0.02	0.02	0.04	0.06	0.10	0.15	0.20	0.30	0.40	0.90
3	0.03	0.03	0.06	0.09	0.15	0.23	0.30	0.45	0.60	1.35
5	0.05	0.05	0.10	0.15	0.25	0.38	0.50	0.75	1.00	2.25
7	0.07	0.07	0.14	0.21	0.35	0.53	0.70	1.05	1.40	3.15
10	0.1	0.10	0.20	0.30	0.50	0.76	1.00	1.50	2.00	4.50
20	0.2	0.20	0.40	0.60	1.00	1.52	2.00	3.00	4.00	9.00
30	0.3	0.30	0.60	0.90	1.50	2.29	3.00	4.50	6.00	13.50
40	0.4	0.40	0.80	1.20	2.00	3.05	4.00	6.00	8.00	18.00
50	0.5	0.50	1.00	1.50	2.50	3.81	5.00	7.50	10.00	22.50
100	1	1.00	2.00	3.00	5.00	7.62	10.00	15.00	20.00	45.00
200	2	2.00	4.00	6.00	10.00	15.24	20.00	30.00	40.00	90.00

Pieces per 100 m	Pieces per m	EDT ratings (categorical only shown here)								
0.1	0.001	4	4	4	4	4	4	4	4	4
0.5	0.005	4	4	4	4	4	4	4	4	4
1	0.01	4	4	4	4	4	4	4	4	3
2	0.02	4	4	4	4	4	4	4	3	3
3	0.03	4	4	4	4	4	4	3	3	2
5	0.05	4	4	4	4	3	3	3	3	2
7	0.07	4	4	4	3	3	3	2	2	0
10	0.1	4	4	4	3	3	3	2	2	0
20	0.2	4	3	3	3	2	2	2	0	0
30	0.3	4	3	3	2	1	2	0	0	0
40	0.4	3	3	2	2	0	0	0	0	0
50	0.5	3	3	2	1	0	0	0	0	0
100	1	3	2	1	0	0	0	0	0	0
200	2	2	0	0	0	0	0	0	0	0

Special Instructions for New Input or Updates

All months should be rated the same for wood load.

Effect on Level 3 Biological Metrics

This attribute affects the Level 3 attributes Channel Stability, Flow, Habitat Diversity, and Harassment, which in turn affect resultant species productivities in several different life stages.

Note: wood also affects the formation of habitat types—Level 2 attributes—which, in turn, compose the Level 3 attribute, Key Habitat. Hence, it acts indirectly on this Level 3 attribute.

References/Sources

Definition: Peterson and others (1992), May and others (1997), Hyatt and Naiman (2001), Collins and others (2002).

Importance and Role: Bisson and others (1987), Maser and Sedell (1994), Spence and others (1996).

Factors Affecting: Johnson and others (1994), Minear (1999), Prichard (1998), Maser and Sedell (1994).

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Appendix. Recommended Approaches for Creating Flow and Width Patterns

EDT characterizes stream reaches using a standard set of attributes. When the procedure is completed, each reach is characterized for all attributes for each month in the year. The input procedure requires only that a single rating be assigned to a reach to a representative month. For some attributes, like Wood, the same rating is applied to all months in the year. For others, like those involving flow and channel width, the procedure requires that a seasonal pattern be defined that is then applied to compute ratings for the months that are not assigned an explicit rating or value.

Procedures for developing patterns are described briefly in this appendix. A seasonal pattern can be defined in different ways; several of these ways are described below along with recommendations about approaches to use in particular circumstances.

The need to analyze flow data for describing flow patterns is well known to hydrologists. Flow regimes are commonly analyzed by using a procedure in which average monthly discharge is compared against the mean annual flow (Gordon and others 1992). The results are then graphed and used to describe a generalized flow pattern for the river. This procedure can be used to compare flow patterns for streams with different sources of flow (e.g., rainfall dominated vs. snowmelt dominated).

