7.0 HABITAT

7.1 AQUATIC HABITAT

Physical, chemical and biological characteristics comprise the aquatic habitat of river systems. Physical habitat includes parameters such as channel dimension, stream flow and riparian vegetation; chemical variables include water pH and nitrate levels; and biological components serve as indicators of the ecological community that utilize the river, e.g. fish and macroinvertebrate species composition and diversity. Discussion in this chapter focuses mainly on the physical and biological habitat indicators of the Entiat subbasin, as many of its chemical characteristics are discussed in Chapter 8, Water Quality; however, because all three components are interrelated, some discussion of chemical characteristics is also included here.

Physical Characteristics

Water Temperature

Aquatic habitat, specifically fish habitat, is very sensitive to water temperature and day to day water temperature fluctuations can influence anadromous salmonid movement (Workman et al. 2002), habitat selection, competitive interactions, and other ecological factors (De Staso and Rahel 1994; Taylor 1988; Coutant 1976). The following discussion was excerpted from Rashin et al. (1993).

Water temperature is a critical factor affecting the survival and growth of salmonid fishes that reside in freshwater streams during the summer low flow period. Lantz (1970) provides the following summary of the relationship between water temperature and salmonids:

1. Water temperature is one of the most important environmental factors affecting fish because they are cold-blooded and their internal body temperature must adjust to the temperature of the external environment.
2. Salmon and trout have a lower level of thermal tolerance than many less desirable species have.
3. Fish have lower and upper lethal temperature limits. These limits are specific for each species, but may vary at different stages in their life history.
4. Within lethal thermal limits, other environmental factors (such as disease, toxic materials, etc.) can operate in conjunction with temperature to reduce survival. The total impact of such interactions may be greater that the sum of their individual effects.
5. Fish are able to acclimatize to seasonal temperature changes and to minor fluctuations in temperature. They acclimatize more readily to an increase than to a decrease in temperature.
6. Growth is an indicator of the well-being of an animal. The most efficient metabolism and utilization of food resources for growth occurs at lower temperatures.
7. Timing of life history events, including adult migrations, fry emergence, and smoltification can be altered by temperature changes.

8. The scope of activity of cold-water fishes is greatest at moderately low temperatures, which correspond closely to the fishes preferred temperatures.

The optimal temperature range for most salmonid species is approximately 12-14° C (54-57° F) (Brett 1952). Increased stream temperature may have a beneficial effect on salmonids when it results in greater food production and increased growth but does not exceed the optimal temperature range (Beschta et al. 1987). Lethal levels for adult salmonids vary according to factors such as the acclimation temperature and the duration of the temperature increase, but lethal levels are generally in the range of 23-29° C (73.4-84.2° F) (Bjornn and Reiser 1991). Bjornn and Reiser (1991) caution that, "although some salmonids can survive at relatively high temperatures, most are placed in life-threatening conditions when temperatures exceed 23-25° C, and they usually try to avoid such temperatures (definite avoidance >59° F) by moving to other areas" (Brett 1952). The egg and juvenile life history stages are the most sensitive to high temperatures (MacDonald et al. 1991). In some cases, the extent of temperature changes may be more critical than the maxima.

Sub-lethal effects of above optimal water temperatures often appear to be more critical than direct mortality. Examples of sub-lethal effects include:

1. reduced survival of eggs and progeny when adults spawn in warm water (Lantz 1970).
2. increased virulence of many of the diseases/pathogens most significant in the Pacific Northwest including kidney disease, furunculosis, vibriosis and columnaris (Lantz 1970).
3. avoidance of warm waters, resulting in changes in distribution or migration patterns (Beschta et al. 1987).
4. increased metabolic activity that results in reduced growth rate when temperatures exceed the optimum level (Lantz 1970, Beschta et al. 1987).
5. change in timing of development and life history stages (Holtby 1988).
6. reduced ability to compete with other species (Beschta et al. 1987).

USFS Entiat RD temperature data collected annually since the early 1990's show state water quality temperature standard exceedences in the Entiat and Mad Rivers during the late summer/fall period for each year of monitoring. The 2002 USFS Entiat RD annual water temperature report is contained in the Reports folder on the CD. The Entiat Watershed Assessment (USFS WNF 1996) reported that the (then) current data base showed much variation in the extent, duration, and location of summertime highs.

Prior to 1998, the emphasis of water temperature monitoring in the Entiat watershed was concentrated on summer maximum temperatures, according to state and Wenatchee Forest Plan standards. Observational conjecture led to speculation that wintertime lows and the formation of anchor ice in the lower mainstem Entiat and Mad Rivers may be a greater limiting factor than summertime highs (USFS WNF 1996). The WRIA 46 Limiting Factors Analysis reported that a lack of overwintering juvenile rearing habitat is perhaps the most limiting factor of the aquatic habitat in the Entiat watershed to fully sustain salmon

populations (Andonaegui 1999). Entiat RD staff concluded that future iterations of watershed analyses would examine water temperature as a limiting factor to fish.

Carie (1999) reported that Combs (1965) demonstrated that if Chinook salmon eggs are initially exposed to water temperatures less than 42.5° F (5.8° C) significant mortality will likely occur. If water temperature is in the range of 42.5° F to 56° F (13.3° C) for the first 72 hours after deposition, a subsequent drop in temperature below this threshold will not cause abnormal mortality. A lower threshold of 35.06° F (1.7° C) for Chinook eggs exists, below which 100% mortality occurs (Tang et al. 1987). Carie (1999) noted that at the time late-run (summer) Chinook salmon are spawning in the Entiat River, water temperatures are very close to, and sometimes below, this lower threshold.

Continuous stream temperature data from RM 26, Forest Boundary, (1967-1978 and 1996-1999) were examined to see if salmon eggs are exposed to lethal low temperatures (as described above) at this location. Spring Chinook salmon typically spawn between RM 16 and RM 28 from late August through September while late-run Chinook salmon typically spawn between RM 15 and RM 25 during October through early November (see the Anadromous Fish section for more information on Chinook in the Entiat subbasin). The following conditions in the Entiat River were noted as being potentially significant to Chinook salmon egg survival:

- **Minimum** daily stream temperatures occasionally fell below 42.5° F in September at RM 26.
- **Minimum** daily stream temperatures always fell below 42.5° F during October and November in all years of data collection at RM 26.
- **Maximum** daily stream temperatures during early to mid-October were near optimal levels but often fell below the lower critical temperature of 42.5° F in November.

Beginning in 1999, the USFS Entiat RD in cooperation with the Planning Unit deployed an expanded network of temperature data loggers for longer durations to collect data to address this and other aquatic habitat questions. A detailed comparison of late-run Chinook redd detections and water temperatures on or near estimated spawning dates in 1999 showed daily maximum temperatures were above the 42.5° F threshold when eggs were most likely deposited, but minimum temperatures were unfavorable (shaded areas in shown in Table 7-1 on page 7-4) during the month of October at all locations in the Entiat River except RM 15.

Table 7-1. Comparison of Entiat River 1999 late-run Chinook spawning survey data and stream temperatures (°F) observed prior to finding the redds.

# of redds	River Mile (RM)	Date found	Monitor-ing site	Max °F 1 week prior	Max °F week of survey	Min °F 1 week Prior	Min °F week of survey
1	24.4	10/6/99	RM24	48.8	51.9	39.9	39.9
7	18.8-20	10/7/99	RM21.1	49.6	52.7	40.6	40.6
16	16-18.8	10/7/99	RM18	50.6	52.8	42.2	42.2
4	20-22	10/21/99	RM24	50.2	43.8	36.5	38.2
6	18-20	10/21/99	RM21	51.3	44.9	36.9	38.4
4	17-18	10/22/99	RM18	51.1	45.8	38.8	39.4
3	16-17	10/22/99	RM15	50.1	47	42.8	43.1
1	3.4	10/22/99	RM3.2	53.7	49.2	39.9	40.8
2	0.5	10/22/99	RM1.4	53	48.2	41.3	42.1
3	0.5	11/9/99	RM1.4	46.3	44.1	40.1	38.2

Continuous water temperature monitoring at Entiat RM 1.4 (Keystone gage) since March 2002 shows extended periods (19 days) of minimum temperatures below 42.5° F during the late-run Chinook spawning period of October through early November. Entiat River winter (incubating) minimum stream temperatures were ≤ 33° F for prolonged periods (32 days) during the winter of 2002-2003. Anchor ice forms in sections of the lower river (RM 0-15) when water temperatures cool into this range for several consecutive days or more. Anchor ice may disturb or destroy spawning and incubation areas through the formation and movement of ice which can scour the streambed, especially during breakup (Swanston 1991). Wide, shallow streams are more susceptible to anchor ice formation than are deep, narrow ones because supercooled water develops more rapidly. There is also a tendency for anchor ice to form more readily in uncanopied stream sections where more rapid cooling can occur (Swanston 1991; see Appendix M). The supercooled conditions that lead to the formation of anchor ice definitely prolong egg development and delay emergence and may also lead to the formation of ice crystals within developing eggs, destroying cell membranes and causing mortality. Anchor ice may also inhibit the exchange of water within redds, reducing dissolved oxygen supply and inhibiting metabolic waste removal from the egg pocket.

BioAnalysts, Inc. (2002a) evaluated water temperature, dissolved oxygen (intragravel and water column), and egg/alevin mortality in 24 chinook redds in the lower 3.5 miles of the Entiat River weekly during a study period from 11/18/2001 through 12/29/2001 and biweekly from 1/6/2002 through 3/23/2002. Trend analysis indicated that the survival of chinook within redds decreased significantly ($F = 4.912$; $P = 0.038$) during the study period. During the first month of the study period (11/18-12/8/2001), 10% of the 449 chinook extracted from redds in the lower Entiat River were dead. During the time period from 12/9/2001 through 3/23/2002, 41% of the 1204 chinook extracted from redds in the lower Entiat River were dead. The highest egg mortality (76% of 160 eggs sampled) occurred during the week of 1/6-12/2002 when intragravel DO was 12.15 mg/L, mean daily water temperatures ranged between 1° C and 2.5° C.

Water column mean DO varied little (12 to 17 mg/L) as did intragravel mean DO (9 to 13 mg/L); however, fine sediments within redds in the Entiat River may have decreased intragravel DO levels as one redd with large amounts of fine sediments had intragravel DO levels that dropped below 5 mg/L. Mean daily water temperature gradually declined from 10° C in mid-October to 0° C in mid-December (10 days <1° C) after which water warmed to about 3° C for one month then dropped back to 0° C on 5 days in mid-January. Mean daily water temperatures ranged between 1° C and 5° C from late January through late March 2002. BioAnalysts (2002) did not observe hatching in the Entiat River until late February-early March when alevins averagred about 30 mm in length. Entiat River Chinook fry did not emerge until late April, likely due to colder water temperatures (BioAnalysts, Inc. 2002a).

The SNTEMP model has been used to examine mitigation alternatives for high water temperatures (Hendrick and Monahan 2003); however, further investigation of low water temperatures and winter habitat conditions is warranted. Future winter temperature data collection is planned by the USFS Entiat RD at three select sites: RM 1.4 (Keystone gage), RM 18 (Ardenvoir gage) and RM 26 (USFS boundary); the lower Mad River may also be included. Some additional winter temperature data are also being collected via the WDOE enhanced stream flow gaging network. Because water temperature is treated as a water quality element in this plan, additional historic data and information about SNTEMP modeling are contained in Chapter 8, Water Quality.

Erosion and Sedimentation

Soils in the Entiat WRIA are generally very erodible, and most land types have high sediment delivery rates. The amount and size of sediment delivered to and deposited in stream channel substrate is directly related to geologic and land type features, which vary throughout the subbasin. For example, the upper glacial troughs produce coarse sediments; whereas in the lower subbasin, unglaciated mountain slopes produce fine sediment. Erosion and sedimentation have helped define the shape of the landscape and provide much of the framework for life in the Entiat (fertile soils for agriculture, adequate gravels for fish habitat, etc.).

Erosion and sedimentation are natural processes, integrally woven into the hydrologic cycle. The erosion/sedimentation cycle in the Entiat is highly variable, and the natural or historic range of variability of sediment production in this system is unknown. Variability is largely a function of snowmelt runoff, storm events and related disturbances. In the Entiat subbasin, it is estimated that approximately 80% of the average annual sediment load within a given year is associated with snowmelt peak flows (USDA 1979). Annual sediment transport is relatively low during moderate to low flow periods, in the absence of storm/flood events. Annual sediment load can vary greatly from year to year, depending on factors such as annual precipitation, timing and rate of snowmelt, occurrence of storm/flood events and watershed conditions (e.g., whether an area has recently burned). The desired condition is a balanced sediment regime that is stable over the long-term, and a watershed system that can respond with resiliency to disturbance.

Both natural and human-caused disturbances can alter the rate of sediment delivery from hill slopes to riparian areas and the stream system, and can also affect beneficial uses of the water resource, including aquatic habitat, domestic and irrigation uses, and aesthetics.

Erosion and sediment production have been high following major wildfires and floods in the subbasin. A large amount of material was introduced into the system following the 1970 fires, causing alteration of floodplains and fish habitat, and problems with the use of surface waters for irrigation. Additional sediment pulses have occurred in as a result of fire/flood scenarios in 1976-1977 (Crum Canyon Fire), 1988-1989 (Dinkelman Fire) and 1994 (Tyee Fire).

Although sediment build-up in irrigation systems in response to high flows and flood events remains a maintenance issue, conditions have continued to improve since the 1970's (C. Petersen, pers. comm. 1999). The Entiat Co-operative Basin Study concluded that sediment reduction efforts should focus on treatment of eroding stream banks and lower slope sediment sources, and much site rehabilitation work has been performed in response to past fire/flood events (USDA 1979). A great deal of natural recovery has also occurred since the events of the early 1970's, and the USFS has placed additional emphasis on road system rehabilitation in the watershed (USFS WNF 1996).

Fine Sediment

The Entiat and Mad Rivers provide significant spawning and rearing habitat for spring and late-spawning Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*), and summer steelhead (*O. mykiss*) and bull trout (*Salvelinus confluentus*). A certain level of fine sediment exists naturally in streambeds; however, elevated levels of fines ($\leq$ 1.0mm in diameter) resulting from accelerated human-caused erosion can adversely affect fish spawning and rearing success. The deleterious effects of excessive sedimentation on egg-to-fry survival of salmon are well documented in scientific literature, and include suffocation and metabolic-waste-poisoning of eggs (Chapman 1988); decreased egg survival to emergence (Reiser and White 1988); and increased mortality due to fry entrapment and suffocation (Chapman 1988). Accelerated sedimentation rates can also lead to channel widening and loss of important pool habitat (Petersen et al. 1992).

The USFS initiated annual fine sediment monitoring in critical reaches of the Entiat and Mad Rivers in 1993 and 1994, respectively, to monitor fine sediment deposition in salmonid spawning habitat, and help identify baseline condition and the natural range of variability for the Entiat River subbasin. Samples are collected from four reaches in the Entiat River and one reach in the Mad River, according to the sampling methodology established by the Northwest Indian Fisheries Commission salmonid spawning gravel composition module (Schuett-Hames et al. 1999). For statistical validity, this methodology specifies a minimum sample size of three reaches per stream, three riffles per reach, and four samples per riffle. Reaches were chosen based on: coincidence with previous USFS study reaches, overlap with WDFW Chinook spawning index reaches, known species use, and for comparison purposes. Intra-reach sampling sites were selected based on their suitability for, or known occurrence of, Chinook salmon and/or bull trout spawning.
Reach-specific data analyses show the following trends (Archibald 2004):

- Entiat Reach 1 long-term decreasing with high variability (plus or minus 5 percent);
- Reach 2 long-term decreasing with moderate variability (plus or minus 2 percent);
- Reach 3 long-term decreasing with moderate variability (plus or minus 3 percent);
- Reach 4 long-term increasing with moderate variability (plus or minus 3 percent); and
- Mad River long-term stable with moderate variability (plus or minus 2 percent)

Analyses of all data collected since 1993 suggest that the Entiat and Mad River watersheds have been working to recover from the effects of fire-related events, as shown by the gradually improving trend in mean annual percent fines ≤ 1.0mm depicted in Figure 7-1 on page 7-8. The 11 year grand mean (mean of annual means) of Entiat River data, and 10 year grand mean of Mad River data, indicate that both the Entiat and Mad River systems are approaching a value that can be considered to be the "baseline" condition (see Figure 7-2).

The overall trend of fine sediment levels in the Entiat and Mad Rivers may be explained by annual weather patterns, precipitation and the magnitude and duration of peak flows (Archibald 2004). Below normal precipitation and streamflow in 1993 and 1994 led to accumulating fine sediment due to lack of flushing flows those years. Above average snowpacks and runoff during the years 1995-1997, and 1999 transported fine sediment out of the upper three Entiat reaches and the Mad River after the 1994 Tyee Fire. In 1999, Entiat River streamflow measured two-three times the 40-year average in August. In 2000, Entiat River streamflow was close to "normal" (40-year mean USGS Ardenvoir gage) except during the June peak period when fine sediment transport is expected to be greatest. The magnitude of peak streamflow during 2001 was 50 percent lower than the 43-year mean. The magnitude of peak streamflow during 2002 was well above the 44-year mean. The magnitude of peak streamflow during 2003 was nearly 800 cfs above the 46-year mean, supporting the conclusion that the overall decrease in fine sediment this year was a result of above average peak flows. Simple linear regression analyses of peak flow at Entiat RM 18 versus percent fine sediment in spawning gravel in four reaches indicate that decreasing fine sediment is weakly positively correlated with increasing peak flows (R-squared values of 0.07, 0.17, 0.10, and 0.23) (Archibald 2004). The results of future sediment monitoring will help further define baseline condition, trends, and range of natural variability for the Entiat subbasin, and guide development of restoration activities aimed at reducing sources of accelerated fine sediment deposition in spawning habitat.

For the complete report on fine sediment in the Entiat and Mad Rivers, refer here for the "2003 Sediment Monitoring Report for the Entiat and Mad Rivers" (Archibald 2004) or the Reports folder on the CD.

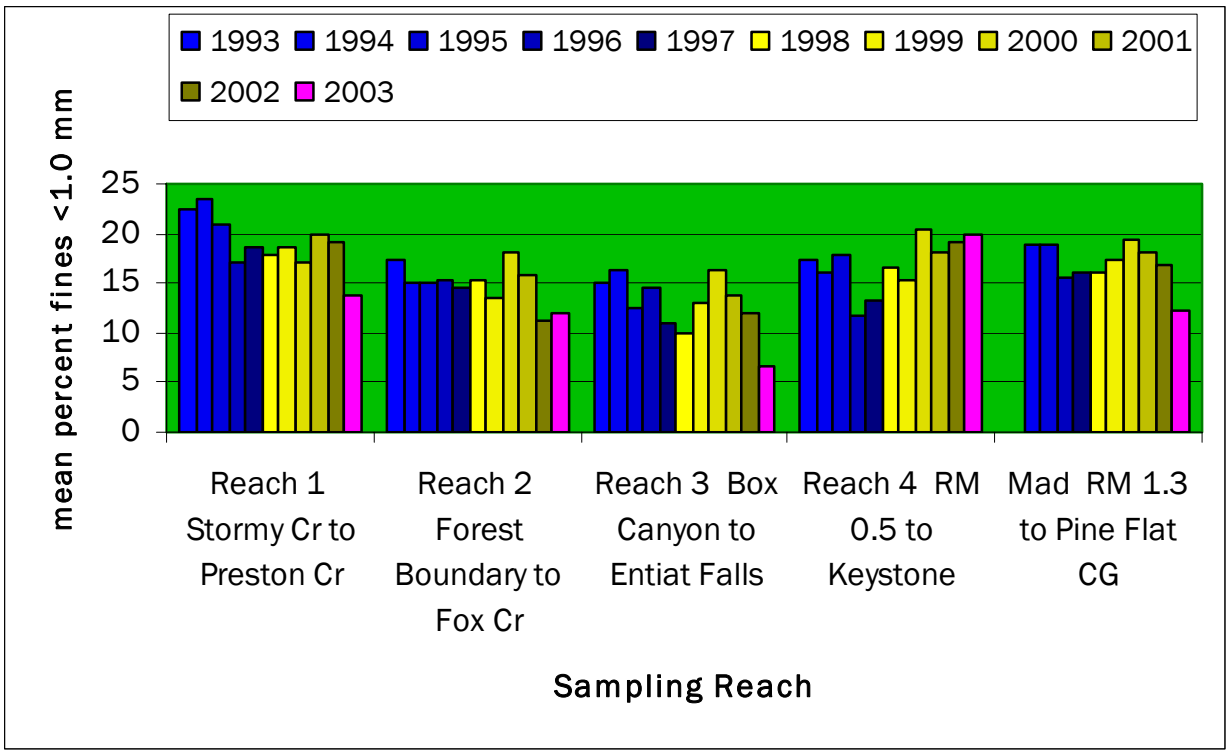

Figure 7-1. Entiat and Mad River fine sediment sampling comparisons by reach, 1993-2003.