What are we trying to capture with patterns?

- We are assigning ratings to Environmental Attributes – not patterns.
- The pattern for an attribute is meant to shape the rating over the calendar year. Typically the rating captures the conclusion for an attribute in a key (or worst case) month. The pattern is a set of multipliers that when applied to the rating gives the condition of that attribute for each month.
- The attribute is to be rated without thinking about patterns. Once the rating is complete, then the pattern should be considered. These tasks should be kept separate.

Channel Width

Attribute Rating

The inputs for wetted channel width are the average channel width during the month when width is greatest (generally the highest flow month) and the average channel width during the month when width is least (generally the lowest flow month). Note that this is not the absolute maximum or minimum in a year nor is the typical maximum width equal to the bank full width. The intent is to provide the typical width during each month to calculate the typical quantity of habitat in each month.

Channel Width Patterns

Most patterns are used to shape a rating across months within a year. However, for width, the need is to calculate the actual width in feet in each month. In the Stream Reach Editor, patterns

are required for both maximum and minimum width. However, identical patterns are used for both maximum and minimum widths. This pattern is generally the hydrograph normalized to monthly values between 0 and 1. However, it is also possible to use actual width measurements for each month in the Stream Reach Editor if that data is available. In fact, almost any information is allowable for the width patterns in the Editor (e.g. width in feet, flow in cfs, or a proportion) so long as the information is proportional to the variation in width over the year. EDT takes the maximum and minimum widths as two points on a curve describing the width across the year. The pattern is used to compute the width in the intervening months.

Flow Attributes

High Flow Attribute Rating (Change in average annual peak flow)

For this attribute we ask: Are the high flows that occur each year higher than they were prior to watershed development? If so, how much higher are they? (Or conversely, how much lower are they?) *Note: while the attribute talks about peak flow, it is not just about peak flow. The attribute addresses whether the high flows in general are higher, the same, or lower than historically.*¹⁰

Once a conclusion is reached about whether high flows have increased over time, the rating (or conclusion) is generally assigned to the month with the highest flow.

The pattern, or set of multipliers, to be applied addresses how the higher flows change over the calendar year. The timing of the highest flows must be captured, as well as the timing of major runoff periods, and this can be complicated for streams that typically experience their peak flows in one season and have a major prolonged runoff in another. For such streams, it is recommended that emphasis be placed on the period when the highest flows are highest. *Note: this will require a judgment call on the part of the person doing the work.*

The Flow Flashiness Rating (Flow—intra-annual flow pattern)

For this attribute we ask: Is runoff flashier than it was prior to watershed development? If so, how much more flashy? The attribute rating is assigned to the month with the lowest flow.

This attribute addresses runoff that occurs primarily due to rainfall, although it might also address how variable and rapid snow melt (or glacial melt) runoff occurs. Hence the pattern of multipliers should reflect when major storms occur that generate a lot of runoff (at the time of the storm event) or, in some cases, how quickly and how variable snow melt occurs.

For the vast majority of cases, it is appropriate to apply the same pattern as described above under high flow. There may be some cases with significant snow melt where the patterns should differ. *Note: this will require a judgment call on the part of the person doing the work.*

¹⁰ / The attribute uses peak flow as a measure of whether high flows have been altered, or in regard to an actual metric, the flow having a two year recurrence interval (or Q at 2 years).

The Low Flow Rating (Flow—change in average annual low flow)

With this attribute we ask: Are low flows (i.e., the flows that occur during low flow periods) that occur each year lower than they were prior to watershed development? If so, by how much?

Note: keep in mind that this attribute addresses only surface water flow.

Formulation of the low flow pattern will usually be the inverse of the high flow pattern, but not always. It will depend on the approach that was used to formulate the high flow pattern.