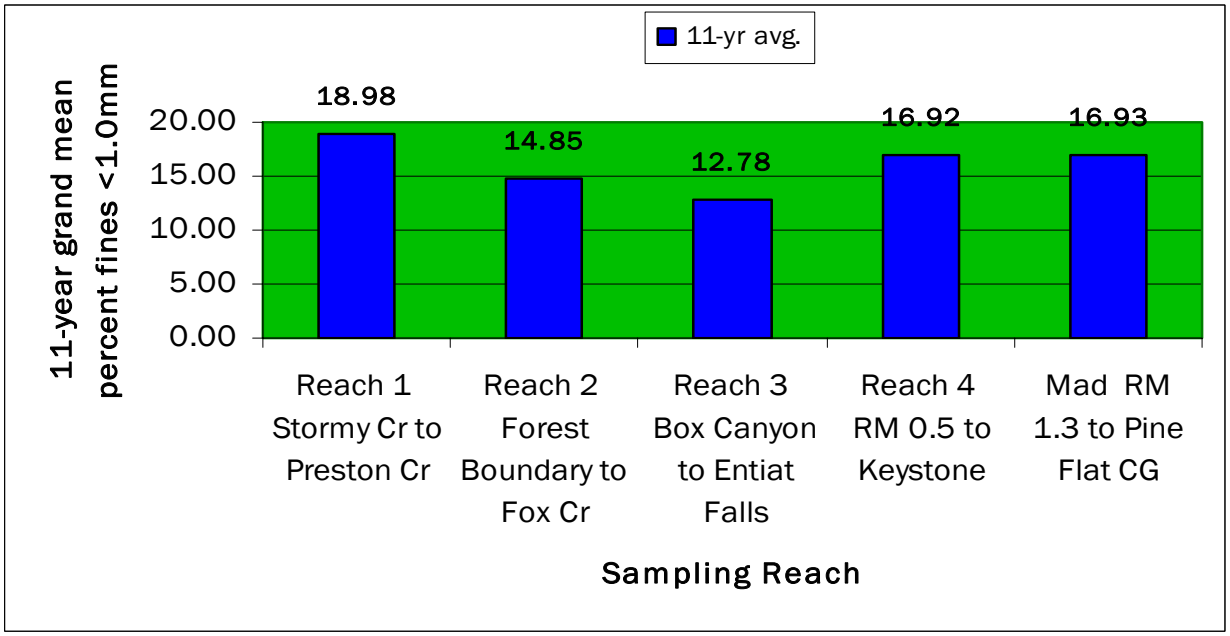

Figure 7-2. Comparison of Entiat and Mad River fine sediment sampling reach grand means.

Channel Morphology

Stream channel morphology (general channel shape) and stream type classification consider numerous parameters, including channel width to depth ratio, slope/gradient, substrate composition and roughness, and sinuosity. Channel morphology and fluvial processes in the Entiat subbasin provide information about fish habitat conditions; the response of the river and its habitat to disturbances; channel stability; and what kind of restoration, management, and land use activities are appropriate within a stream segment, given past and current channel condition. As mentioned in Chapter 3, the upper half of the Entiat subbasin is characterized by steep mountain topography and past glaciation events. The differences between geomorphic stream types located in glacial outwash and moraine areas and those found in the steeper, narrower valley areas of the subbasin are highly significant to the management of its aquatic and riparian resources.

In the fall of 1995, the NRCS "Stream Team" (an interdisciplinary team composed of specialists in riparian ecology, stream geomorphology, fish ecology, aquatic habitat, and geology) conducted a comprehensive survey of the lower 20.1 miles of privately held lands in the Entiat River corridor in order to inventory and classify stream types "...for the purpose of generating alternatives for stream bank management, fish habitat improvement, and river restoration that was compatible with the river's geomorphic features and historic anadromous fish populations" (CCCD 1998). Little data on privately held lands were available prior to the NRCS study. The Entiat was broken into 8 reaches averaging 2.5 miles, and various data were collected using cross sections, Wolman pebble counts, hydraulic geometry, and river hydrology. Field procedures closely followed those found in "Stream Channel Reference Sites: An illustrated guide to field technique" (Harrelson, C.C. et al. 1994). Data were then analyzed and the Rosgen methodology was used to assign fluvial geomorphic stream types to different sections of the Entiat River (Rosgen 1994).

Information about select alpha-numeric Rosgen stream type classification codes is contained in Table 7-2 and Table 7-3 on the following page. Table 7-4, also on the next page, provides a description of the Entiat River study survey reaches, and information about the geomorphic stream type classifications assigned to each (CCCD 1998). Refer to Figure 7-3 on page 7-11 for a depiction of these reaches.

During the NRCS Stream Team inventory of the Entiat River, data were also collected on salmonid habitat, riparian canopy and age class structure, large woody debris, stream bank stability, and adjacent land use. Refer to the Entiat River Inventory and Analysis report on the CD. A more detailed discussion of riparian habitat can be found in Section 7.2, Riparian Condition. The combined effects of physical, biological and chemical characteristics, as well as riparian condition/function, on fish habitat are described in Section 7.3, Fish Habitat Condition. Please refer to Chapter 3 for land use information.

Table 7-2. Select Rosgen geomorphic stream classification alpha-code descriptions.

CODE	DESCRIPTION
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with deposition soils. Very stable when dominated by bedrock or boulder.
B	Moderately entrenched, moderate gradient, riffle dominant channel, with frequently spaced pools. Stable plan and profile.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains.
F	Entrenched, meandering riffle/pool channels on low gradients with high width:depth ratios.

Table 7-3. Rosgen geomorphic stream classification numeric-code descriptions.

CODE	DESCRIPTION
1	Bedrock
2	Boulder, d_{50} > 256cm (10 inches)
3	Cobble, d_{50} is 64cm (2.5 inches) to $\leq$ 256cm (10 inches)
4	Gravel, d_{50} is 2mm (0.08 inches) to $\leq$ 64cm (2.5 inches)
5	Sand, d_{50} is 0.0625mm (0.002 inches) to $\leq$ 2mm (0.08 inches)
6	Silts or clays, d_{50} is less than 0.0625mm (0.002 inches)

Note: d_{50} value is determined by recording the diameter of all substrate particles in a sample, and calculating the median sample value. The d_{50} value is used to classify and describe channel substrate composition.

Table 7-4. Summary of Entiat River reaches and Rosgen geomorphic stream classifications.

REACH	DESCRIPTION	Length (RM)	Stream Classification
1	Slack water to fire station bridge	2.3	C3, F3, B3c
2	Fire station bridge to old hatchery bridge	3.0	C3, B3c, F3
3	Old hatchery bridge to Johnson/Stevens Bridge	2.7	F3, C3, B3c
4	Johnson/Stevens bridge to bridge near Mud Ck.	3.03	F3, B3c, C3
5	Bridge near Mud Ck. to Ryan/Small bridge	2.17	F3, B3c, C3
6	Ryan/Small bridge to Potato moraine at Shorty's	2.24	F3, B3c, F2
7	Potato moraine to USGS gaging station (Stormy)	2.17	C4, C5
8	USGS gaging station to section 14, USFS boundary	2.5	C4, C5

Note: lower case letters following numeric code denote a steeper or gentler slope than the majority of rivers within that category (e.g., B3c is a B3 type stream with less than 2% slope. Most subscripted types exist because of alterations to natural streams by human activities.

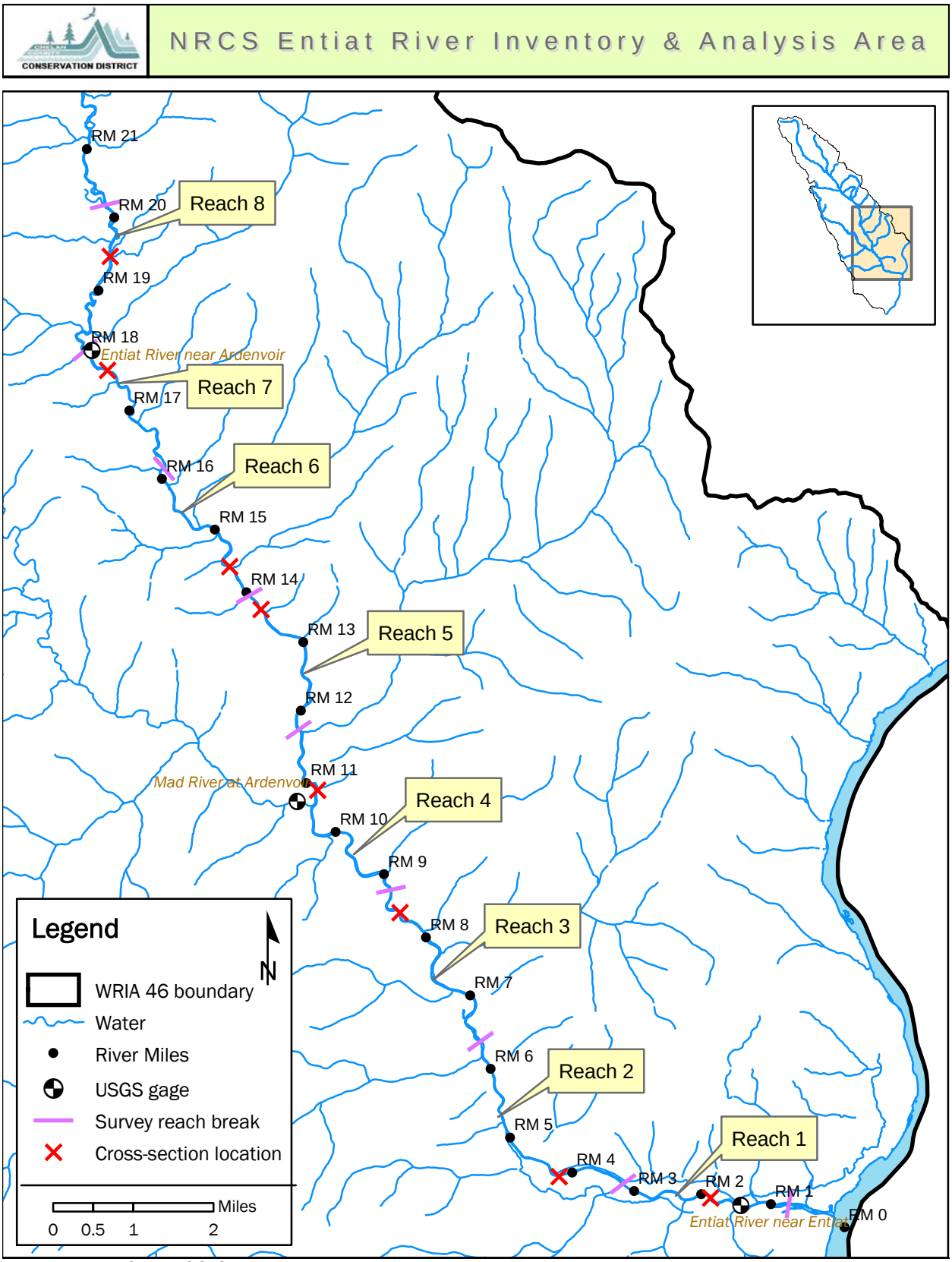

Figure 7-3. NRCS Stream Team Entiat River study reaches and cross-section locations.

The Potato Creek terminal moraine at Albert "Shorty" Long's property (RM 16.2) is a key location for discussion of channel structure in the drainage. Upstream of the moraine, channel morphology is glacially influenced, and channel shape is dictated primarily by natural fluvial processes, such as bankfull discharge, and valley geomorphology. This is illustrated by the C4 and C5 stream types present upstream of the moraine (low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains). Within this reach, conflict between streamside development and floodplain function is an increasing concern.

Downstream of the Potato Creek moraine, between the town of Ardenvoir and the mouth of the Entiat, current stream channel shape has been influenced by past human activities, such as channel straightening/widening and diking (performed in an attempt to carry flood flows safely out of the subbasin) and streamside vegetation disturbance. Consequently, the F3 stream type is prevalent below the moraine, and the lack of aquatic habitat diversity, high width:depth ratio, and stream downcutting are concerns. The overall width to depth ratio of the lower 25 miles of the Entiat River is high (greater than 25), due to a combination of natural and human disturbances.

Historical Changes to Channel Geometry

The Entiat Coordinated Resource Management Plan, WRIA 46 Limiting Factors Analysis, and other studies have documented man-made alterations made to the Entiat River's channel geometry, natural channel-forming processes, and floodplain function (CCCD 1998 and 2002; Andonaegui 1999; Erickson 2003). The earliest recorded river damming, associated with the Cannon/Harris Mill, occurred in 1889 (additional history information is contained in Chapter 3). Other hydromodification activities associated with logging and saw mills, farmland protection, and flood control efforts occurred between 1889 and 1948. Typical flood and bank protection works included dikes, rock riprap, and log revetments.

On June 8, 1948 the flood of record in the Entiat valley occurred. A letter from the U.S. Army Corps of Engineers, in response to the Chelan County Commissioners' request for flood control works reconstruction on the Entiat River after the 1948 flood, noted that "damage to existing flood control structures along the river was great with 21 levee and bank protection works being damaged" (USACE pers. comm. September 27, 1948). The 21 damaged projects documented by the Corps covered a total of 5350 feet along the left bank, and 8350 feet along the right bank of the lower Entiat River between approximately RM 8 and the mouth. In 1949, the USACE repaired 2025 linear feet of levee and provided 910 linear feet of rock bank protection in 4 priority areas. Soil Conservation Service and local funds were also used to repair dikes and bank stabilization works to prevent further loss of farm land through erosion, which was identified as the foremost problem resulting from the flood.

Hydrology

As mentioned in Chapter 3, the Entiat River's flow regime is characterized by a wide range between peak flows and low flows. Figure 7-4 on the following page depicts this range of variability, as well as the difference in flows during "wet" and "dry" water years. The mainstem Entiat responds rapidly to runoff and relatively frequent flood events. It is an unregulated, snow melt driven system sustained largely by ground water (vs. precipitation) during the late summer to late winter (August through February) period. Bankfull discharge,

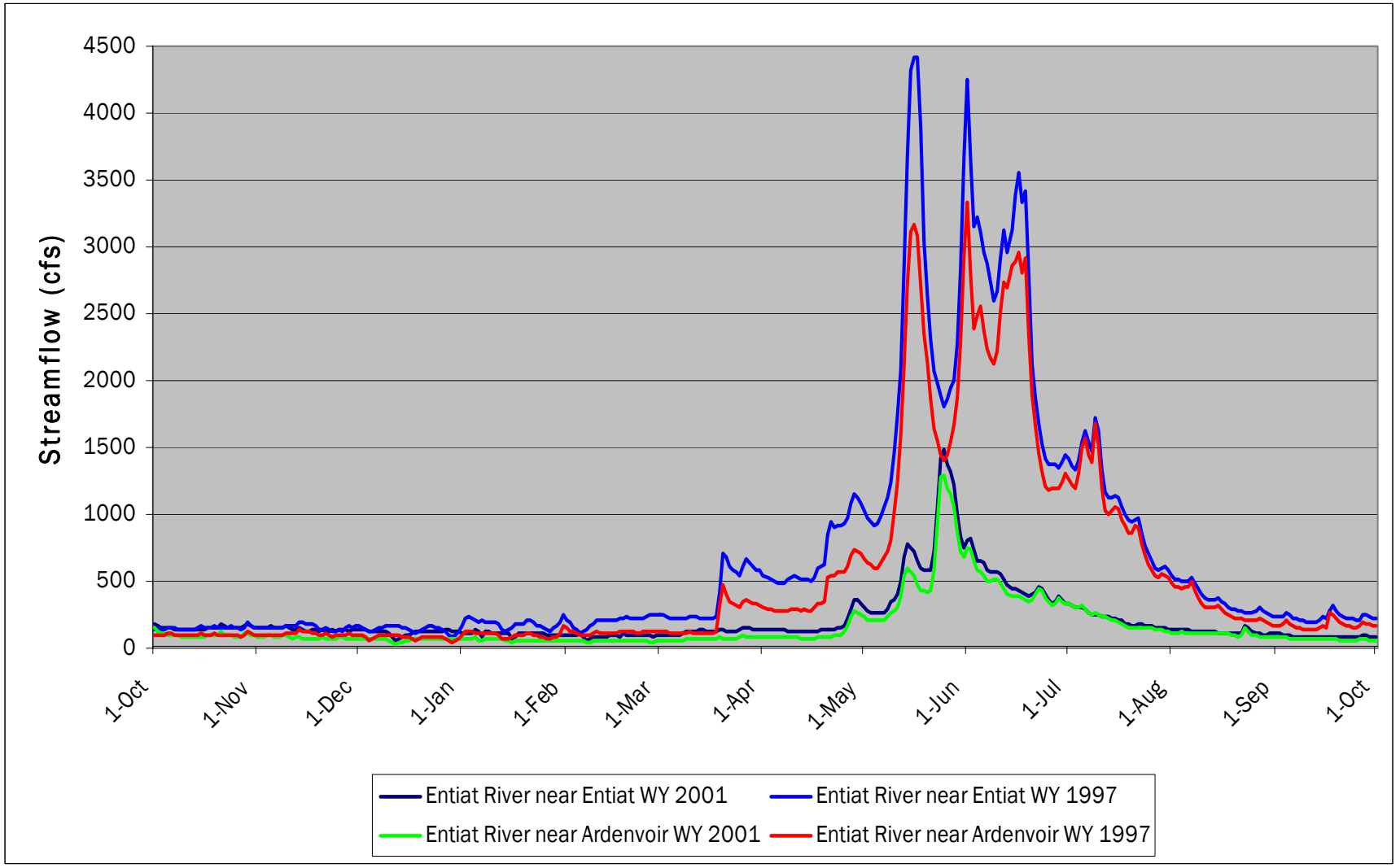

Figure 7-4. Comparison of daily mean streamflows as recorded at the Keystone gage (USGS gage Entiat near Entiat) and the Stormy gage (USGS gage Entiat near Ardenvoir), for water years 1997 and 2001.

commonly thought of as the flow that fills the channel up to the top of banks prior to flooding, is primarily responsible for the maintenance of current channel geometry in the Entiat River. In this system, bankfull discharge approximates mean annual peak flow or a 1.5 year return period event. These flows move and redistribute streambed and bank material, sediment, and incoming debris, and these processes are most responsible for forming or removing channel bars, bends and meanders. Current system dynamics are working to develop channel features that create a balance between stream flow and sediment loads. Much additional information about the hydrology of the Entiat and Mad Rivers is available in Chapter 4, Water Quantity.

Biological Characteristics

Macroinvertebrates

Macroinvertebrates are larger-than-microscopic invertebrate animals. Fresh water examples include aquatic insects, worms, snails, etc. Benthic macroinvertebrates are important indicators of water quality and environmental change because they live in or near streams; have relatively long life-cycles; respond to natural and human caused changes to the physical / chemical composition of streambeds; and are good indicators of site-specific conditions.

The USFS Entiat RD collected macroinvertebrate samples on April 22, 1992 as part of a forest-wide macroinvertebrate identification effort. Samples were collected from the lower Mad River and the lower Entiat River (near the fire station). Central Washington University used six biological metrics to evaluate overall community health: species richness, modified Hilsenhoff Biotic Index, ratio of scraper and filtering collector functional feeding groups, ratio of Ephemeroptera-Plecoptera-Trichoptera to Chironomidae abundances, percent contribution of dominant taxon, and Ephemeroptera-Plecoptera-Trichopetera Index (Smith 1992). Mad River site results showed good macroinvertebrate species richness and diversity; in comparison, the lower Entiat River site had low species richness with a high Percent Dominant Taxon value, which may have indicated environmental stress or an altered site (Smith 1992).

The WDOE Environmental Assessment Program collected biological samples in the lower Entiat River near the Keystone gage on August 15, 2002 as part of a state-wide effort to collect baseline macroinvertebrate community information, determine whether streams are biologically impaired, and provide a means to see whether biological results concur with ambient water quality monitoring data. Data indicate that the benthic macroinvertebrate community condition is generally healthy; however, specific characteristics of the community condition indicate slight degradation (C. Wiseman, WDOE, pers. comm. December 30, 2003). Only one species of Plecoptera (the stoneflies) was present (Skwala sp.). The lack of other plecopteran species suggests temperature impairment (C. Wiseman, WDOE, pers. comm. December 30, 2003). While most stoneflies require year-round cold water, Skwala sp. is found in waterbodies averaging 18.5 degrees C in the summer. Temperature exceedances recorded at the Keystone ambient water quality monitoring station (46A070) support this biological indication. This station also experiences pH exceedances, suggesting some degree of eutrophication. Thirty-two percent of the macroinvertebrate community was composed of insects that scrape periphyton off of rocks as a food source. This relatively

large percentage may be due to nutrient-driven periphyton production. Dense periphyton communities may have caused the observed pH exceedences (C. Wiseman, WDOE, pers. comm. December 30, 2003).

WDOE macroinvertebrate sampling data for the lower Entiat are available via the link: http://www.ecy.wa.gov/apps/watersheds/streambio/station.asp?selectedtab=&scrolly=0&showrelief=0&sta=384&mapscale=1247&printversion=false&wria=46

Fish

Many species of anadromous and non-anadromous fish utilize the aquatic habitat of the Entiat and Mad River watersheds. Some fish found in the subbasin are currently listed under the Endangered Species Act. Table 7-5 provides a summary of fish known and likely to occur in the subbasin, along with federally listed fish designations and species of concern which may be proposed for listing by the USFWS and/or NOAA Fisheries. The Washington Department of Fish and Wildlife maintains a state "Species of Concern" (SOC) list, which includes all *state* designated endangered, threatened, sensitive, and candidate species; state SOC list designations assigned to federally listed species are also provided.

Table 7-5. Summary of known and expected fish in the Entiat subbasin, and federal and state status.

Species	Scientific Name	Federal ESA Listing and Date	State SOC Listing
Upper Columbia River late-run (summer) Chinook salmon	(*Oncorhynchus tshawytscha*)	---	---
Upper Columbia River spring Chinook salmon	(*O. tshawytscha*)	Endangered March 24, 1999	Candidate
Upper Columbia River summer steelhead	(*O. mykiss*)	Endangered August 18, 1997	Candidate
Sockeye salmon	*(O. nerka)*	---	---
Coho salmon	*(O. kisutch)*	---	---
Columbia River bull trout	(*Salvelinus confluentus*)	Threatened June 10, 1998	Candidate
Westslope cutthroat trout	(*O. clarki lewisi*)	Species of Concern	---
Redband trout+	*(O. mykiss gardiner)*	---	---
Brook trout	*(S. fontinalis)*	---	---
Mountain whitefish	*(Prosopium williamsoni)*	---	---
Longnose dace+	*(Rhinichthys cataractae)*	---	---
Mottled sculpin+	*(Cottus bairdi)*	---	---
Torrent sculpin	*(C. rhotheus)*	---	---
Largescale sucker	*(Catostomus macrochelius)*	---	---
Bridgelip sucker	*(C. columbianus)*	---	---
Pacific lamprey	*(Entosphenus tridentatus)*	Species of Concern	---
Northern pikeminnow	*(Ptychocheilus oregonensis)*	---	---
Redside shiner	*(Richardsonius balteatus)*	---	---

+ *Indicates expected presence based on information contained in the USFWS Entiat NFH Hatchery Genetic Management Plan and Mullan et al. 1992.*

On 9/12/94, NOAA Fisheries initiated a status review of late-run Chinook, sockeye, and Coho salmon to determine if listing was warranted. Although it was determined at that time that listing was not warranted, these three species should also be considered Candidate ESA species. For a complete list of all State and Federal species of concern, refer to Appendix K.

Anadromous Fish

Several populations of economically and culturally important anadromous fish species reside within the Entiat subbasin. The Entiat and Mad Rivers currently support runs of steelhead and bull trout, and spring and late-run Chinook salmon. Coho salmon were once present in the Entiat watershed (Mullan et al. 1992), but are now considered extirpated (Nehlsen et al. 1991). Sockeye salmon were also introduced into the Entiat River at one point. Notably, both Coho and Sockeye have recently been found utilizing the Entiat River (Hamstreet and Carie 2002, 2003). Upper Columbia River (UCR) spring Chinook salmon and summer steelhead trout are listed as endangered and Columbia River bull trout are listed as threatened under the Federal Endangered Species Act (ESA).

Dams constructed near the mouth of the Entiat River beginning in 1889 blocked salmon from returning to the Entiat to spawn. Barriers erected on Entiat River persisted through the mid-1930s, and probably contributed to the Coho's extirpation (Craig and Suomela 1941). A Bureau of Fisheries survey of the Entiat in 1934, 1935 and 1936 showed the river was virtually devoid of salmon (Bryant and Parkhurst 1950) and salmon runs in general were essentially nonexistent by the time Grand Coulee Dam was built in 1939 (Craig and Suomela 1941).

As part of the Grand Coulee Fish Maintenance Project (GCFMP), all returning adult salmon were trapped at Rock Island Dam from 1939 to 1943. A total of 3,015 adult late-run Chinook were collected from commingled upper river stocks and placed in upper Entiat River spawning areas; only an estimated 1,308 of these survived to spawn (Fish and Hanavan 1948). Shorty Long recalls that fish were planted in two locations above the terminal moraine, at Burns Creek and Decker's near Gray Canyon. A weir was constructed at the terminal moraine to keep the adult salmon from migrating downstream to the Columbia River before spawning. Fish were also planted into Nason Creek and the Methow River, or spawned in hatcheries, including the Leavenworth, Winthrop and Entiat National Fish Hatcheries (NFH) (Fish and Hanavan 1948). Current fish distribution maps, a summary of anadromous and non-anadromous stocking that has occurred in the Entiat WRIA since 1933, and fishing regulations are provided in Appendix N.

Entiat National Fish Hatchery

The U.S. Bureau of Reclamation constructed the Entiat NFH approximately seven miles above the confluence of the Entiat and Columbia Rivers. It was authorized by Congress through the GCFMP on April 3, 1937 and reauthorized by the Mitchell Act (52 Stat. 345) on May 11, 1938. It was constructed by the US Bureau of Reclamation as mitigation for the Grand Coulee Dam, Columbia Basin Project. "The goal of these efforts was to rebuild salmon runs in the tributary streams to mitigate for lost production above Grand Coulee Dam" (Carie 1999).

Fish culture at the ENFH began in 1942. Various salmon and trout species have been reared at the facility, including spring and summer Chinook, Coho, and sockeye salmon; steelhead; kokanee; and rainbow and cutthroat trout. From 1942-1944 late-run Chinook juveniles were released from the Entiat NFH into the Entiat River (Mullan et al. 1992). Early egg sources used by the ENFH came from commingled upriver stocks (1939-1943), Methow River (1944), Carson NFH (1944), Entiat River (1946-1964), Spring Creek NFH (1964), and Wells Dam (1974) (Hamstreet and Carie 2003).

No spring Chinook were released from 1945 to 1975. Production resumed in 1975, and since 1976 only spring Chinook salmon have been reared and released. Since 1974, the egg sources and yearling releases have been from several lower river sources as well as from the USFWS Leavenworth and Winthrop NFHs (USFWS 2002a).

The U.S. Fish and Wildlife Service currently operate the hatchery as part of the Leavenworth NFH Mid-Columbia River Fisheries Research Office (MCRFRO) Complex. It is used for adult collection, egg incubation, and rearing of spring Chinook salmon. Rearing facilities include 42 starter tanks, 30 raceways, and two adult holding ponds. The Entiat River, Packwood Spring, and six wells provide water for the hatchery.

The annual Entiat NFH spring Chinook yearling production goal is 800,000; however, the hatchery is unable to produced this many yearlings due to water quality/quantity limitations. In recent years, Entiat NFH has experienced disease problems related to the use of river water for the rearing of their fish. Diseases are caused by natural, water-borne pathogens. To alleviate the problem, the hatchery uses well water only during the period when the fish are most susceptible to disease. Under this rearing regime, the volume of well water the hatchery is able to pump limits production to only 400,000 yearlings and 400,000 sub-yearlings; sub-yearlings can be reared at a much higher density because they require less water.

The average adult return for spring Chinook to the ENFH for the past 25 years has been just over 600 adults. This prohibits any significant harvest as all returning fish are needed to meet hatchery production level derived from the U.S. v. Oregon court decision, and other legal obligations (USFWS 2002a). Under an agreement with the Bureau of Indian Affairs, adults collected in excess of brood stock needs are donated to various tribes for ceremonial and subsistence purposes; a few may also be donated to non-profit groups/food banks. Also, up to 100 adults may be transferred to Omak Creek in Okanogan County (USFWS 2002a). When return can become more predictable and with 100% marking of hatchery stock, a limited sport harvest combined with an on station tribal surplus may occur (USFWS 2002a).

Past transplantation and artificial propagation efforts associated with the ENFH/GCFMP, as well as the influence of current hatchery activities, has made it difficult to discern the genetic makeup and origins of Chinook salmon and steelhead populations in the Entiat subbasin. Additionally, current hatchery spring Chinook broodstock displays morphological and life history traits similar to the natural population (USFWS 2002a). Thus, the term 'natural', rather than 'wild' is used throughout the following species discussions. The term natural is understood to mean locally adapted, naturally reproducing stock.

Late-Run Chinook Salmon

Chinook salmon which inhabit the Columbia River system are defined as either "ocean-type" or "stream-type" based on overall life history traits. Ocean-type Chinook juveniles migrate to the sea as subyearlings and return as adults to their natal stream from late summer to fall, and spawn almost immediately. They are also referred to as summer/fall, or 'late-run' Chinook. The term 'late-run', rather than summer or fall, will be used for discussion purposes in this section; late-run and ocean-type may be used interchangeably.

Upper Columbia River late-run Chinook return to the Entiat River primarily in July and August, but may enter the river into early October. Virtually all late-run Chinook salmon returning to the Entiat River spawn in 23 miles of the mainstem downstream of Preston Creek confluence, although they have been observed above Box Canyon and as far upstream as Entiat Falls (USFWS WNF 1996). No late-run Chinook spawn in the tributaries of the Entiat River. Data indicate the primary mainstem spawning area is just upstream of the Potato moraine, in USFWS Survey Reach 5 (RM 16.2 to 18.7). Spawning begins in the upstream reaches of the mainstem in late September, peaks from October 13-20, and ends in early November in the lower river (Peven 1992). Emergence timing is probably January through April. Juveniles likely emigrate to the ocean as subyearlings, leaving the Entiat River from one to four months after emerging from the gravel in April; however, some may rear up to one year before migrating downstream when conditions are favorable for this strategy

It is suspected that late-run Chinook salmon were not a dominant life history type in the Entiat River system (Craig and Suomela 1941); however, a great effort was made to establish late-run Chinook in the Entiat after the GCFMP. Historically, two late-run anadromous life history strategies may have been present in the subbasin:

1. Spawn in the mainstem and leave the system in late spring/summer as subyearlings
2. Spawn in the mainstem and leave the system in the fall as subyearlings

The Chelan County Public Utility District (PUD) monitored late-run Chinook spawning in the lower Entiat River (RM 0.0 to 10.4) via aerial surveys from 1957 to 1991. PUD late-run Chinook redd count expansions were used to estimate average escapement to the watershed at 37 for the period 1957-1966, 55 for the period 1967-1976, 9 for the period 1977-1986, and 11 for the period 1987-1991. It is likely that aerial surveys underestimated actual redd numbers, as aerial counts averaged just fewer than five redds a year for the period 1972-1991 (Hamstreet and Carie 2003).

In 1994, the USFWS MCRFRO began more intensive monitoring of late-run Chinook on the Entiat River, and expanded the spawning survey area to include reaches upstream of RM 10.4 (refer to Figure 7-5 on page 7-19 for a depiction of survey areas and reaches).

Past MCRFRO late-run escapement estimates used the multiplier of 2.4 fish per redd; however, historic spawning ground survey results from the Wenatchee River indicate that this multiplier may have underestimated adult returns. Mosey and Murphy performed an analysis of late-run redd counts from the Wenatchee River for 1992-2001, and calculated a fish per redd ratio of 4.0 (Mosey and Murphy 2002). Thus, the multiplier of 4.0 was used to estimate late-run adult spawning escapement in 2002 (Hamstreet and Carie 2003).

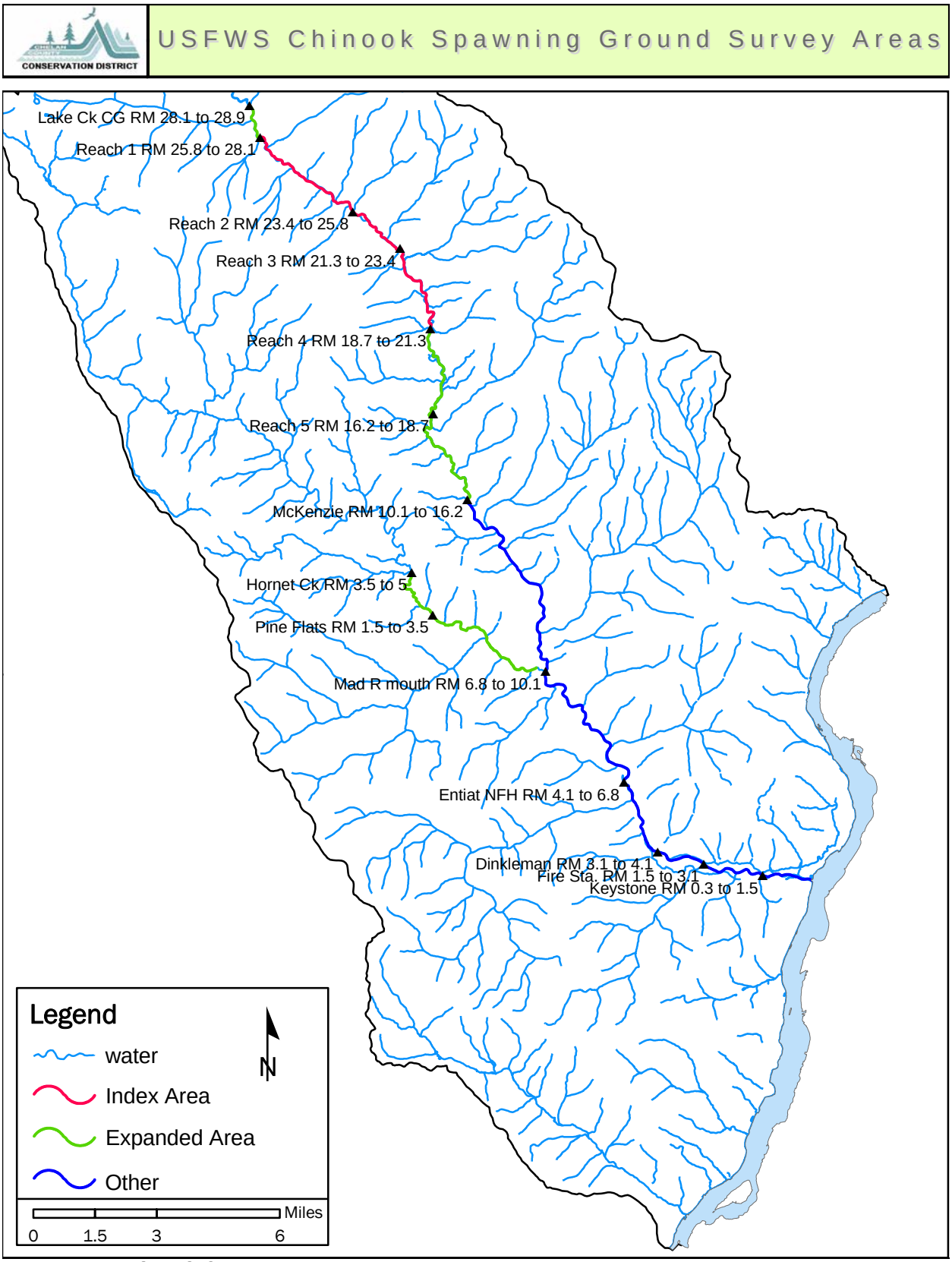

Figure 7-5. USFWS Chinook spawning survey reaches, index area and expanded survey area boundaries.

Figure 7-6 below summarizes the past nine years of late-run Chinook salmon redd counts on the Entiat River (Carie 1994-2001; Hamstreet and Carie 2002, 2003).

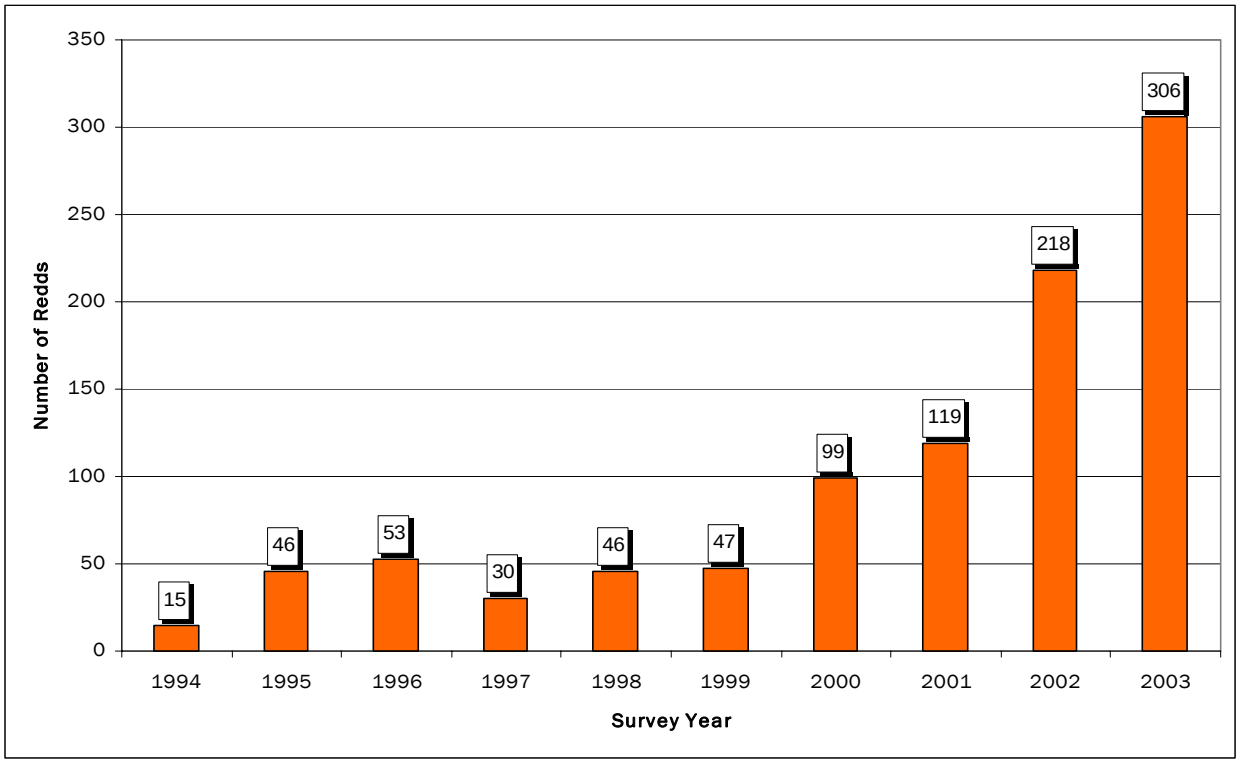

Figure 7-6. Total late-run Chinook salmon redds, Entiat River, 1994-2003.

The MCRFRO began bio-sampling of late-run adult carcasses in 2001 as part of their spawning survey efforts in the Entiat River. Scales were viewed using a microfiche reader to determine carcass origin and age, and coded-wire tags implanted in hatchery fish (indicated by clipped adipose fin) were retrieved from carcasses and analyzed in order to determine specific hatchery of origin and help assess possible straying of hatchery fish. Examination of the 99 female carcasses sampled in 2002 that showed some sort of spawning activity revealed a difference in spawning success between hatchery and natural females: 48 (90%) of the natural females spawned successfully, versus nine (21%) of the hatchery females (Hamstreet and Carie 2003).

Table 7-6 and Table 7-7 on pages 7-21 and 7-22, respectively, provide a summary of the 2001 and 2002 bio-sampling and coded-wire tag recovery data for late-run Chinook (Hamstreet and Carie 2002, 2003).

Table 7-6. Entiat River late-run Chinook age composition based on USFWS MCRFRO carcass recoveries, 2001-2002.

Sampling Year	Carcass Origin	Age Designation[1]	Male	Female	Total
2001	Hatchery	3/2	3	0	3
		4/2	29	40	69
		5/2	6	25	31
		6/2	1	3	4
		Hatchery totals	**39**	**68**	**107**
	'Natural'	3/2	3	0	3
		4/2	18	8	26
		5/2	8	14	22
		'Natural' totals	**29**	**22**	**51**
	Unknown		**12**	**12**	**24**
2001 TOTALS			**80**	**102**	**182**
2002	Hatchery	4/2	7	7	14
		5/2	6	34	40
		6/2	0	1	1
		Hatchery totals	**13**	**42**	**55**
	'Natural'	3/1	1	1	2
		4/1	34	25	59
		4/2	21	7	28
		5/1	3	14	17
		5/2	0	8	8
		'Natural' totals	**59**	**55**	**114**
	Unknown		**12**	**6**	**18**
2002 TOTALS			**84**	**103**	**187**

[1] *Age designation follows the Gilbert-Rich (1927) system, where total age is referenced by the first digit and age at the time of migration from freshwater is indicated by the subscript.*

Although late-run Chinook juveniles likely emigrate to the ocean as subyearlings, some may rear up to one year before migrating downstream when conditions are favorable for this strategy. The fact that migration from freshwater for late-run Chinook juveniles in the Entiat appears to be occurring when they are yearlings, as indicated by the "2" age designation subscript in the table, may be explained by a combination of factors. Late-run Chinook hatchery juveniles are sometimes reared for 1 ½ years, held through the winter, and then released in the spring in order to allow additional growth and chance for survival. This additional rearing time makes the age at time of migration a 2 when expressed using the Gilbert-Rich system (C. Hamstreet, pers. comm. December 12, 2003). Additional expert review of 2002 late-run Chinook scale patterns was performed by WDFW Fisheries Biologist John Sneva (C. Hamstreet, pers. comm. December 12, 2003). His analysis of the carcass scale samples revealed that some of the natural late-run Chinook may migrate out of the Entiat River as subyearlings but spend additional time rearing in reservoir areas of the Columbia River prior to emigration to the ocean, which provides another possible explanation why the age of some natural late-run Chinook was also expressed as a 2 (C. Hamstreet, pers comm December 12, 2003).

Table 7-7. USFWS coded-wire tag recoveries, Entiat late-run Chinook carcasses, 2001-2003.