Standard Approach to Developing Flow Patterns

A number of approaches to capturing monthly flow patterns in EDT have been developed. Alternative approaches are sometimes used to capture unique situations that occur in some subbasins. However, for most applications the standard EDT procedure is a simple approach that captures flow patterns while ensuring that a rating for both high flow and low flow do not occur in the same month. Remember that patterns are designed to shape an attribute rating and that the rating applied in any month is the overall rating times the monthly multiplier in the pattern. Based on these considerations, the following is the recommended procedure for most cases:

Recommended Procedure to Derive Standard EDT Flow Patterns

1. Compute (or obtain directly from USGS) the mean flow for each month based on an available period of record. The result is a typical flow shape for a year.
2. Compute (or obtain directly from USGS) the mean annual flow.
3. Subtract the mean annual flow from each monthly mean flow. Values > 0 will be used to compute the high flow pattern and values ≤ 0 will be used to compute the low flow pattern.
4. For the high flow pattern, divide each of the values > 0 by the maximum monthly mean flow. The result will be that the highest flow month will have a value of 1 and all other high flow months will have lesser values; low flow months (values less than the average) have zero.
5. For the low flow pattern, divide each of the values < 0 (converted to positive values) by the minimum monthly flow. The result will be that the lowest flow month will have a value of 1 and all other low flow months will have lesser values; high flow months (values greater than the average) have zero.

Alternative Approach to Flow Patterns

There are many ways of formulating the patterns that may be useful to capture special conditions. Alternative approaches are warranted if the hydrologic pattern has unique characteristics that lead to important biological conditions. For example, an alternative approach that captures winter peak flow events is explained below:

Pattern from Peaks (based on single peak flow values for each year): This approach uses the reported peak instantaneous flows for each year in the data record. The data are easily applied to

build the pattern. This pattern will differ from the High Q Difference pattern for many east streams having significant snow melt runoff, as well as those mainstems on the west side also fed by snow melt. This approach is recommended when the spring snow runoff does not tend to produce the annual peaks. Examples of where this approach might be used instead of the Standard procedure include the Klickitat and perhaps the Grande Ronde. In both cases, winter rain-on-snow events produce brief flow peaks outside the normal high flow period (figures A3 and A4). Data for this approach come directly from USGS ready to build the pattern with no intermediate processing. A minimum of 20 years of data should be available to build such a pattern.

Pattern from Mins - No Overlap (based on the annual daily minimum flow): This pattern is very similar to the pattern based on peaks. It considers when the annual low flow is likely to happen. It may have some utility in some cases, but it is difficult to derive and tends to put too much emphasis on exactly when the extreme low flow occurs versus the longer time period when flows are low in general. A minimum of 20 years of data should be available to build such a pattern.

Flow Pattern Examples

The following examples are provided:

- (1) Newaukum River (tributary to the upper Chehalis River) is a rainfall runoff dominated stream with peaks that follow precipitation patterns (Figure A1). The Standard Approach is recommended.
- (2) Swamp Creek is an urbanized stream in Puget Sound. It is rainfall dominated but is very flashy, reflecting its urban setting (Figure A2). The stream would receive a high Flow IntraAnn rating to capture flashiness but the Standard Approach is recommended for the flow pattern.
- (3) The Klickitat River is a transitional rain on snow stream. Although there is a spring flow peak, extreme winter flow peaks are normal as a result of rain on snow events (Figure A3). Because the winter peaks are an important feature of the flow dynamics in the Klickitat, the alternative approach based on peaks is recommended.
- (4) The Grande Ronde River is a snowmelt dominated system. However, like the Klickitat, rain on snow events can lead to extreme winter peaks (Figure A4). The alternative flow pattern approach may be applicable here if the decision is made that the winter flow peaks are important hydrologic features.