Sampling Year	Tag Code	Number Recovered	Hatchery
2001	630124	24	Turtle Rock State Fish Hatchery (SFH)
	631032	2	Turtle Rock SFH
	630139	3	East Bank SFH
	634607	2	Turtle Rock SFH
	630145	1	East Bank SFH
	636049	2	East Bank SFH
	630602	4	Wells SFH
	636324	1	Turtle Rock SFH
	630606	30	Turtle Rock SFH
	092455	1	CEDC / ODFW
	630611	13	Wells SFH
	630612	19	East Bank SFH
	No Tag	7	---
	Lost Tag	2	---
	2001 TOTAL	111	
2002	630124	1	Turtle Rock SFH
	630606	20	Turtle Rock SFH
	630610	1	Similkameen SFH
	630611	8	Wells SFH
	630612	11	Dryden Ponds
	631032	8	Chelan PUD
	631061	1	Wells SFH
	631151	5	Dryden Ponds
	No Tag	8	---
	2002 TOTAL	13	
2003	630177	1	Turtle Rock SFH
	630470	1	Turtle Rock SFH
	630475	1	Dryden Ponds
	630606	1	Turtle Rock SFH
	630610	1	Similkameen SFH
	630612	1	Dryden Ponds
	631032	23	Turtle Rock SFH
	631061	9	Wells SFH
	631148	1	Similkameen SFH
	631151	14	Dryden Ponds
	631212	1	Lyons Ferry SFH
	631271	2	Dryden Ponds

Spring Chinook Salmon

"Stream-type" Chinook salmon juveniles overwinter in the river and remain within the system for at least a year prior to migrating to the sea as yearlings. They return as adults to freshwater in the spring, but do not spawn until several months after their arrival. Stream-type Chinook are also referred to as spring Chinook.

Upper Columbia River spring Chinook return to the Entiat River from late May through July,. Their primary spawning area in the Entiat is from upstream of the Potato Creek moraine (RM 16.2) to the Fox Creek confluence (RM 28.1) (Hamstreet and Carie 2002). Spring Chinook spawning begins in early August in the upstream reaches, and continues through August and September in the downstream reaches. The complete 2002 spawning report is available in the Reports folder on the CD.

Juveniles emerge from the gravel from late March through early May, generally spend their first summer in the subbasin, and leave in late fall through the following spring. The peak of emigration occurs late April through May, but downstream movement from the tributaries may be continuous, and not always associated with parr/smolt transformation.

Historically, all of the following stream-type anadromous fish life history types may have been present in the subbasin:

1. Spawn, rear, overwinter in upper Entiat reach tributaries -- above terminal moraine
2. Spawn, rear, and overwinter in lower Entiat reach tributaries -- below terminal moraine
3. Spawn, rear in Mad River, Roaring Creek, i.e. tributaries; overwinter in lower mainstem Entiat
4. Spawn in tributaries or mainstem Entiat, rear or overwinter in accessible side channels
5. Spawn, rear in tributaries, and emigrate in fall/winter

The Washington Department of Fish and Wildlife monitored spring Chinook spawning in the seven-mile "index area" (RM 21.3 to 28.1) of the Entiat River from 1962 to 1994. Average natural escapement to the Entiat River, based on WDFW dam count turnoff estimates, was estimated to be 3,229 for the period 1960-1969, 2,965 for the period 1970-1979, 2,708 for the period 1980-1989, and 1,056 for the period 1990-1995. Some of these escapement values are not corroborated by data from the recently expanded USFWS spawning survey area, discussed below (see Figure 7-5).

In 1994, the MCRFRO began more intensive monitoring of spring Chinook in the Entiat River, and added additional spawning survey reaches downstream of the index area, and in the lower Mad River. Past MCRFRO late-run escapement estimates used the multiplier of 2.4 fish per redd; however, Wenatchee River tributary spawning survey data indicate that use of 2.4 fish per redd may have underestimated adult returns. 2002 redd survey counts from Peshastin and Icicle Creek were analyzed, and used to calculate a fish per redd ratio of 3.3; thus, 3.3 was used to estimate spring Chinook escapement in 2002 (Hamstreet and Carie 2003). Figure 7-7and Figure 7-8 on the following page provide a summary of spring Chinook redd expanded survey and index reach counts on the Entiat River.

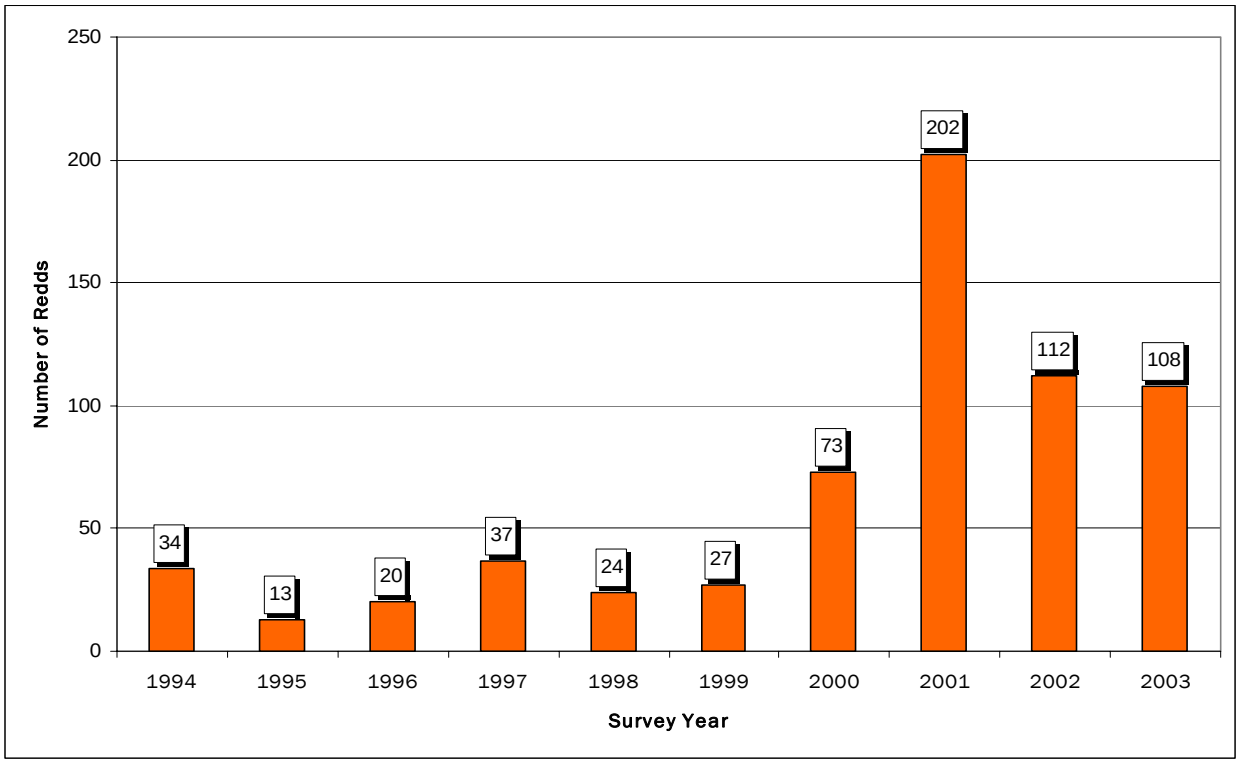

Figure 7-7. Total spring Chinook salmon redds, Entiat River expanded survey, 1994-2003.

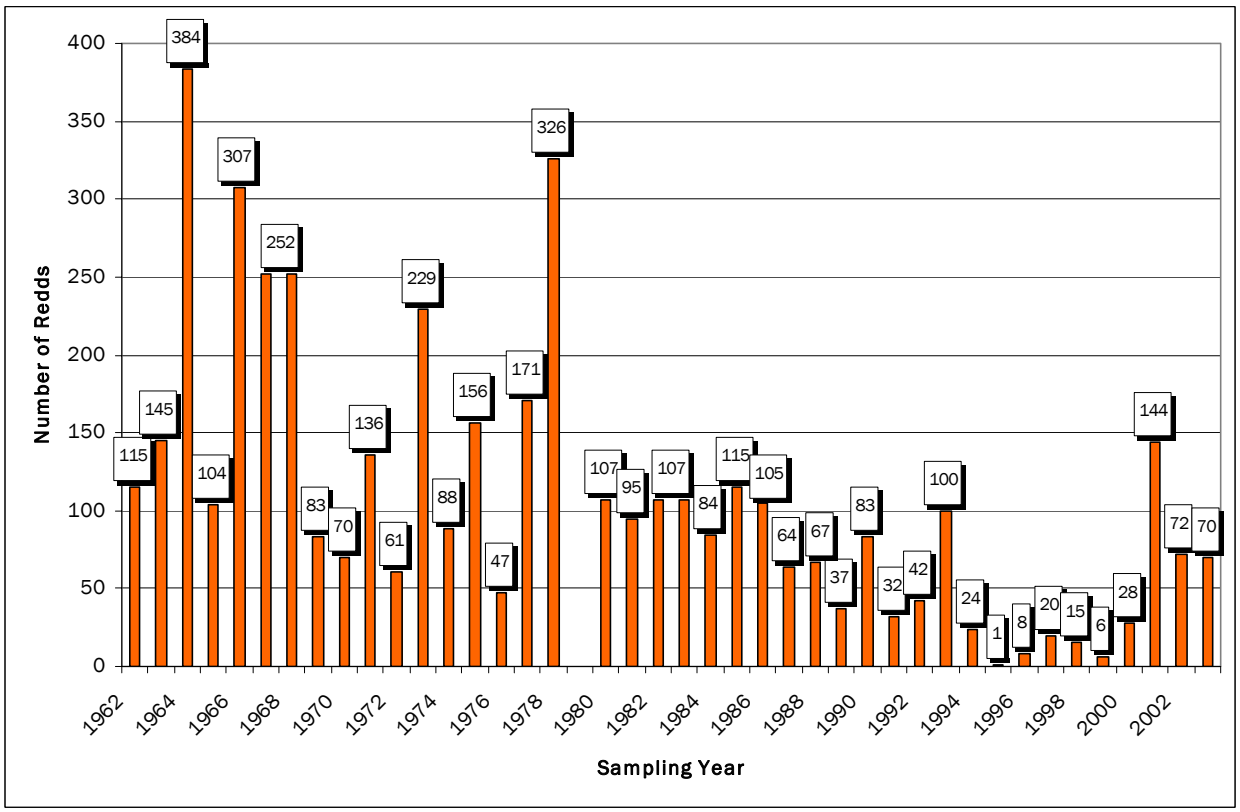

Figure 7-8. Spring Chinook salmon redds found in the Entiat River index area, 1962-2003.

Entiat River UCR spring Chinook were listed as "native stock with wild reproduction" in the 1992 Washington State SaSSI (Salmon and Steelhead Stock Index) report, while stock status was listed as "depressed, based on chronically low escapement (1984-1991)" (Washington Department of Fisheries et al. 1993). WDFW 2002 SaSI data now show Entiat spring Chinook stock as "mixed origin with composite production type" with "critical" status (WDFW 2002). As mentioned earlier, past transplantation and hatchery efforts have made it difficult to discern whether there is a significant difference between the current genetic makeup of naturally reproducing Entiat River UCR Chinook stocks and hatchery fish. Thirty-eight useable female carcasses sampled by the MCFRFO in 2002 showed some sort of spawning activity, although no difference in spawning success between hatchery and natural females was detected (Hamstreet and Carie 2003).

Meyers et al. (1998) state that, despite the influence of hatchery fish, UCR spring Chinook still represent an important genetic resource, because it is presumed that they still contain genetic material from Columbia River headwaters populations (Meyers et al. 1998). Recent findings indicate that the Entiat subbasin UCR spring Chinook population is distinct from the Wenatchee and Methow populations, and that subpopulations which exist within these three populations should be considered when making management recommendations (Ford et al. 2001). The National Oceanic and Atmospheric Administration (NOAA) Fisheries Interior Columbia River Basin Technical Recovery Team (TRT) agreed with the initial findings of Ford et al. (2001), and also concluded that the Entiat River spring Chinook population has received very few strays from hatchery programs in either the Wenatchee or Methow Rivers (Interior Columbia River Basin Technical Recovery Team 2003). The TRT also noted that genetic samples were particularly lacking from the Entiat River, and that additional/continued sampling should be done to ensure that current spring Chinook population structure has not been compromised by hatchery influences (Interior Columbia River Basin Technical Recovery Team 2003)

Table 7-8. Summary of Interior Columbia Basin TRT findings* for Entiat River spring Chinook.

Parameter	Finding
Entiat Population Spatial Structure	Branched continuous
Current Core Spawning Areas	Mainstem Entiat River from Fox Preston Creek confluence downstream to McKenzie Ditch and diversion dam to RM 17 (RM16-23.1).
Genetic Evidence of Hatchery Introgression	All Upper Columbia ESU fish have been heavily influenced by GCFMP
Natural Spawning of Hatchery-Origin Fish	High (over 25% [avg. over the last 5 years] of natural spawners are hatchery-origin fish
Hatchery Outplants, Last 10 years	Medium (average of 50,000 to 500,000 released per year in the last 10 years); majority of releases from within population brood-stock.

** taken from Tables II-5, II-6, and II-7, pp. 47-49 of the draft report (Interior Columbia River Basin TRT 2003).*

The USFWS MCRFRO began collecting natural spring Chinook adult carcass tissue samples in 2001 in order to compare natural fish DNA with that of Entiat National Fish Hatchery

broodstock, and determine if hatchery and natural populations spawning in the Entiat River show genetic differences. In 2001, 100 DNA samples were collected from the 128 bio-sampled carcasses; in 2002, 62 DNA samples were collected from the 68 bio-sampled carcasses. Scales were viewed using a microfiche reader to determine carcass age and origin. In 2003, the USFWS also collected DNA samples from natural spring Chinook contained in a screw trap upstream from the hatchery (C. Hamstreet, pers. comm. December 3, 2003). Coded-wire tags implanted in hatchery fish (indicated by clipped adipose fin) were retrieved from carcasses and analyzed in order to determine specific hatchery of origin, and help assess possible straying of hatchery spring Chinook salmon. Table 7-9 and Table 7-10 below and on page 7-27 summarize the bio-sampling results from 2001-2002, and coded-wire tag recovery data collected in 2001-2003. All DNA samples were sent to NOAA Fisheries for analysis; results had not yet been released at the time of this document's publication.

Table 7-9. USFWS Entiat River spring Chinook carcass bio-sampling results, 2001-2002.

Sampling Year	Carcass Origin	Age Composition	Sex		Total
			Male	Female	
2001	Hatchery	3/2	0	0	0
		4/2	10	21	31
		5/2	1	0	1
		Hatchery totals	**11**	**21**	**32**
	'Natural'	3/2	0	0	0
		4/2	24	35	59
		5/2	5	10	15
		'Natural' totals	**29**	**45**	**74**
	Unknown		**15**	**7**	**22**
		2001 TOTALS	**55**	**73**	**128**
2002	Hatchery	3/2	2	0	2
		4/2	4	14	18
		5/2	0	1	1
		Hatchery totals	**6**	**15**	**21**
	'Natural'	3/2	0	0	0
		4/2	5	13	18
		5/2	13	10	23
		'Natural' totals	**18**	**23**	**41**
	Unknown		**4**	**2**	**6**
		2002 TOTALS	**28**	**40**	**68**

Table 7-10. USFWS Entiat River spring Chinook carcass coded-wire tag recoveries, 2001-2003.

Sampling Year	Tag Code	Number Recovered	Hatchery
2001	050531	4	Entiat National Fish Hatchery
	053913	2	Entiat NFH
	054526	3	Winthrop NFH
	054907	1	Winthrop NFH
	054948	1	Winthrop NFH
	630613	1	Methow State Fish Hatchery
	630740	1	Chiwawa Rearing Ponds
	No Tag	2	--
	2001 TOTAL	15	
2002	053926	1	Entiat NFH
	053927	1	Entiat NFH
	054950	2	Entiat NFH
	630740	1	Chiwawa Rearing Ponds
	631024	1	Methow State Fish Hatchery
	631102	5	Chiwawa Rearing Ponds
	No Head	1	--
	No Tag	1	--
	2002 TOTAL	13	
2003	054517	1	Entiat NFH
	054528	1	Entiat NFH
	054931	1	Winthrop NFH
	054950	1	Entiat NFH
	054951	2	Entiat NFH
	093413	1	Lookingglass Hatchery (Oregon)
	630791	1	Chiwawa Rearing Ponds
	631024	1	Methow SFH
	Total	9	

Steelhead

Upper Columbia River summer steelhead spawn in the lower and mid-Entiat River (RM 0.5 to RM 28) and some of its tributaries, and in the lower Mad River, from March 15 to May 31. Mid-to-late-April has been observed to be the most likely steelhead spawning window in the Entiat and Mad Rivers (Archibald 2003). Most steelhead smolts leave the system at age 2 or 3, depending on stream temperatures, after spending time rearing in the mainstem or its tributaries. A given year-class undergoes almost continuous emigration from the river during this period; movements are complex and not fully explainable. Most adults spend two years in the ocean (females tend to stay a bit longer) prior to returning to their natal stream. From 1964-1999 check dates Chelan, Wells and East Bank SFH smolts were reared for nearly 14 months, and then planted into the mainstem Entiat River from April 20 until May 20. Almost 10% of these hatchery fish are believed to spend an additional year in residence prior to emigration.

In 1997, the USFS Entiat RD initiated spring spawning surveys for rainbow and steelhead trout in the Entiat and Mad Rivers. In 2001, redds were identified in the lower Mad River between the mouth and Camp Nine (RM 1-10), in the lower Entiat River between the Entiat City Limit sign and Keystone Bridge (RM 0.5-1.5), and in the mid-Entiat River between Stormy Creek and Fox Creek (RM 18-27). Adult steelhead radio telemetry results (English et al. 2001) confirmed the three major spawning areas described above, as well as an additional spawning area in the Entiat River near the mouth of Crum Canyon (RM 7.5). Survey data were used to designate a steelhead spawning index reach on the lower Mad River (RM 1.3-7.2), and future surveys of the Mad River will focus on this area. Refer to Table 7-11 for a summary of USFS spawning survey results in the Mad River.

Table 7-11. USFS steelhead/rainbow trout redd counts in the Mad River, 1997 & 1999 - 2003.

Year	1997	1998	1999	2000	2001	2002	2003
Definite Redds	8	No survey	0	3	15	14	38
Probable or Possible Redds	Not distinguished	No survey	3	5	2	3	6
River Miles surveyed	1 to 3	No survey	1 to 4	1 to 10	1 to 10	1 to 7	1 to 7

USFS Entiat RD fish biologists have surveyed lower Roaring Creek (RM 1-2) during the spring of each year since 1999 in an attempt to confirm anecdotal accounts of historic steelhead spawning there. In 2003, two definite rainbow/steelhead redds with one 20-inch adult steelhead present were observed at approximately RM 1.5 (Archibald 2003). The USFWS MCRFRO assumed responsibility for summer steelhead spawning surveys in the Entiat River beginning in 2003. See Table 7-12 below for a draft data summary of steelhead redds by USFWS MCRFRO staff in the Entiat River during the spring of 2003.

Table 7-12. Draft USFWS steelhead spawning survey results for the Entiat River, 2003.

Index Site No.	Site description	Approx. RM	Start date	End date	No. of Surveys	No. of Redds	Count/ Total
1	Spawning channel to forest boundary	26 - 28	April 9	May 22	5	21	
4	Foss bridge to Don Gene's property	19 - 21	March 21	May 16	7	25	
7	Keystone Bridge to end of flowing water	0.3 - 2	March 21	May 7	6	13	
							59
Extended	Forest boundary to Brief	23 - 26	9-May	-	1	6	
Extended	Brief to Foss bridge	21 - 23	7-May	-	1	8	
Extended	Don Gene's property to McKenzie diversion	16 - 19	6-May	-	1	5	
Extended	Dinkleman Canyon bridge to Keystone bridge	2 - 4	6-May	7-May	1	2	
							21
						TOTAL	**80**

The full 2003 report on spring spawning surveys for steelhead and rainbow trout, Entiat Ranger District is available in the Reports folder on the CD.

Steelhead probably exhibit all of the life history types associated with spring Chinook salmon, compounded by variable fresh water residence. They penetrate deeper into most of the tributaries than spring Chinook salmon do; thus, steelhead are more susceptible to direct land use impacts (e.g., shoreline and riparian disturbances) in upper tributaries than spring Chinook. However, the steelhead's life history is more fail-safe when habitat is disturbed (Mullan et al. 1992). Categorization of steelhead robustness is better done by analysis of distribution rather than phenotypic diversity.

The following is a categorization of steelhead life history type macrodistribution in the Entiat subbasin, based upon the likelihood of protecting or restoring their habitat:

1. Preston Creek, Brennegan Creek, upper Entiat River (above Fox Creek confluence), Mad River, Roaring Creek
2. Stormy Creek, Potato Creek, middle Entiat River -- terminal moraine to Fox Creek
3. Mud Creek, lower mainstem Entiat River --below terminal moraine

The Entiat subbasin population of UCR summer steelhead was determined by Ford et al. (2001) to be independent from other Upper Columbia ESU populations, and the TRT agreed with Ford et al.'s initial findings (Interior Columbia River Basin Technical Recovery Team 2003). UCR steelhead currently spawning in the Entiat subbasin are predominantly hatchery origin fish, with natural stock/recruitment relationships showing little or no replacement. After the GCFMP, there was widespread hatchery propagation of steelhead, and data show that between 71 and 90% of the steelhead passing Priest Rapids Dam since 1985 were hatchery produced (Interior Columbia River Basin Technical Recovery Team 2003). In 1992 WDFW listed Upper Columbia River summer steelhead in the Entiat River as a "mixed stock sustained by composite production", with stock status "depressed based on chronically low wild spawner escapement" (Washington Department of Fisheries et al. 1993). WDFW 2002 SaSI data list Entiat summer steelhead status as "unknown", with "mixed origin and composite production" (WDFW 2002).

Table 7-13. Summary of Interior Columbia Basin TRT findings* for Entiat River summer steelhead.

Parameter	Finding
Entiat Population Spatial Structure	Branched continuous
Current Core Spawning Areas Description	Preston Falls downstream to the mouth of the Entiat River; lower Mad River.
Genetic Evidence of Hatchery Introgression	All Upper Columbia ESU fish have been heavily influenced by GCFMP
Natural Spawning of Hatchery-Origin Fish	High (over 25% [avg. over the last 5 years] of natural spawners are hatchery-origin fish.
Hatchery Outplants, Last 10 years	Low (average of <50,000 released per year in the last 10 years); All releases from in-ESU broodstock.

** taken from Tables V-4, V-5, and V-6 on pp. 86-87 of the draft TRT report (Interior Columbia River Basin Technical Recovery Team 2003).*

Sockeye Salmon

Sockeye salmon are not indigenous to the Entiat River (Craig and Suomela 1941). They were stocked only twice, in 1943 and 1944, from Lake Quinault and Lake Whatcom stocks (Mullan 1986). A small run of sockeye became established in the Entiat River, and were observed spawning in the Entiat River from 1945 to 1955 (Mullan 1986). The Entiat NFH collected sockeye from 1944 to 1963, propagated them between 1941 and 1969, and planted them elsewhere (Mullan 1986). Between 75 and 150 sockeye salmon were noted in the Entiat River during incidental counts over the period 1969 - 1981 (Mullan 1986).

Little is known about sockeye life history strategy. Spawning occurs between mid-September and mid-October. Gravel emergence occurs from March through May, and juveniles are assumed to move downstream immediately afterward to the rear in the impounded lower reach of the Entiat River and the Columbia River reservoir (Chapman et al. 1995).

Since 1996, the USFWS MCRFRO and others have observed sockeye salmon adults and redds on a discontinuous basis during spawning ground surveys for spring and late-run Chinook salmon (refer to Table 7-14). It is assumed that these fish are either strays from the Wenatchee and Okanogan stocks, or may be artifacts of the Entiat NFH releases (Mullan 1986). The table below summarizes the incidental sockeye sightings in the Entiat River.

Table 7-14. Summary of Entiat River sockeye observed by the USFWS, 1996-2002.

Survey Year	Live Adults	Redds	Carcasses	Age	Location
1996	0	2	0	--	Reach 4 (RM 18.7-21.3)
1997	1	0	0	--	Reach 5 (RM 16.2-18.7), near RM 16.5. Not observed during time of survey.
1998	9	3	1	4	Reach 2 (RM 23.4-25.8), near RM 24.3.
1999	No sockeye found				
2000	2	2	0	--	
2001	21	10	0	--	Reach 4 (18.7-21.3)
2002	165	139	12	--	Reaches 2 - 5 (RM 16.2-25.8)

Coho Salmon

Although Coho were once present in the Entiat subbasin, only 475 Coho were counted at Rock Island Dam from 1933-1943 (Andonaegui 1999). 46 million juveniles were released by hatcheries from 1942-1975; however, this effort failed to re-establish populations, and Mid- and Upper Columbia River Coho are now considered an extirpated species under the ESA (Andonaegui 1999). In an effort to reintroduce Coho, the Yakama Nation recently initiated a juvenile release program in the Wenatchee and Methow subbasins. Although no Coho were released in the Entiat subbasin, substantial straying of returning adults was documented in 2001 (Hamstreet and Carie 2003). In October 2001, during their late-run Chinook spawning ground surveys on the Entiat River, the USFWS identified 12 Coho redds, three adults, and three carcasses between Dinkleman Canyon and Fire Station restoration sites (Hamstreet and Carie 2002). In 2002, one Coho carcass was noted between Keystone Bridge and the confluence with the Columbia River (Hamstreet and Carie 2003).

Non-Anadromous Fish

Rainbow (a resident form of steelhead), bull (*Salvelinus confluentus*), westslope cutthroat (*O. clarki lewisi*), brook and interior redband trout use Entiat River and tributary habitat most or all their lives. Other important resident species found within the subbasin include mountain whitefish and Pacific lamprey. Bull trout are listed as threatened under the ESA, and in 2001 petition was made to list westslope cutthroat, Pacific lamprey, and other lamprey. The petition to list westslope cutthroat trout as threatened under the ESA was found to be "not warranted" by the USFWS in April 2000. However, on March 31, 2002 as US District Court remanded the "not warranted" listing and ordered the USFWS to initiate a new status review for westslope cutthroat trout within the United States. The reconsidered 12-month finding for an amended petition to list westslope cutthroat reaffirmed the "not warranted" listing (*Federal Register/Vol. 68/August 7, 2003/46989-47009*). Westslope cutturoat trout continue to be a species of "concern" as their status is uncertain in the Entiat River and they are a Regional Forester's Sensitive Species.

Bull Trout

Currently, bull trout found in the mainstem Entiat and Mad River are considered to be two distinct local populations. Bull trout have been found in small numbers in the mainstem Entiat River up to Entiat Falls, a natural barrier. The 1998 Bull Trout/Dolly Varden volume of the SaSI (Salmon Stock Inventory) report listed Entiat River bull trout stock as native with wild reproduction; however, stock status was listed as unknown. The Mad River population was listed as native with wild reproduction, and healthy (WDFW 1998). Bull trout in the Entiat River are believed to be primarily fluvial (USFWS 2002b*).* Bull trout in the Mad River may be a combination of fluvial and resident fish (USFWS 2002b*).*

The WDFW conducted bull trout spawning surveys on the mainstem Entiat River in 1984 and 1987 (Hamstreet and Carie 2002), and since 1994 the MCRFRO has observed bull trout and/or redds in the Entiat River at RMs 18, 19 and 27, and just below Entiat Falls (RM 33) during their spring and late-run Chinook spawning surveys. Incidental mainstem Entiat sightings by MCRFRO staff from 1994 through 2002 total ten bull trout redds and three adults. Most known bull trout spawning and rearing occurs in the Mad River, to the natural barrier falls upstream of Jimmy Creek. The WDFW surveyed the Mad River for bull trout in 1989, 1990 and 1991. Since 1992 the USFS Entiat RD has been solely responsible for bull trout spawning surveys on the Mad River in the WDFW index reach, which covers 7.5 miles from the confluence of Young Creek upstream to the confluence of Jimmy Creek.

Adult bull trout were radio-tagged in 2001 and 2002 at Rock Island, Rocky Reach and Wells Dams as part of a multi-year study sponsored by Chelan/Douglas/Grant County PUDs to determine the movements and migration patterns of adult bull trout, and the effects of dams on these patterns. Fish tagged in 2001 were found in the mainstem Entiat River from Silver Creek downstream to the mouth during spawning and migration periods, with repeat identifications near Lake Creek, near Box Canyon, and just below Entiat Falls during aerial surveys in the fall of 2001 and 2002, indicating likely spawning areas (BioAnalysts, Inc. 2002b). Adult bull trout located in the Mad River, from just below the Hornet Creek confluence to just below the Alma Creek confluence (RM 14.5), during aerial surveys in fall 2001 and 2002 (BioAnalysts, Inc. 2002b).

In 2002, 21 out of a total of 40 tagged fish entered the Entiat subbasin from June 6 to July 13, with more than half the fish entering the system by the end of June 2002 (BioAnalysts, Inc. 2003). Ten bull trout resided in the mainstem Entiat River (BioAnalysts, Inc. 2003). Of the mainstem fish, two were located downstream of the Mad River confluence, one was between the Mad confluence and Preston Creek confluence, and seven resided upstream of the Preston Creek confluence (BioAnalysts, Inc. 2003). Eleven fish were identified in the Mad River upstream from the Pine Flats campground (RM2). Of the 21 bull trout that entered the Entiat subbasin, 15 left the system by December 17th; one died and two others may have died; and three remained in the Mad River (BioAnalysts, Inc. 2003). The 15 that left moved downstream into the Columbia River to reside in the Rocky Reach, Rock Island or Wanapum reservoirs (BioAnalysts, Inc. 2003).

Figure 7-9, below, summarizes the results of all bull trout spawning surveys performed in the index reach of the Mad River. The full 2003 bull trout spawning survey report is available in the Reports folder of the CD.

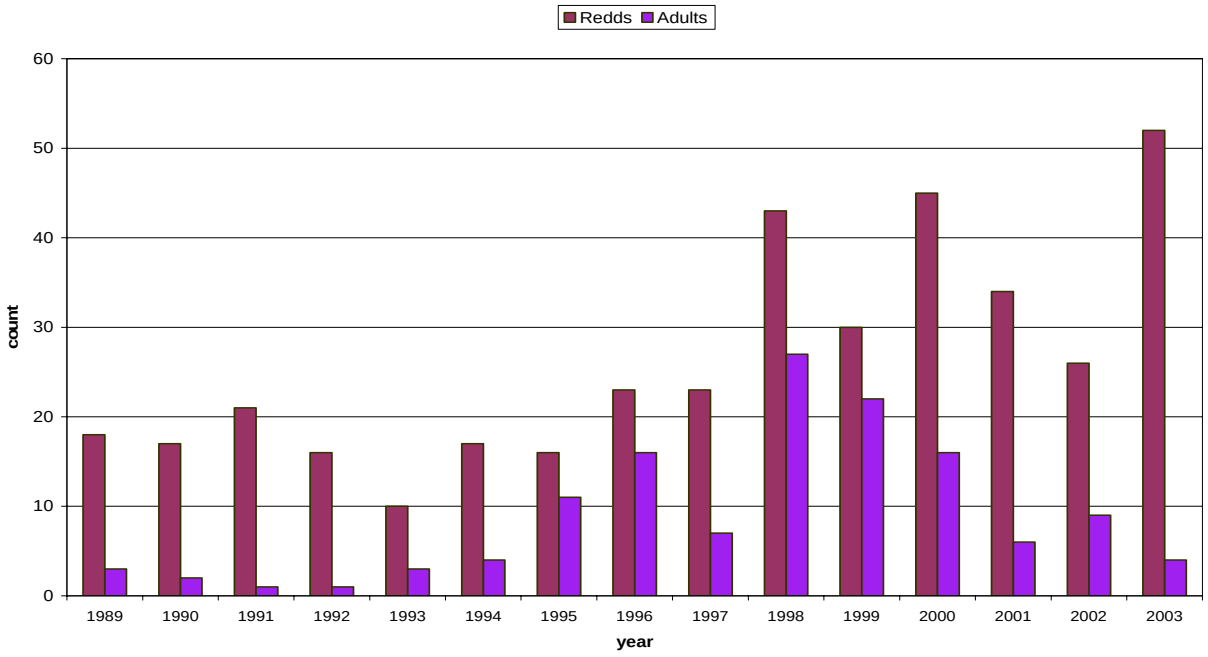

Figure 7-9. Bull trout redds and adults observed in the Mad River Index Reach, 1989-2003.

The mainstem Entiat and Mad Rivers comprise the Entiat Core Area of the Upper Columbia River Basin bull trout recovery unit, as identified by the USFWS in their draft recovery plan for Columbia River Basin, Klamath River Basin, and St. Mary-Belly River Basin distinct population segments of bull trout (USFWS 2002b). Critical habitat was proposed for the Columbia and Klamath River Basins, while the final designation of critical habitat for bull trout in the Columbia River Basin was scheduled for October 2003. Final designation for the Columbia River Basin is not likely to occur until sometime in 2004. To view the bull trout draft recovery plan for the Columbia River Basin, visit the following link: http://pacific.fws.gov/bulltrout/recovery/Default.htm

7.2 RIPARIAN CONDITION

A properly functioning riparian corridor provides numerous benefits to physical, chemical and biological characteristics of aquatic habitat. Riparian shade helps provide refuge for fish species during high temperatures, as well as refuge from predators and other extreme habitat conditions. Shade provided by riparian vegetation can also reduce heat loss during winter months, thus reducing anchor ice formation and extreme cold events (Swanston 1991). Riparian vegetation provides both a food source (macroinvertebrates using leaf litter) and a source for the recruitment of large woody debris (LWD), an important structural component of aquatic habitat. A healthy riparian zone helps stabilize stream banks and reduce flood hazard and sediment delivery. Biological diversity is also increased by a properly functioning riparian zone, providing nutrients for fish, wildlife, and other important species.

Studies and Data Sources

The USFS characterized riparian vegetation from the headwaters to Entiat Falls, near RM 34 (transport zone) as consisting of grand fir, Engelmann spruce, Douglas-fir, lodgepole pine, western red cedar, cottonwood, grasses and forbs (USFS WNF 1996). Shade levels and the recruitment of large woody debris into riparian/aquatic habitat were reported as predominantly good to excellent. About 6.6 miles of road in this zone was noted within 300 feet of a stream channel, with road densities below 1.0 mile per square mile. The USFS reported that riparian area impacts at developed campgrounds in this zone are localized and minimal, except for the concentrated use at Cottonwood Campground. Riparian zone function as a buffer to stream sediment input was deemed adequate where vegetative ground cover is good.

Riparian species noted from Entiat Falls to McCrea Creek, near river mile 25 (transitional zone), consist of cottonwood, red cedar, and grand fir, with dogwood and alder in lower elevations, with Engelmann spruce and western hemlock in higher elevation reaches. The USFS characterized large woody debris recruitment and shade levels as predominantly fair to excellent, and reported 43 miles of road within 300 feet of stream channels in this zone, with most of native surface with minimal surface water control features (USFS WNF 1996). The USFS noted riparian zone function as a buffer to stream sediment was adequate where there is good vegetative ground cover.

Vegetation from McCrea Creek to the river mouth (depositional zone) was reported as primarily deciduous species, with alder, willow, cottonwood, aspen, elderberry, redosier dogwood, river birch, and maple as the dominant species. Conifers (Ponderosa pine and Douglas-fir) were also present. The USFS described shade and LWD recruitment as poor to good (USFS WNF 1996). In some reaches, loss of vigorous shrubs in the riparian zone had reduced instream organic input and shade, and contributed to unstable stream banks and associated erosion. There were 205 miles of road identified within 300 feet of streams in this zone, with many having native surface with minimal surface water control features. The USFS noted that roads adjacent to streams and associated road management have reduced LWD recruitment. Riparian zone function as a sediment delivery buffer was deemed poor in the roaded segments and in some of the riparian area that is not roaded.

The NRCS Stream Team performed an extensive survey of the lower 20 RMs of the Entiat River in 1995 (CCCD 1998). During the riparian inventory, they determined the dominant overstory species, percent of canopy cover, and dominate age class of the existing vegetation along the river. The study reported that degradation to riparian vegetation in the upper Entiat watershed was tied to historical overgrazing, road construction, certain timber harvesting activities, and recreation (CCCD 1998). Riparian vegetation and function in the lower portion of the Entiat watershed (below the FS boundary) has been affected by wildfire, agricultural encroachment on the floodplain, past flood control and channel straightening efforts, historic grazing, and rural residential development in the floodplain (CCCD 1998, Andonaegui 1999). Wildfire was noted as one of the primary disturbance factors affecting riparian vegetation.

Table 7-15. Summary of Entiat River riparian vegetation inventory findings (RM 0-20.1)

Reach	Description	Length (RM)	Canopy Cover %	Dominant Age Class	Dominant Plant Community
1	Slack water to fire station bridge	2.3	0-10	Small tree (8.0"-20.9" dbh)	cottonwood/ red osier dogwood
2	Fire station bridge to old hatchery bridge	3.0	0-10	Small tree	cottonwood/erect willow/ red osier dogwood
3	Old hatchery bridge to Johnson/Stevens Bridge	2.7	0-10	Large tree (21.0"-31.0" dbh)	cottonwood/erect willow
4	Johnson/Stevens bridge to bridge near Mud Ck.	3.03	0-10	Small tree	Cottonwood/alder
5	Bridge near Mud Ck. to Ryan/Small bridge	2.17	0-10	Small tree	cottonwood/alder conifer/alder
6	Ryan/Small bridge to Potato moraine at Shorty's	2..24	0-10	Shrub/Seedling and burned dead tree	mixed conifer/alder
7	Potato moraine to USGS gaging station (Ardenvoir)	2.17	0-10	Shrub/Seedling Grass/Forb	river birch/ broadleaf sedge
8	USGS gaging station to USFS boundary (RM 26).	2.5	20-30	Large tree and burned dead tree	cottonwood/river birch/ red osier dogwood

The WRIA 46 LFA listed a lack of and/or an improperly functioning riparian zone in the lower 10 RMs as a major limiting factor for fish habitat (Andonaegui 1999). The LFA recommended, as a long-term goal, that riparian habitat be protected, wherever feasible, in areas that presently allow unrestricted stream channel diversity and floodplain function (Andonaegui 1999). The "Stillwater" reach of the Entiat River, between the Potato moraine (RM 16.2) and Preston Creek (RM 23.1) was identified as the top priority for riparian zone protection. Other priority locations for riparian protection include the side channels between Preston Creek (RM 23.1) and Fox Creek (RM 27.7) and riparian bottomlands in the lower Mad River, Stormy Creek, and Roaring Creek (Andonaegui 1999). In addition, the LFA recommended riparian enhancement to aid the recovery of natural hydrologic and geomorphic processes that allow for good habitat conditions. The placement of LWD, along with other structural instream improvements such as rock weirs and riparian plantings, were recommended as short-term strategies for habitat improvements (Andonaegui 1999). The NRCS identified specific areas within the lower 20 RMs that could be planted to help increase the amount and quality of fish habitat, improve stream bank stability, and assist with flood control (see Table 7-16 on the following page).

Table 7-16. Streambank planting recommendations from 1995 NRCS study.

Reach	Length (miles)	Reach Description	Canopy Cover (%)	Potential Planting Sites (feet)	Dominant Plant Community
1	2.3	End of slackwater to Fire Station bridge.	0–10	4700	cottonwood/ red osier dogwood
2	3.0	Fire Station bridge to Old Hatchery bridge.	0–10	5900	cottonwood/ red osier dogwood/ erect willow
3	2.7	Old Hatchery Bridge to Johnson/Steven's bridge.	0–10	3900	cottonwood/ erect willow
4	3.0	Johnson/Steven's bridge to bridge near Mud Creek.	0–10	2900	cottonwood/ alder
5	2.2	Bridge near Mud Creek to Ryan/Small bridge.	10–20	2000	cottonwood/alder conifer/alder
6	2.2	Ryan/Small bridge to terminal moraine at Shorty's	0–10	10,350	mixed conifer/ alder
7	2.2	Terminal moraine at Shorty's to USGS gaging station.	0–10	6600	river birch/ broadleaf sedge
8	2.5	USGS gaging station to USFS boundary (section 14).	20–30	3600	cottonwood/ river birch/ red osier dogwood
Total	**20.1**			**39,950 (7.6 miles)**	

[a] - From Hankin and Reeves 1988.

[b] - From Rosgen 1994.

On August 11th and 12th, 2001 additional information about riparian condition was collected during a Forward Looking Infrared (FLIR) flight of the Entiat and Mad Rivers. Thermal Infrared pictures were taken of the river/riparian corridors in order to assess surface water temperature and provide additional data to support temperature modeling and monitoring efforts (Watershed Sciences, LLC 2001). True color photographs, which provided a good view of the riparian vegetation present along the river and the amount of vegetative cover (shade) provided in certain reaches, were also taken during the flight.

In 2002, Central Washington University (CWU) was contracted to produce land use and riparian vegetation GIS coverages. Riparian data were produced using the 2001 FLIR true color photos, 1998 digital orthophotographs, and field work/ground truthing. The riparian assessment noted general vegetation presence/absence; community type (riparian forest, riparian forest burned, riparian meadow, riparian meadow burned); and relative height (1-25 feet, 25-70 feet, 71-100 feet) (Lillquist and Erickson 2002).

The Ecosystem Diagnosis and Treatment (EDT) methodology was also used by the EWPU to describe historic and current fish habitat conditions in the Entiat River watershed. Riparian function and woody debris habitat attributes were considered as part of the Entiat EDT effort, and all treatment alternatives that were generated include a riparian planting component. For more information and detail about the Entiat EDT watershed analysis (Mobrand Biometrics Inc., 2003), refer to Section 7.4.

The WDOE completed a water temperature assessment of the Entiat River using the Stream Network Temperature model (SNTEMP) in 2003 (Hendrick and Monahan 2003; see Chapter 8). This assessment simulated potential alternative actions and treatments that could reduce water temperatures during critical high temperature periods. This assessment recommended increasing current riparian vegetation system-wide, and decreasing width:depth ratios in the lower 10 miles as the best means to address summer/fall high water temperatures, which would improve overall water quality for humans, fish and wildlife within the Entiat subbasin.

Summary of Findings

The Chelan County Conservation District examined all of the aforementioned riparian information sources and data. GIS data produced as part of the 1995 NRCS Stream Survey and 2002 CWU Riparian Assessment were used in conjunction with other Entiat Geographical Information System (EGIS) data layers, 1998 digital-orhophotographs, and SNTEMP report information to verify agreement among study recommendations. Field checks were also conducted to confirm priority locations and identify additional sites for riparian plantings and/or protection (see Table 7-17). In general, planting recommendations set forth by NRCS in the 1995 study coincided with areas identified as void of vegetation in the 2002 CWU study. Locations where the NRCS study recommended riparian plantings also corresponded well with locations in the riparian GIS data layer that showed a weak and/or thin riparian zone. Field checks of these areas confirmed riparian condition, as did examination of the FLIR true color aerial photographs.

Table 7-17. Additional priority planting recommendations not previously detailed by 1995 NRCS study.