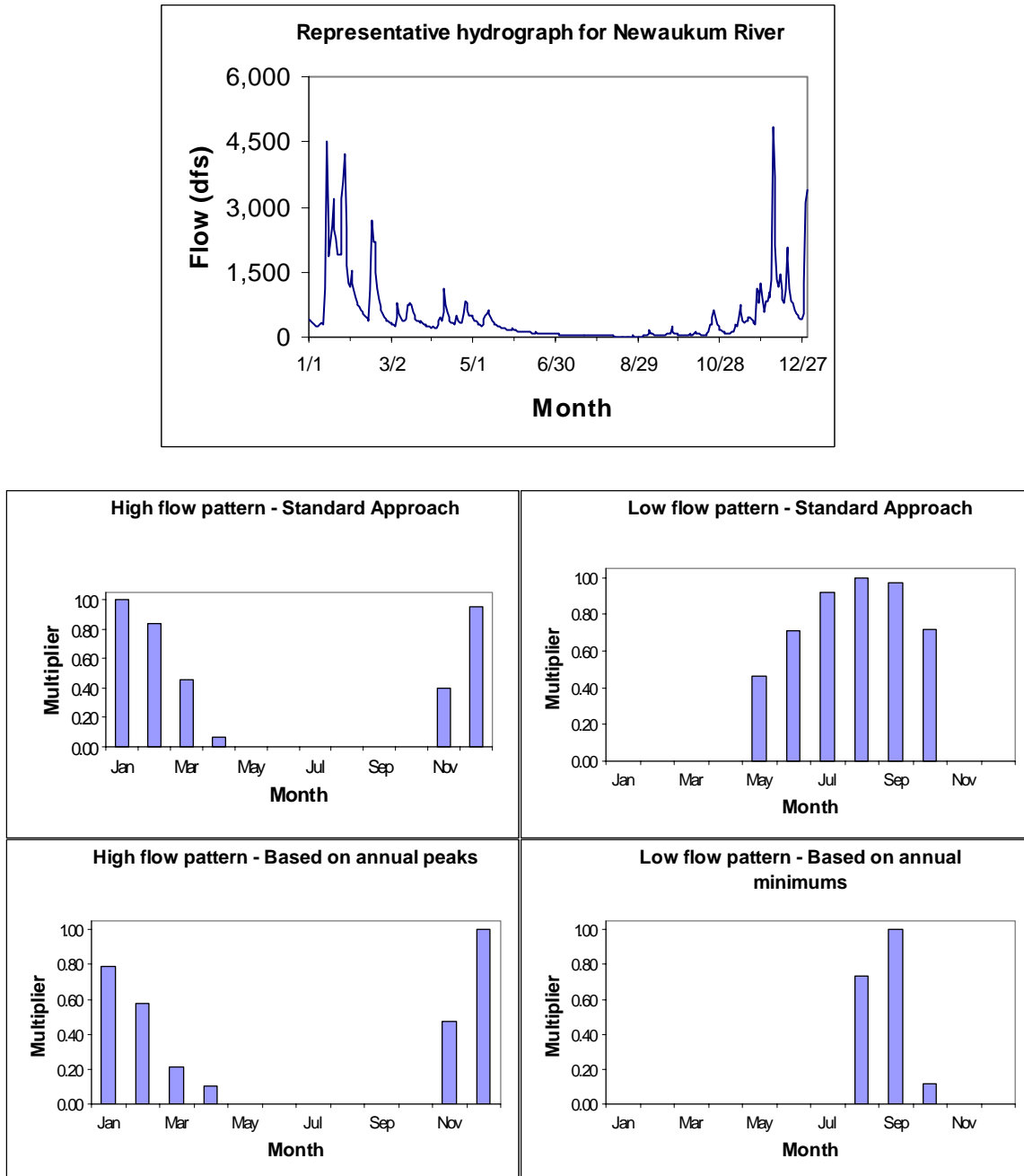


Figure A1. Newaukum River (tributary to Chehalis River, Washington).

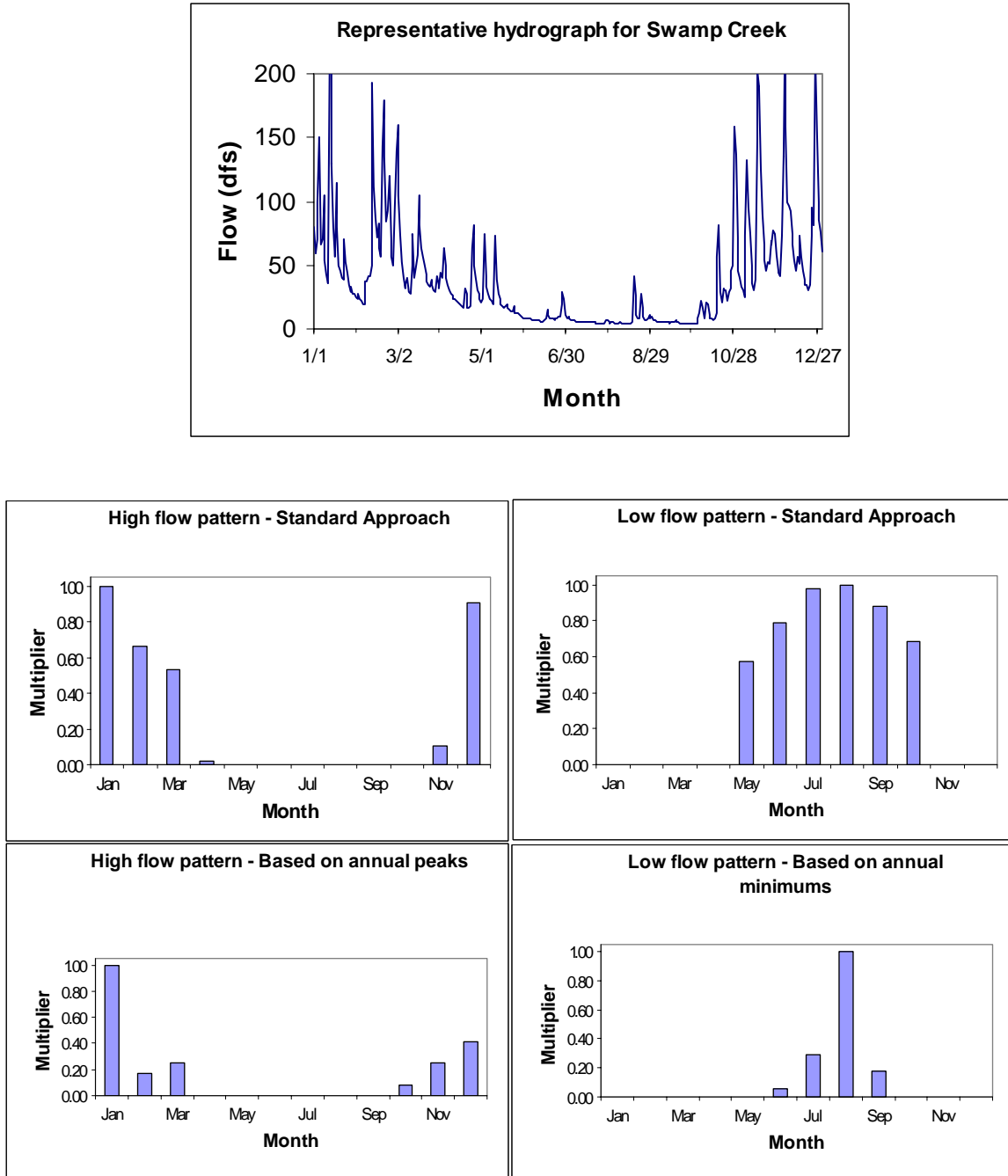


Figure A2. Swamp Creek (tributary to Lake Washington near Seattle – urbanized stream).