Approximate location	Description of site/rationale
RM 1.2 - 3.2	Keystone Ranch to Fire Station Bridge near rock cross vane
RM 3-5 and RM6-7	Areas shown by CWU study to have largest decrease in riparian area from 1945-1998.
RM 4.2	Old Naumes warehouse site
RMs 7-9	Near Roaring Creek to Morical Canyon
RM 10.2	Mad River confluence old Mill site
RMs 11-13	Near Mud Creek confluence to Medsker Canyon
RMs 14-16	McKenzie Canyon to Potato Creek moraine -- heavy Tyee Fire effects.

Although the SNTEMP study did not provide specific priority locations for its riparian planting recommendations, it did identify the lower 10 RMs of the Entiat River as having the highest water temperatures, which comports with NRCS and CWU findings of decreased amounts of riparian vegetation within this reach.

The following text summarizes current riparian condition and recommendations for protection and/or enhancement of riparian vegetation within the three analysis zones as described by the USFS WNF (1996).

From the headwaters to Entiat Falls, near RM 33.8 (transport zone): As described previously, riparian condition within this reach is good to excellent. Because most of this land is publicly owned the threat of future development and other environmental change is minimal. In this reach public land managers should to continue to maintain and enhance riparian vegetation, with a priority being with fire maintenance and/or protection.

From Entiat Falls to McCrea Creek, near RM 25 (transitional zone): Riparian condition within this reach is fair to excellent. As most of this zone is also publicly owned, the threat of development and other environmental change is again minimal. In this reach, public land managers should continue to maintain and enhance riparian vegetation, with a priority being with fire maintenance and/or protection.

From McCrea Creek to Mad River Confluence, near RM 10.5 (depositional zone): This reach includes the "stillwater" area, which is considered a prime fish habitat area. Some areas within the stillwater have been permanently protected via acquisition by the Chelan-Douglas Land Trust. Large segments of this reach burned in the 1994 Tyee fire; recreation and residential development has also affected riparian condition and function. As a result there are some areas of private property within this reach that are either completely void of vegetation or have poor riparian function (small width). In this reach protection of current riparian vegetation and encouragement of new and existing vegetation growth, specifically in areas that were burned by the Tyee and other wildfires, are the priorities. Assistance should be provided to willing landowners with riverfront property that wish to initiate planting in areas void of riparian vegetation (especially those burned by the Tyee and other wildfires) or with a narrow riparian zone.

From Mad River Confluence, near RM 10.5 to the river mouth (depositional zone): This is considered the priority area for riparian plantings within the Entiat watershed. Most of the stream-side land within this reach is privately owned, and data from the CWU study show that many of these areas are used for agriculture, including irrigated orchards and pastures. Furthermore, a number of current pastures were previously orchard. These lands are ideal for exploring restoration/planting partnerships with property owners. Any irrigation helps establish new plantings, and water rights associated with orchard still exist; thus, irrigation water could be used to help establish and increase the growth of new plantings. In this reach willing property owners should be encouraged to allow for plantings along the banks of the river and/or allow current vegetation to continue to grow, both in height and width.

7.3 FISH HABITAT CONDITION

The NRCS Stream Team inventoried the type and quality of fish habitat during their survey of the lower 20.1 miles of the Entiat River in 1995 (CCCD 1998). Pools, riffles, glides/runs, and cascades were noted, as well as the presence of large pools, overhanging vegetation, large woody debris, large boulders, substrate, and undercut banks. Habitat frequency was also determined. The USFS Entiat RD also collects habitat data in reaches upstream of RM 20 via recurring stream surveys. The following synopsis of fish habitat conditions in the Entiat is based on the three analysis zones (transport, transitional, and depositional) described in the Watershed Assessment Entiat Analysis Area (USFS WNF 1996) and also

contains information from the NRCS "Stream Team" Inventory (CCCD 1998) and the WRIA 46 Limiting Factors Analysis (Andonaegui 1989).

Transport Zone

In the transport zone [headwaters downstream to Entiat Falls (RM 33.8)], fish habitat condition in the mainstem is stable and assumed to be similar to the historic condition, with unembedded cobble/gravel streams and the number of large pools similar to or higher than numbers observed in the 1930's. Side channels, boulders and large woody debris provide habitat diversity, and resident fish occupy this good to excellent quality habitat. The glacially derived channel geomorphology of the upper Entiat watershed has important implications for fish and habitat access. Barrier falls (Box Canyon, partial barrier; Entiat Falls, complete barrier) prevent fish from migrating into the uppermost reaches of the mainstem Entiat River, and natural barriers created by hanging valleys prevent from fish migrating into all but the lowest segments of the Entiat River's tributaries. Accordingly, anadromous fish are absent from this zone due to natural barriers.

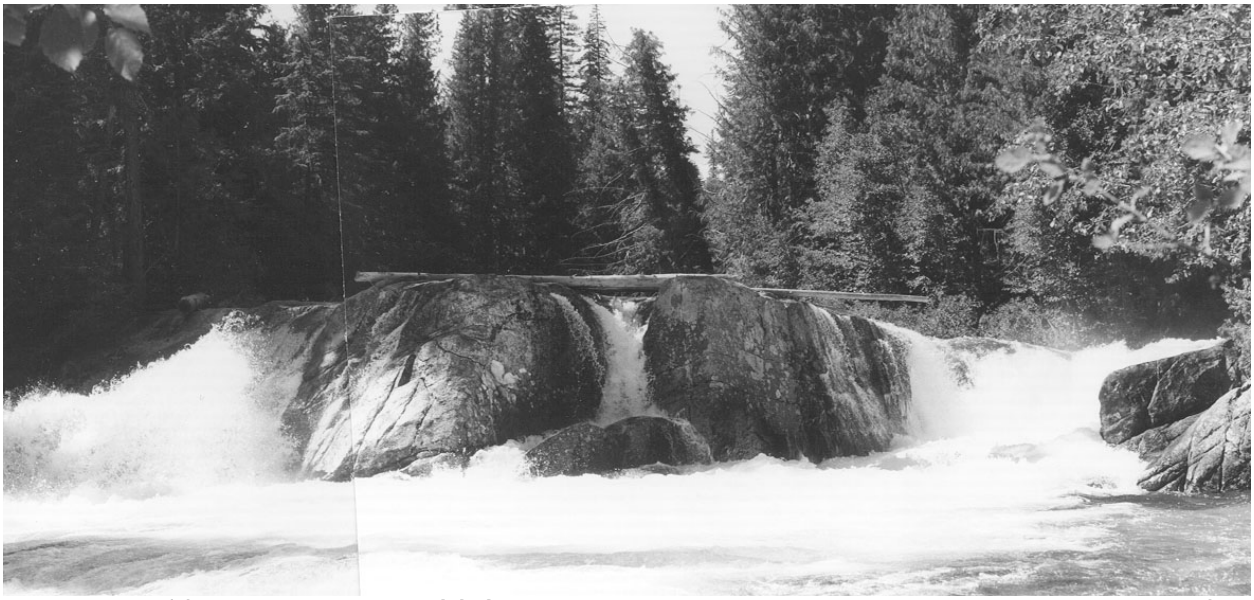

Figure 7-10. Entiat Falls (RM 33.8) is considered a barrier to the upstream migration of anadromous fish.

Transitional Zone

In the transitional zone [RM 33.8 to McCrea confluence (RM 25)] the current condition of fish habitat in the mainstem Entiat has been modified from the condition found in 1930's surveys. Data indicate a 30-60% loss of pool habitat, yet the amount of pool habitat and large woody debris within this reach is the highest of the three Entiat reaches (CCCD 1998). The trend in habitat condition is variable and uncertain, and some channel sections have been locally impacted by timber harvest in tributaries, and by road crossings. Primarily bull trout and other resident fish utilize the fair to excellent quality habitat in this zone; spring Chinook and summer steelhead use is limited to the lower reaches due to natural barriers.

Depositional Zone

The depositional zone [McCrea Creek confluence (RM 25) downstream to the mouth] contains the principal spawning and rearing habitat for anadromous fish in the Entiat River. Spring and summer Chinook and sockeye salmon, steelhead and bull trout, and other resident species all use the zone. The distribution of salmonids within this area is limited to the few fish-accessible tributaries above (Stormy Creek) and below (Roaring Creek, Mad River, Potato Creek) the Potato Creek moraine (RM 16.2). Overall, the condition of fish habitat in the depositional zone is fair to poor. Many stream reaches within this zone have been artificially constrained and simplified, especially in the mid- to lower mainstem Entiat River. The amount of large woody debris and pool habitat in this section of the mainstem is the least of the three reaches; pool habitat has been reduced by 90% since the 1930's. Conversely, pool habitat in the Mad River has increased since the 1930s surveys. The mainstem and accessible tributaries in this zone are of prime importance for maintaining and restoring fish habitat. The trend in habitat conditions is variable and uncertain, partially due to the frequency and extent of recent wildfires.

Fish habitat in the depositional zone upstream from Potato Creek Moraine (RM 16.2-RM 25) is in good condition. In general, this reach has a good pool-riffle ratio, with pool habitat (geomorphic) at every 5 to 7 bankfull channel widths. Off-channel habitat exists in stable locations. Large woody debris is locally lacking, however, and in some areas there is stream bank loss due to lateral channel migration, which has been accelerated by bank clearing. It is evident, based on stream survey information from USFS, USFWS, and WDFW, and the observations of fish biologists familiar with the subbasin, that most Entiat River stream-type anadromous fish spawn in this area, which has been least modified by land use practices and flood control projects; early rearing also occurs in this more pristine area.

In general, above the Potato Creek moraine, spawning and rearing conditions for salmon and steelhead are considered to be good to excellent, with adequate cover, favorable velocities and high flow refuge habitat (USFS WNF 1996). Chinook and sockeye salmon enter the lower Entiat under favorable flow depth and velocity conditions, when flows are declining from the June peak. Spawning occurs in the reach above the moraine from late August to mid-October, and eggs incubate for about 90 days, depending on water temperature. Under favorable conditions, fry emerge from the gravels in December prior to winter extremes. Juvenile rearing begins in early spring during a period when the river provides increasingly favorable conditions of flow, temperature and food supply. A portion of the juvenile population may gradually move downstream of the Potato Creek moraine to the lower reach during summer, fall, and winter rearing (Hillman and Chapman 1989a,b,c).

Figure 7-11 and Figure 7-12 on the following two pages provide a graphic overview of the relationship among fish distribution, channel morphology, and land uses in the three analysis zones of the Entiat and Mad Rivers. Figure 7-13 and Figure 7-14 on the following pages provide a summary of Entiat and Mad River pool habitat changes.

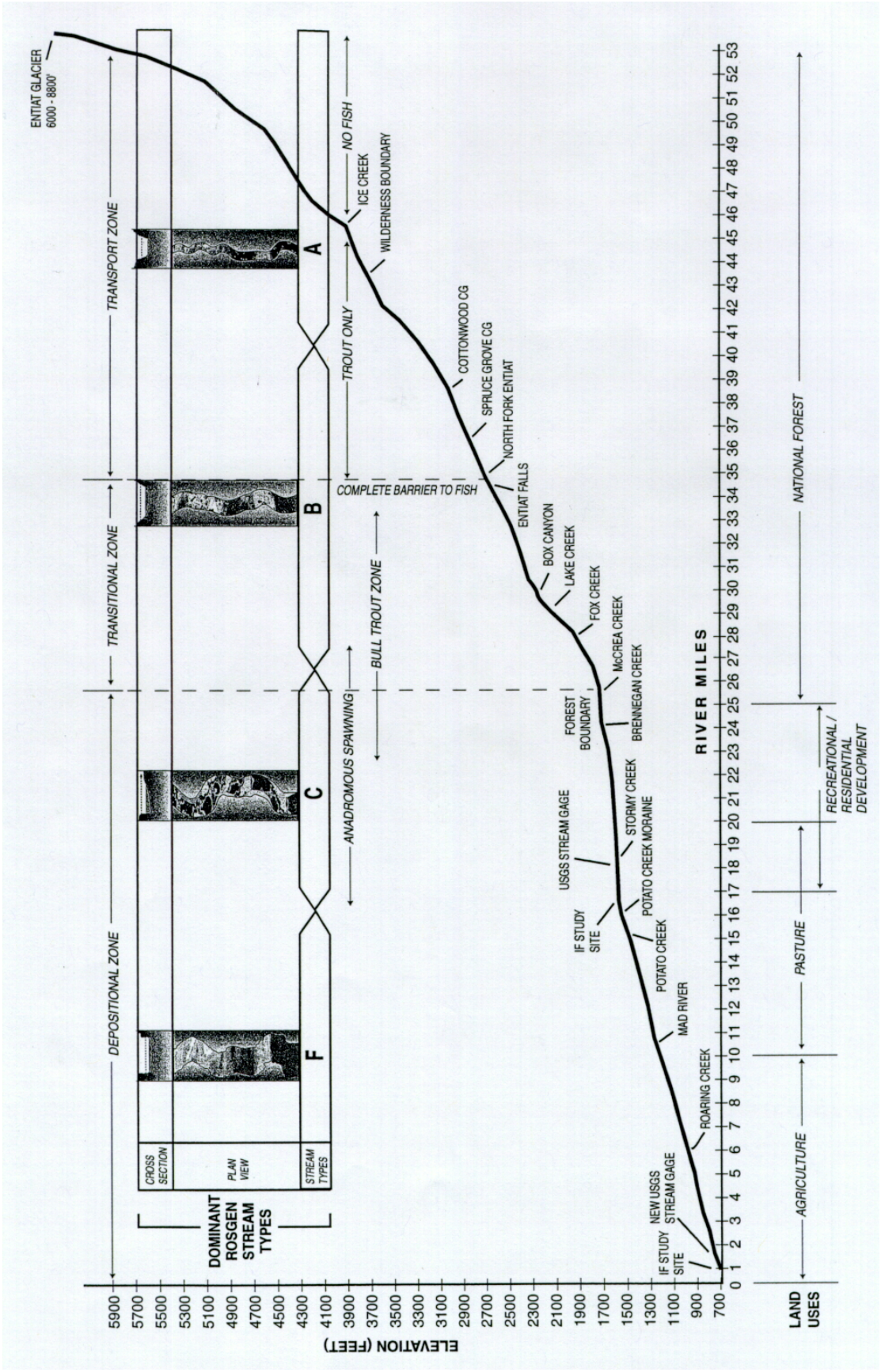

Figure 7-11. Longitudinal profile of Entiat River analysis zones, channel type, gradient, fish use and landmarks.

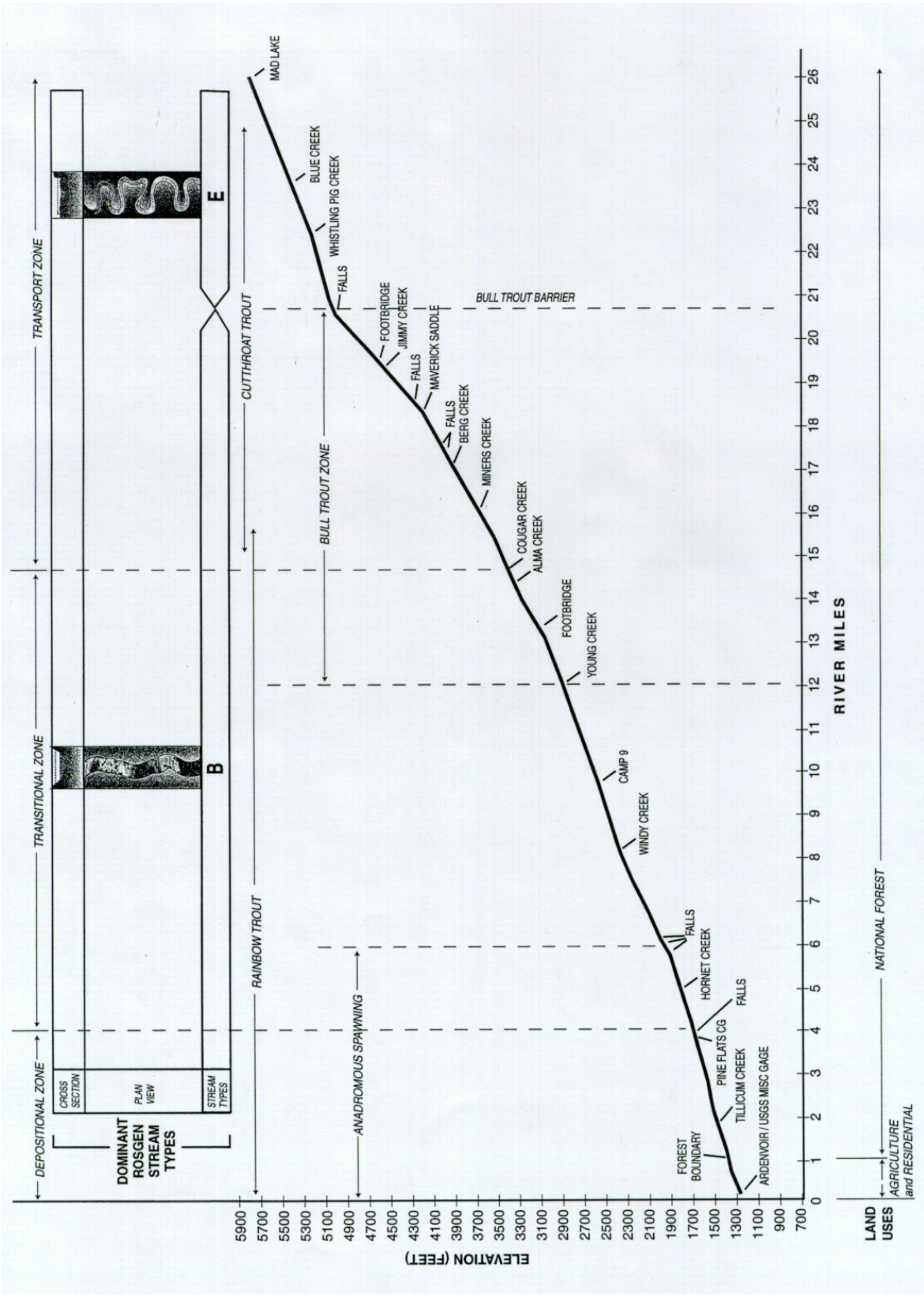

Figure 7-12. Longitudinal profile of Mad River analysis zones, channel type, gradient, fish use and landmarks.

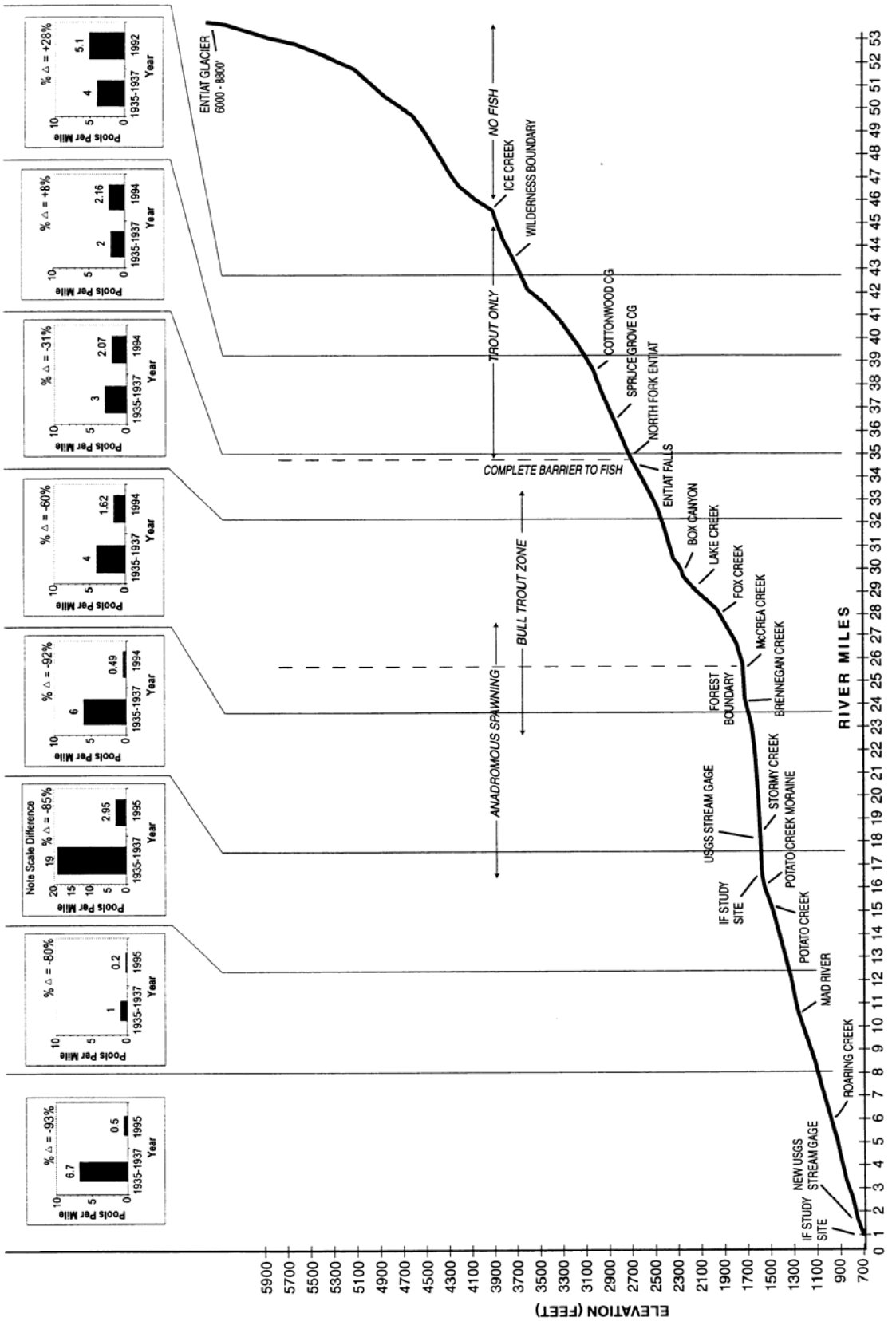

Figure 7-13. Pool frequency comparisons for the Entiat River 1930's to 1990's.