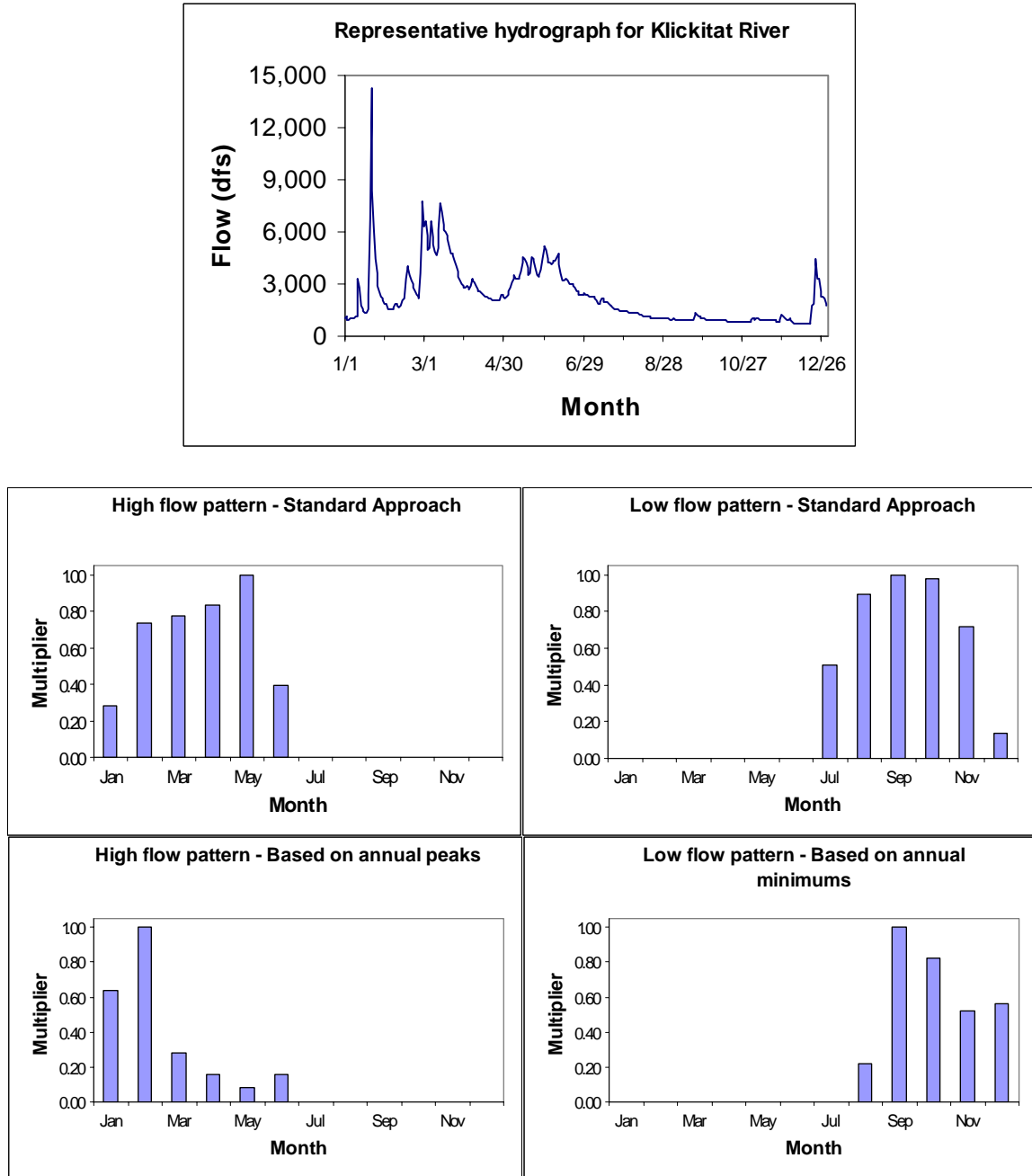


Figure A3. Klickitat River (tributary to Columbia River, Washington).

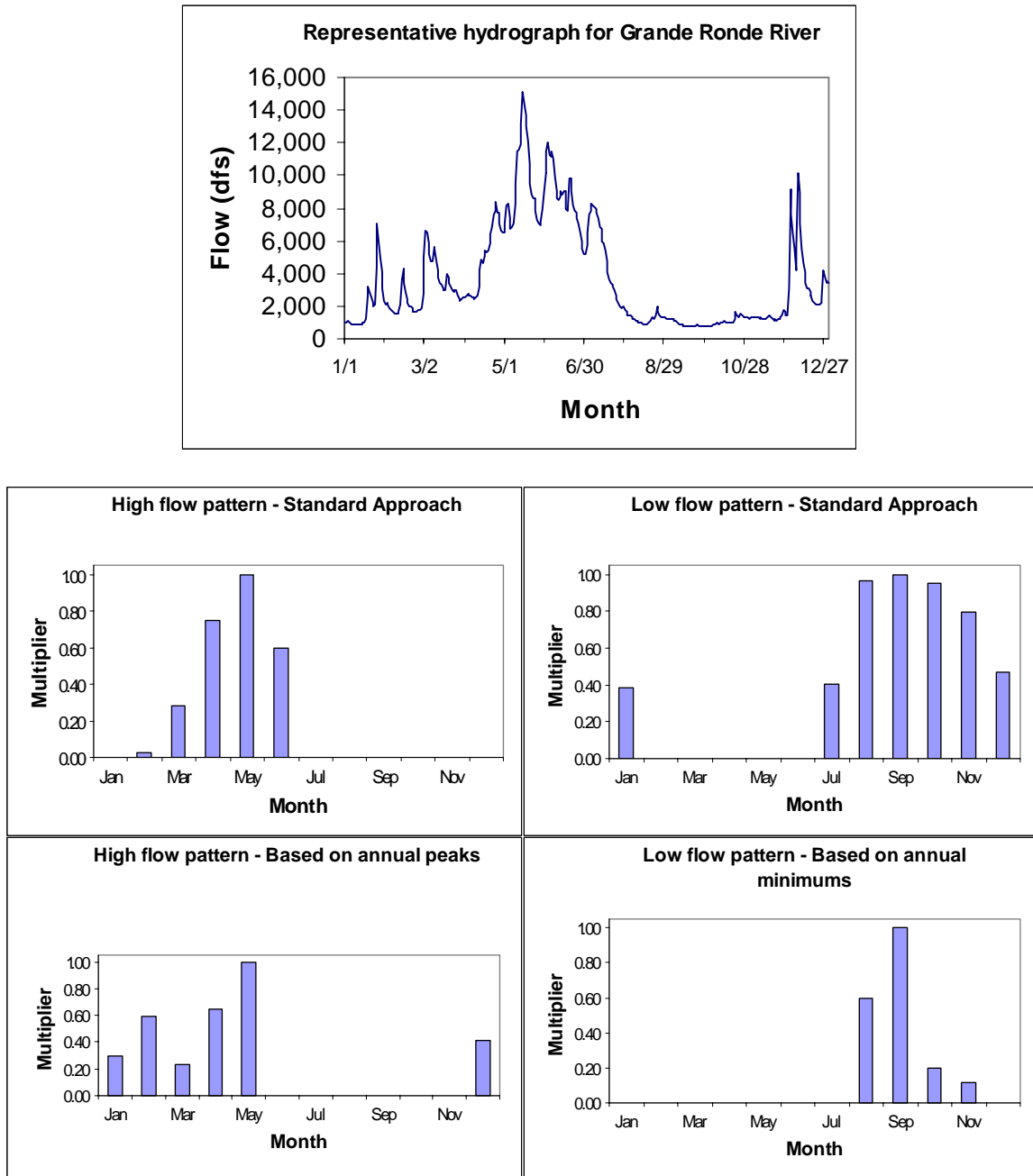


Figure A4. Grande Ronde River (tributary to Snake River, northeast Oregon).

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