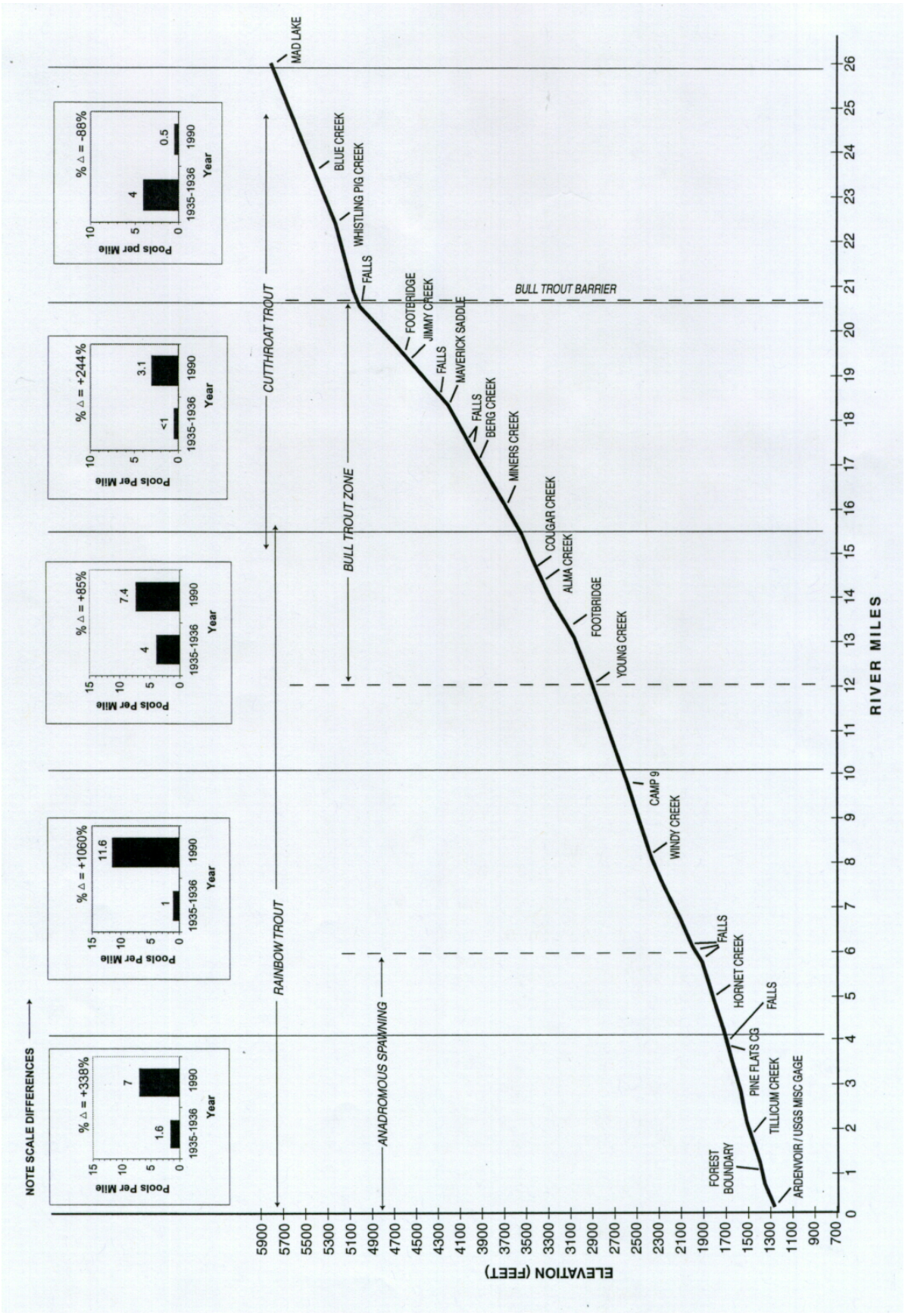

Figure 7-14. Pool frequency comparisons for the Mad River – 1930's to 1990's.

Spawning and rearing conditions for salmonids in the lower mainstem Entiat River below the moraine are generally deemed poor (USFS WNF 1996). The first 15.4 miles of the Entiat River show the result of human disturbances (CCCD 1998); county roads, flood control dikes and channel straightening associated with past flood control projects have dramatically simplified habitat in this section of the river, particularly below the Mad River confluence (RM 10.5) (see Historical Changes to Channel Geometry for more information on past channel modifications). Channel segments in the lower mainstem are highly confined with a lack of pools and effective floodplain function. As a result, stream energy is not well dissipated; in many reaches there is not a well-defined thalweg, resulting in a poor distribution of water velocities. Wood removal and the loss of large woody debris recruitment resulting from these and other actions have exacerbated conditions. Today, the lower mainstem is almost entirely devoid of LWD, and there are some areas with no riparian vegetation remaining. Refer to Section 7.2 for more detailed information about riparian condition in the lower Entiat.

Adult salmon moving upstream to spawn during low flow years find a shortage of deep resting pools and much of the suitable spawning gravel dewatered. Water over the spawning gravels is shallow (less than one foot deep) and cools more quickly, resulting in extended egg incubation periods, direct mortality and the formation of anchor ice that can damage eggs and emerging fry. "Wide, shallow streams are more susceptible to anchor-ice formation than are deep, narrow ones because supercooled water develops more rapidly. There is also a tendency for anchor ice to form more readily in uncanopied stream sections where more rapid cooling can occur" (Swanston 1991). In addition to anchor ice, sedimentation and gravel scour are potential sources of pre-emergence mortality. In extreme low flow years, fry emergence is delayed until January or February when conditions in the river are harshest (i.e., low temperatures, low flows, low food supply, anchor ice).

The combination of natural and artificial channel confinement severely limits the availability of suitable early rearing habitat. Food supply has been reduced and high flow refuge habitat (primarily created via LWD recruitment) is lacking due to the loss of riparian vegetation. Current velocity refugia are primarily associated with riprap and afford little cover from avian or piscine predators. Habitat enhancement efforts should include creating additional velocity refugia and better cover (Andonaegui 1999). Late rearing habitat also lacks in-channel diversity. The lack of cover, particularly as flows drop in the summer and fall, may be limiting salmonid productivity through density dependant mechanisms. Overwinter habitat quality was also severely reduced by the actions described above. Winter water temperatures often hover near freezing. Frazil and anchor ice are common winter phenomena, and can occupy most of the substrate in this reach in a cold winter following a dry summer.

All of the aforementioned practices in combination constitute the greatest impact to salmonid habitat in the mainstem Entiat downstream of the Mad River confluence. Alterations to channel shape have reduced the amount of habitat available at current flow levels; the increase in water required to provide historic habitat in the altered channel is simply unavailable or impractical to attempt to achieve. A more pragmatic approach is to focus on restoring an appropriate channel morphology that supports adequate habitat given

the existing hydrology. This does not preclude water conservation measures, it merely emphasizes that water alone is not the solution to restoring lost habitat.

Many of the key habitat factors that apply to anadromous salmonids also apply to inland fish. Resident salmonids are found with anadromous fish in many areas, but usually reside in smaller-order streams with higher gradients. They occur primarily in more forested drainages away from many of the habitat problems associated with human development. Habitat priorities for resident fish, in particular rainbow, westslope cutthroat, and bull trout, include minimizing sedimentation and gravel scour, providing cover, and maintaining or providing passage.

In 1996, the NRCS began work to design three rock cross-vanes for installation in the lower river. This effort was based on the baseline habitat and geomorphology information and restoration recommendations contained in the Entiat River Inventory and Analysis (CCCD 1998), and data from the WRIA 46 LFA (Andonaegui 1999) and USFS Entiat RD stream surveys. The three demonstration habitat improvement structures were installed in the fall of 2001, with the goals of restoring habitat complexity and large resting pools, as well as improving channel morphology (width-to-depth ratio) in selected reaches of the mainstem. Two rock cross vanes with rootwads were installed just downstream of a county bridge near the Entiat fire station, at RM 3.1. An additional rock cross vane/rootwad project was placed upstream of the old highway bridge on Dinkleman Canyon Road (RM 4.1). The BLM installed also installed habitat enhancement projects on property they manage adjacent to the mainstem Entiat River in 2001. All project sites and appropriate types of structures were identified in and recommended by the Entiat River Inventory and Analysis (CCCD 1998). (See Figure 7-15, Figure 7-16, Figure 7-17, and Figure 7-18, shown below and on the following pages).

Figure 7-15. Looking downstream at two of rock cross vane structures installed in 2001 at the Fire Station Bridge site (RM 3.1).

Figure 7-16. View of rock cross vane installed furthest upstream in 2001.

Figure 7-17 One of two engineered log jams installed by the Bureau of Land Management in the lower Entiat River (RM 10.3) during the fall of 2001.

Figure 7-18 One of two large boulder barbs with root wads installed near RM 15 by the BLM during the fall of 2001.

Site information necessary for implementation of the three rock cross vane structures was collected prior to construction in 2000, and the USFWS performed as-built and post-construction snorkel surveys in 2001, 2002 and 2003, along with redd counts, to identify species use of the pool habitat. Annual site effectiveness monitoring for physical and environmental variables is ongoing. Initial monitoring results show that the pools that were created are maintaining their depth, and many species, including steelhead and bull trout, spring and late-run Chinook salmon, and other resident fish are using the pools. Table 7-18 on the following page contains the results of the USFWS MCRFRO pool snorkel survey findings for 2000-2003.

Table 7-18. Summary of fish species found during USFWS snorkel surveys of the three demonstration restoration sites in lower Entiat River, 2000-2003.

Fire Station Site (Lower Pool)											
Year	BT juv.	BT adult	RT/SH juv.	RT adult	SH adult	CH juv.	LrCH adult	CO juv.	White-fish	Sucker	Sculpin
2000											1
2001					2						
2002	2		11			1			10	50	
2003			34	6		98	1		45	75	
Fire Station Site (Upper Pool)											
Year	BT juv.	BT adult	RT/SH juv.	RT adult	SH adult	CH juv.	LrCH adult	CO juv.	White-fish	Sucker	Sculpin
2000											
2001				1			9		1	1	1
2002			12			19			24	17	
2003			19	5		156	2		33	50	
Dinkelman Canyon Road Site											
Year	BT juv.	BT adult	RT/SH juv.	RT adult	SH adult	CH juv.	LrCH adult	CO juv.	White-fish	Sucker	Sculpin
2000				3							1
2001		1		2			2				
2002		2	75			250		3	20	6	
2003		2	39	7		137	1		35	25	
Species Totals (all three sites)											
Year	BT juv.	BT adult	RT/SH juv.	RT adult	SH adult	CH juv.	LrCH adult	CO juv.	White-fish	Sucker	Sculpin
2000				3							2
2001		1		3	2		11		1	1	1
2002	2	2	98			270		3	54	73	
2003		2	92			391			113	150	

Species codes: BT = bull trout
RT/SH = rainbow trout/steelhead
RT = rainbow trout
SH = steelhead
CH = Chinook
LrCH = late-run Chinook;
CO = Coho.

7.4 ENTIAT ECOSYSTEM DIAGNOSIS AND TREATMENT (EDT) ANALYSIS

Recently, the Yakama Nation and other EWPU Habitat Subcommittee members worked with Mobrand Biometrics, Inc. to model Chinook salmon response to various restoration scenarios using the Ecosystem Diagnosis and Treatment (EDT) methodology. This section presents the initial EDT "Diagnosis" for planning restoration and protection of salmon habitat in the Entiat River subbasin. The Diagnosis is based on an assessment of the relative contributions of environmental factors to the biologic performance of naturally produced Chinook salmon.

EDT is an analytical method relating habitat features and biological performance to support conservation and recovery planning. It acts as an analytical framework that brings together information from empirical observation, stakeholders and local experts, and other models and analyses tools.

To view the full report, go to: Reports\EDT\Entiat_EDT.pdf. The EDT document and associated appendices are found in the Reports/EDT folder on the CD.

Objectives

The EDT analysis consisted of two phases with unique objectives:

1) Watershed Assessment (Diagnosis): To complete a watershed assessment with respect to Chinook salmon (the focal or diagnostic species selected for the Entiat), assessing current and historic measures of population performance relative to habitat conditions, and to derive strategic priorities for protection and restoration actions.
2) Analysis of Action Alternatives (Treatment): To assess how various future management actions might contribute to the long-term enhancement or restoration of biologic productivity of salmonid species – specifically Chinook salmon.

In the assessment phase, the EWPU Habitat subcommittee characterized baseline reference conditions with regard to both environmental conditions and population performance measures. Two baseline reference scenarios were characterized: historic (predevelopment) conditions and current conditions. The comparison of these scenarios forms the basis of the diagnostic conclusions about how the Entiat subbasin and associated salmon performance have been altered by human development. The historic reference scenario also serves to define the natural limits to potential recovery actions within the subbasin.

During the assessment of future management actions, five alternative management scenarios were modeled. These alternatives were based on and consistent with alternatives developed and outlined in the Entiat River Inventory and Analysis (CCCD 1998), and contained in the Entiat Final Coordinated Resource Management Plan/First Draft WRIA 46 Management Plan (CCCD 2002).

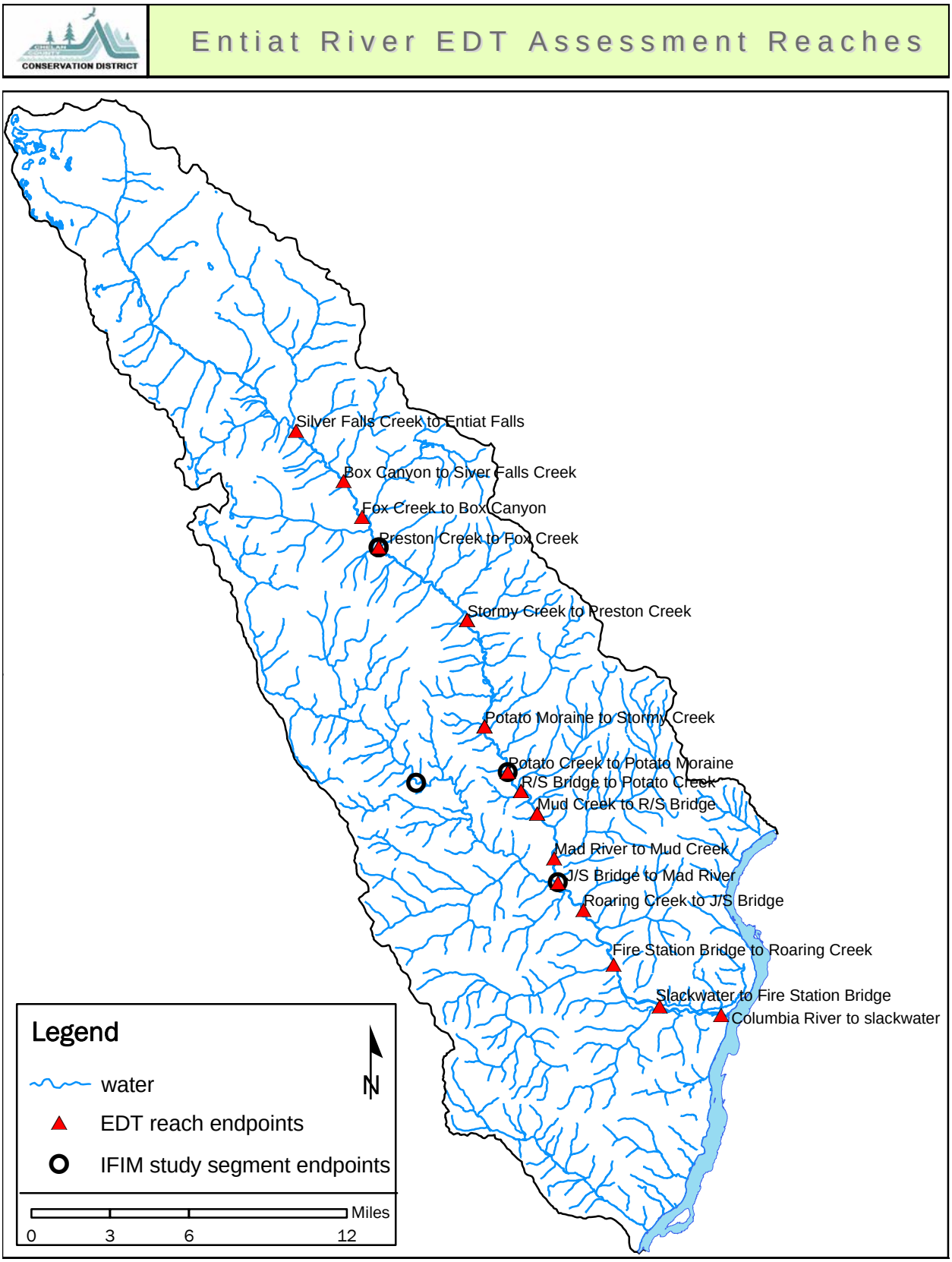

Figure 7-19. 2002 Entiat River EDT assessment reaches.

Basis of the EDT Analysis

As mentioned above, the EDT analysis describes how certain salmonid populations interact with their environment, relative to habitat conditions. The EWPU Habitat Subcommittee defined 24 specific stream reaches within the Entiat subbasin used by Chinook salmon, and evaluated approximately 47 habitat attributes for each of these reaches. The Planning Unit also performed field site visits to validate habitat condition assumptions against current conditions. Table 7-19 below summarizes the EDT reaches defined by the EWPU.

Table 7-20 beginning on page 7-52 shows the organization of Ecological Attributes (Level 2) by categories of major stream corridor features. Characterization of the Level 2 attributes was completed by the EWPU Habitat Subcommittee. Corresponding salmonid Survival Factors (Level 3) are shown associated with groups of Level 2 attributes. Values associated with these attributes are the result of the EDT modeling process. This table is specific to Chinook salmon; associations can differ by species and life stage.

Table 7-19. EDT stream reach designations for the Entiat and Mad Rivers.

EDT Reach	Description
Entiat-1	Entiat-1: From Columbia River to End of slack water; Length (mi): 0.6
Entiat-2	Entiat-2: From Slack water to Fire Station Bridge; Length (mi): 2.6
Entiat-3	Entiat-3: From Fire Station Bridge to Roaring Creek; Length (mi): 3
Entiat-4	Entiat-4: From Roaring Creek to J/S Bridge; Length (mi): 2.6
Entiat-5	Entiat-5: From J/S Bridge to Mad River; Length (mi): 1.8
Entiat-6	Entiat-6: From Mad River to Mud Creek; Length (mi): 1.2
Entiat-7	Entiat-7: From Mud Creek to R/S Bridge; Length (mi): 2.2
Entiat-8	Entiat-8: From R/S Bridge to Potato Creek; Length (mi): 1.2
Entiat-9	Entiat-9: From Potato Creek to Potato Moraine; Length (mi): 0.9
Entiat-10	Entiat-10: From Potato Moraine to Stormy Creek; Length (mi): 2.2
Entiat-11	Entiat-11: From Stormy Creek to Preston Creek; Length (mi): 4.8
Entiat-12	Entiat-12: From Preston Creek to Fox Creek; Length (mi): 4.7
Entiat-13	Entiat-13: From Fox Creek to Box Canyon; Length (mi): 1.5
Entiat-14	Box Canyon
Entiat-15	Entiat 15: From Box Canyon to Silver Falls Creek; Length (mi): 1.7
Entiat-16	Entiat-16: From Silver Falls Creek to Entiat Falls; Length (mi): 2.8
Mad-1	Mad River Mouth to Tillicum Creek
Mad-2	Tillicum Creek to Pine Flat
Mad-3	Pine Flat to Camp 9

Table 7-20. Level 2 EDT habitat attributes evaluated for Chinook salmon.

Ecological Attributes (Level 2 Attributes)		Related Survival Factors (Level 3 Attributes)
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 stability Channel width Habitat diversity Key habitat Obstructions Sediment load
	Channel width - month maximum width	
	Channel width - month minimum width	
	Gradient	
2.2 Confinement	Confinement - hydromodifications	
	Confinement - natural	
2.3 Habitat type	Habitat type - backwater pools	
	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	
3 Water Quality		
3.1 Chemistry	Alkalinity	Chemicals (toxic substances) Oxygen Temperature
	Dissolved oxygen	
	Metals - in water column	
	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 Competition with other fish
	Fish pathogens	
	Fish species introductions	

Ecological Attributes (Level 2 Attributes)		Related Survival Factors (Level 3 Attributes)
	Harassment	Food Harassment Pathogens Predation
	Hatchery fish outplants	
	Predation risk	
	Salmon carcasses	
4.2 Macroinvertebrates	Benthos diversity and production	

Because of the substantial complexity of how well various life stages of Chinook salmon survive in different reaches at different times of the year, a computer-based computational model is necessary to track all of the interactions and assumptions to provide resource managers defensible decision-making tools. The primary output of the EDT modeling process describes a population's "biological performance" (in this case, the Entiat spring Chinook and Entiat summer [late-run] Chinook populations) with respect to the different treatments.

Biological performance can be defined in terms of three elements: 1) biologic productivity, 2) environmental capacity, and 3) life history diversity. These measures are characteristics of the ecosystem that describes a population's persistence, abundance, and distribution potential. These three elements are also the core performance measures used by the NOAA Fisheries (formerly NOAA National Marine Fisheries Service) as part of its viable population concept. Each measure is defined briefly below.

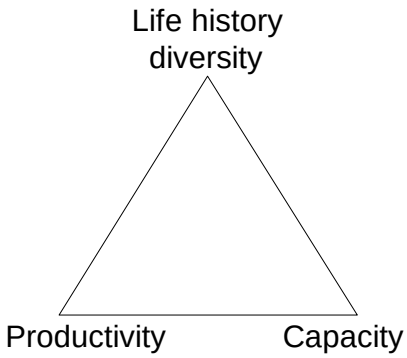

Figure 7-20. Three core performance measures of biological performance.

1) Productivity. This element represents the relative success of the species to complete its life cycle within the environment it experiences[1]. It determines resilience to mortality pressures, such as from fishing, dams, and further habitat degradation. *Habitat quality* (including water quality) is a major determinant of a population's productivity.
2) Capacity. This element defines how large a population can grow within the environment it experiences, as a result of finite space and food resources. It determines the effect of this upper limit on abundance to survival and distribution.

[1] The productivity rate is the reproductive rate measured over a full generation that would occur at low population density, i.e., when competition for resources among the population is minimal.

Habitat quantity is a major determinant of the environmental capacity to support population abundance.

3) Life History Diversity. This element represents the multitude of pathways through space and time available to, and used by, a species in completing its life cycle. Populations that can sustain a wide variety of life history patterns are likely to be more resilient to the influences of environmental change. Thus a loss of life history diversity is an indication of declining health of a population and perhaps its environment.

EDT Diagnosis Results

Modeling results were completed and reported in the Entiat EDT Watershed Analysis, February, 2003 (Mobrand Biometrics, Inc. 2003). A complete review of EDT results and conclusions is beyond the scope of this document, but the reader is encouraged to review Chapter 3.0 of the full Entiat EDT report (Subsection 3.1 Entiat spring Chinook and Subsection 3.2 Entiat summer Chinook) for the complete analysis.

Table 7-21 summarizes the EDT modeling results for both Entiat late-run and spring Chinook salmon populations after taking into account ocean and Columbia River harvest and an assumed loss of genetic fitness (due to hatchery interactions).

Table 7-21. Baseline spawner population performance parameters for Entiat late-run (summer) Chinook and Entiat spring Chinook.

Population	Scenario	Life History Diversity Index	Biologic Productivity	Environmental Capacity	Average Modeled Abundance
Entiat Late-run Chinook	Historic	100%	10.7	2,955	2,680
	Current	13%	1.5	296	99
Entiat Spring Chinook	Historic	93%	12.0	2,789	2,557
	Current	35%	2.0	321	170

From Table 7-21 it is estimated that a substantial reduction in life history diversity has resulted since historic times, particularly for late-run Chinook. Biologic productivity (the average number progeny that will return as adult spawners) is estimated to be very low. A population with a biologic productivity value of 1.0 is just able to maintain itself, and a (average) value of less than 1.0 will eventually go towards extirpation. The amount of habitat available (Environmental Capacity) for these fish has also diminished substantially from historic conditions (approximately 10% capacity is estimated from historic conditions).

Not surprisingly, the above table also suggests (Average Modeled Abundance) that there is a substantial capacity for the Entiat subbasin to increase abundance for both spring and late-run Chinook populations.

It should be carefully noted that degradation of these performance measures, especially biologic productivity and average modeled abundance, also reflects environmental conditions outside of the Entiat subbasin. Additionally, the EWPU Habitat subcommittee recognizes that it is unrealistic to believe that the historic conditions modeled here provide for realistic future expectations. The values provided in the Diagnosis provide reference points for comparison, and are useful to suggest management options, but do not imply management goals.

The primary environmental attributes that have lead to the decline of the above performance measures within the Entiat subbasin include lost habitat diversity, reduction of food resources (decrease in salmon carcasses), increased channel instability and a decrease of the amount (quantity) of habitat available. In the Mad River system, additional problems related with elevated water temperatures, predation, fish pathogens are also noted.

It is worth noting that beginning in 2000, the USFWS Leavenworth National Fish Hatchery Complex in conjunction with the Mid-Columbia River FRO began outplanting post-spawn hatchery spring Chinook carcasses in the Entiat River among others. Carcasses were sanitized through freezing and the carcasses were distributed in known spring Chinook spawning areas. Recently, spawning practices have changed to the extent that few suitable carcasses are available for outplant. In order to continue nutrient supplementation in 2003, 1200 pounds (the equivalent of 400 Chinook carcasses) of "carcass analog" pellets were distributed in the Entiat River between rivermiles 17.5 and 28 during the autumn months of 2003. The carcass analog is a manufactured pelletized product that is composed primarily of post-spawn hatchery Chinook salmon and binder that is pasteurized by heating and desiccation (Cooper 2003). The process of nutrient supplementation by this (or other) method is expected to continue in the Entiat River.

<u>Alternative Management and Restoration Scenarios (Treatments)</u>

In an EDT analysis, restoration scenarios are comprised of different combinations of distinct types of restoration actions. In the Entiat analysis, five types of restoration actions were combined into five restoration scenarios targeting 11 of the 16 reaches of the Entiat mainstem -- Entiat River reaches 2 through 12. These scenarios included measures to protect critical habitat areas as well as to restore habitat quality and quantity. To a large degree, the Entiat scenarios were cumulative; actions taken in a scenario of lower intensity were preserved and augmented in the "next" scenario. The actions and scenarios modeled in this analysis were proposed by the Entiat Habitat subcommittee/EDT work group, and were based partly on the EDT Diagnosis and partly on a consensus among stakeholders of what was practicable.

1. Construction of variable numbers of "cross vanes" (or other appropriate instream structures) throughout a progressively larger proportion of the Entiat mainstem. The general effects of these actions were to increase the amount of pool habitat, to increase LWD loading and thus habitat diversity, and to reduce channel confinement and restore a measure of riparian function. All of these effects, but especially the last three, are consistent with the Diagnosis for Entiat spring and late-run Chinook.

2. Planting progressively larger portions of the riparian corridor of the mainstem Entiat River with riparian vegetation. The intended impact of these measures, in addition to stabilizing riverbanks and protecting roads and private property, were to moderate maximum & minimum water temperatures, to reduce icing damage, to increase the production of benthic invertebrates (a food resource for juvenile Chinook salmon), and to enhance riparian function. All of these effects, and especially the last two, were highlighted by the Diagnosis.

3. The "Easements" action, which consisted of establishing easements or other habitat protection measures with willing landowners on the riparian corridor in three reaches of the upper middle Entiat mainstem -- Entiat River reaches 10, 11 and 12. The intended impact of this measure, in addition to protecting critical adult holding, spawning and early rearing areas for spring and late-run Chinook, was to allow riparian vegetation to recover naturally, and eventually to increase habitat diversity by increasing the recruitment of LWD. This action targets a high priority geographic area for protection of spring and late-run Chinook production.

4. The "Side Channel/Ditch" action, which consists of hydraulically reconnecting a disconnected side channel of the lower Entiat mainstem, restoring habitat quality within the side channel, and converting a portion of an irrigation ditch to juvenile rearing habitat. Because both of these actions target Entiat River reach 3, they were considered as a unit. The intended impacts of this action is to add additional high quality juvenile rearing habitat, to increase LWD loading and thus habitat diversity, and to increase the proportion of river channel consisting of pools and pool tailouts. The effects of this action are entirely consistent with the Diagnosis for restoring spring and late-run Chinook production in the reach targeted.

5. The "Log Catchers" action, which consists of installing 40 "log retention structures" in Entiat River reaches 10 and 11 (upper middle Entiat). The log retention structures were to be evenly distributed between reaches 10 and 11. The intended impact of this measure was to increase LWD density and habitat diversity, as well as the amount of backwater pool and pool tail-out habitat. These measures affect the fry life stage more than any other, as well as some of the major limiting factors for fry in these reaches (e.g., habitat diversity, food, flow, key habitat), and therefore are consistent with the diagnoses for Entiat spring and late-run Chinook. They also target the number one and two intra-Entiat geographic areas for Preservation and Restoration, respectively, of Entiat spring Chinook.

Table 7-22 on the following page summarizes the five alternative management scenarios that were evaluated by the Entiat Habitat Subcommittee and modeled using EDT.

Table 7-22. Alternative Management Scenarios for EDT Modeling

Actions	Cross Vanes or other structures (Reaches 2-9)	Riparian Plantings (Reaches 2-9)	Log / LWD Placement	Side Channel Connection (Reach 3)	Irrigation Ditch as Habitat	Habitat Protection and Restoration (Reaches 10,11,12)
Alternatives	(structures)	(lineal feet)	(sites)	Yes / No	Yes / No	(sites)
1	20	10,000	5	No	No	No
2	40	20,000	10	No	No	No
3	80	40,000	20	No	No	No
4	80	40,000	20+	Yes / No	Yes / No	Yes / No
5	80	50,000	40	Yes / No	Yes / No	Yes / No

Alternative Themes

Alt 1	This alternative describes a relatively low level of effort towards application of the "Bridge to Bridge" concept (focuses Fire Station Bridge to J/S Bridge), using additional cross vanes, associated riparian plantings and some channel stability using root-wads and LWD structures.
Alt 2	This alternative is directly associated with **Alternative 2 from the Entiat Coordinated Resource Management Plan (CRMP)**. Most of the work would occur in the lower Entiat main-stem. This alternative describes a "minimal" requirement for migration, spawning, resting and rearing habitats in CRMP Reaches 1-6 and minimum root-wad revetments in CRMP Reaches 7-8.
Alt 3	This alternative is directly associated with **Alternative 4 from the Entiat CRMP**. All of the work would be spread throughout Reaches 2-9 (as identified in the CRMP) of the Entiat main-stem. This alternative provides for "approximately 40% of the historic pool frequency, resulting in an average of 3 pools per mile in Reaches 1-6 and 8 pools per mile in Reaches 7-8".
Alt 4	This alternative provides for the maximum recommended action included in the CRMP Alternative 4. Additional enhancement components are anticipated in the Bridge to Bridge concept (Reach 3), and upstream into the Stillwater area Reaches 10, 11, 12.
Alt 5	This alternative enhances Alternative 4 by providing substantially more large wood structures, and consequently more pool habitat and habitat diversity to reaches 10 and 11. Approximately 4 lineal miles of riparian plantings are also considered. This alternative assumes some degree of conservation easements or habitat protection option would be implemented by willing landowners.

Discussion of Results

The incremental benefits of Alternative Management Scenarios 1-5 as indicated in Table 7-23 on page 7-58 are roughly the same for spring Chinook and late-run Chinook when benefits assume current harvest levels and assumed genetic fitness impacts. Equilibrium abundance for spring Chinook increases from the current value of 138 to 187 under scenario 5, an overall increase of 36%. Late-run Chinook abundance increases from its current value of 99 to 152 under scenario 5, an increase of 53%. The increase in carrying capacity from current conditions to scenario 5 is 29% for *both* spring Chinook and late-run

Chinook. Moreover, there are no qualitatively different improvement patterns in equilibrium abundance or carrying capacity between stocks in moving from scenario to scenario, and the benefits to both stocks seem to be leveling off after scenario 4.

The major differences between stocks concern productivity and, especially, life history diversity. For spring Chinook, productivity increases from its current value of 1.96 to 2.06 under scenario 5, an increase of only about 5%. By contrast, productivity for late-run Chinook increases more than twice as much – from 1.5 to 1.66, a 10.7% increase. The increase in spring Chinook life history diversity of 46% is nearly quadrupled by late-run Chinook in going from current conditions to scenario 5. These differences in relative benefit, however, are likely more apparent than real, and are largely due to the extremely tenuous status of late-run Chinook under current conditions. Indeed, productivity, and life history diversity for late-run Chinook under scenario 5 are still less than the comparable measures for spring Chinook without any enhancement whatever. Thus the benefits of the modeled scenarios to late-run Chinook production may be primarily to improve performance enough to prevent the extirpation of the population.

Table 7-23. Results of the EDT alternative management scenarios for Entiat spring and late-run (summer) Chinook under the five restoration alternatives.

		Current Conditions	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Historic Conditions
Entiat Summer Chinook	Life History Diversity	13%	18%	21%	28%	31%	32%	100%
	Biologic Productivity	1.50	1.49	1.57	1.59	1.65	1.66	10.74
	Environmental Capacity	296	315	332	367	379	381	2,901
	Abundance	99	104	120	136	149	152	2,631
Entiat Spring Chinook	Life History Diversity	35%	37%	40%	42%	49%	50%	93%
	Biologic Productivity	1.96	1.99	2.02	2.03	2.04	2.06	12.03
	Environmental Capacity	281	294	307	334	358	363	2,789
	Abundance	138	146	155	169	182	187	2557

7.5 WILDLIFE HABITAT

Background

Wildlife habitats and their dependent populations have always been in a somewhat dynamic state in the Entiat WRIA. Weather and a number of natural disturbance events including wildfire have created a wide variety of changes to wildlife habitats over time. Wildlife populations have adapted to these changes, with short-term fluctuations in numbers. Deviations from natural habitat conditions have probably never been as great as they are at this time due to human influence, e.g. development, logging, roads, altered riparian zones, and fire suppression and its effects on the natural fire cycle. Development and land use activities have caused habitat fragmentation affecting most species including mammals,

birds, invertebrates, amphibians and reptiles. Riparian habitat alteration has affected herons and other waterfowl, as well as amphibians, reptiles and beaver.

Before the arrival of European Settlers, wildfires occurred frequently in the lower elevations, but they were relatively low in intensity, and a wildlife-habitat equilibrium was maintained over time. Big game populations were more diverse; although deer populations were lower than today. Wolves and grizzly bears occurred regularly, as well as currently common coyotes, cougars and black bears. Some of the old growth associated wildlife in the fire-adapted forest was found in dry open forests dominated by ponderosa pine. These species included pileated and white-headed woodpeckers, flammulated owls, and pygmy nuthatches. Lynx, bobcats, marten, wolverine and fisher also inhabited the more dense forest types and higher elevations.

Between 1800 and 1900, human settlement altered wildlife habitat and populations. Market hunting was used to supply the army and miners. Furbearers were heavily harvested through trapping, and early settlers harvested game bird populations. Heavy grazing competition from domestic animals also began; elk and big horn sheep eventually disappeared from the area.

From 1900 through 1965 many conservation efforts focused on game animals. Elk and big horn sheep were reintroduced, while predator populations were controlled through bounties and predator poisons. Game populations increased and exotic species were also introduced. Some exotic populations such as chukars increased very rapidly, aided by predator control and farming practices. Stand replacing fires were less frequent, due to fire suppression and control efforts, which resulted in denser understory shrubs in the lower elevations of the WRIA, and more trees per acre in the mid and lower elevation forest types. Many of the additional trees were of a less fire tolerant species than the larger old growth ponderosa pines.

Beginning in the late 1950's wildfires covered more acres and burned more intensely, partially due to fire suppression policies that had increased fuel loads. Most all wildlife species and habitats have been affected by modification of cover and foraging areas. The 1994 Tyee fire may very well be the largest acreage burned at one time in the Entiat. Recovery of wildlife habitat resulting from wildfire is in progress and will be for many years.

Federally Designated Wildlife Species

Based on information received from the USFWS in May 2004 (D. Morgan, pers. comm. May 10, 11, 2004), wildlife and plant species and habitats with Federal designations in the Entiat subbasin include:

LISTED

Threatened

Bald eagle (*Haliaeetus leucocephalus*)
Canada lynx (*Lynx canadensis*)
Gray wolf (*Canis lupus*)

Grizzly bear (*Ursus arctos = U.a. horribilis*)
Marbled murrelet (*Brachyramphus marmoratus marmoratus*)
Northern spotted owl (*Strix occidentalis caurina*)
Ute ladies'-tresses (*Spiranthes diluvialis*), plant

Designated
Critical habitat for the northern spotted owl

CANDIDATE

Fisher (Martes pennanti), West Coast distinct population segment
Yellow-billed cuckoo (Coccyzus americanus)

State Priority Habitats and Species
The Washington State Department of Fish and Wildlife publishes a "Priority Habitats and Species" (PHS) list which helps to identify vertebrate and invertebrate species and habitats that are considered to be priorities for conservation and management (WDFW 2004a). Priority species require protective measures for their perpetuation due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance. These species include State Endangered, Threatened, Sensitive, and Candidate species; animal aggregations considered vulnerable; and those species of recreational, commercial, or tribal importance that are vulnerable. Priority habitats are those habitat types or elements with unique or significant value to a diverse assemblage of species. A Priority habitat may consist of a unique vegetation type or dominant plant species, a described successional stage, or a specific structural element (WDFW 2004a).

There are 18 habitat types, 140 vertebrate species, 28 invertebrate species, and 14 species groups currently on the State PHS List. Many priority species use the wildlife habitats within the Entiat WRIA for at least part of the year. Some of the more common species known to occur, or which have occurred in the past, and their State status are shown in Table 7-24 on the following page. For a complete list of all priority species found in WDFW Region 2, which includes the Entiat WRIA, refer to Appendix K. Note that some of the Region 2 species may not have been observed in or exist in the Entiat WRIA itself. Priority habitats that occur in the Entiat WRIA include: aspen stands, caves, cliffs, old-growth/mature forests, prairies and steppe, instream, riparian, shrub-steppe (both large and small blocks), snag habitat, talus, rural and urban natural open space, freshwater wetlands and fresh deepwater habitats. For more detail about priority habitats and criteria, also refer to Appendix K.

Table 7-24. Common WDFW priority wildlife species found in WRIA 46.

Species	State Status	Comments
MAMMALS		
Big Game Ungulates		
Bighorn sheep	Game	Animals from a small, introduced population in Swakane Canyon may use a portion of the basin. The biggest threat results from disease transmitted by domestic sheep.
Mountain goat	Game	A small population uses the higher country in the watershed. Changes in the amount of foraging areas due to fire exclusion may be a threat.
Elk	Game	A small population uses the subbasin. Elk are not managed for, or their presence is not encouraged, by the State Department of Fish and Wildlife north of State Highway 2, which includes the Entiat watershed.
Mule deer	Game	Mule deer are the most important big game animal in the basin, although populations have been depressed since the '94 wildfires. It will take 10-15 years for populations to recover to post-fire levels.
Carnivores		
Fisher	Endangered	Occurred in the past, but there have been no recent confirmed sightings within the Entiat watershed.
Gray wolf	Endangered	There have unconfirmed sightings in the past several years.
Grizzly bear	Endangered	Habitat exists and occurrence is suspected, but not confirmed, within the watershed. Range is quite large, with individuals requiring several sq. miles of habitat.
Marten	Game	Was the most extensively trapped furbearer in the subbasin in late 1800's; occur in the more dense forest habitats in the mid and upper portions of the watershed.
Canada Lynx	Threatened	Sightings have been documented in the subbasin.
BIRDS		
Marine birds		
Common loon	Sensitive	Occurrence documented in the past, but there have not been any sightings in the past 30 years.
Black-crowned and Great blue herons	Monitor	Great blue herons are commonly observed in the lower subbasin.
Waterfowl		
Cavity-nesting ducks, mallards, et.al.	Game	These waterfowl are found within parts of the watershed during breeding and migration periods.
Hawks/Falcons/Eagles		
Peregrine falcon	Endangered	Birds have been seen in the subbasin.
Bald eagle	Threatened	Bald eagles are known to feed in the watershed.
Golden eagle, Northern goshawk,	Candidate	Both species have been observed in the Entiat subbasin; Golden eagle and goshawk are basin residents.
Upland Game Birds		
Chukar, Ruffed and Blue grouse, Calif. quail	Game	Occur within the basin with Blue Grouse, chukar and quail common in places.
Owls and Woodpeckers		
Northern spotted owl	Endangered	Resident within the WRIA
Burrowing owl and Flammulated owl	Candidate	Both species nest and forage in the basin.
Black-backed woodpecker	Candidate	Nest and forage within the watershed
Pileated and White-headed woodpeckers	Candidate	Both species nest and forage in the basin.

State and Federal Species of Concern

The WDFW also publishes a Species of Concern list of only native Washington fish and wildlife species that are listed as Endangered, Threatened, or Sensitive, or as Candidates for these designations. Endangered, Threatened, and Sensitive species are legally established in Washington Administrative Codes. Candidate species are established by WDFW policy. There are currently 24 Endangered, 11 Threatened, 4 Sensitive, and 103 Candidate species on the WDFW SOC List. The USFWS also provides a list of Species of Concern as advance notice to federal agencies of species that may be proposed for listing in the future. Refer to Appendix K for a list of all WDFW Region 2 Species of Concern, and Federal species of concern in Chelan County. Again, some of the WDFW Region 2 and USFWS Chelan County Species of Concern may not have been observed in or exist in the Entiat WRIA itself (see Appendix K for all State and Federal Species of Concern) (WDFW 2004b, pers. comm. D. Morgan, May 10, 11, 2004).

Rare Plants

The Washington Department of Natural Resources Natural Heritage Program maintains a database of known rare plan occurrences, and plant state and federal status. A list of rare plants known to occur in Chelan County is also provided in Appendix K.