AQUATIC SPECIES AND HABITAT ASSESSMENT: WENATCHEE, ENTIAT, METHOW, AND OKANOGAN WATERSHEDS

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LIST OF ACRONYMS

BCME	British Columbia Ministry of Environment
BFCW	Bankfull channel width
BLM	Bureau of Land Management
BMP	Best Management Practice
CCT	Colville Confederated Tribes
CCCD	Chelan County Conservation District
cfs	cubic feet per second
CRMP	Coordinated Resource Management Plan
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FH	Fish Hatchery
GDU	Genetic Diversity Unit
HCP	Habitat Conservation Plan
ha	hectare
IFIM	Instream flow incremental methodology
JARPA	Joint Aquatic Resource Permit Application
LWD	Large woody debris
MAF	Million acre feet
NFH	National Fish Hatchery
NFP	National Forest Plan
NMFS	National Marine Fisheries Service
NRCS	Natural Resource Conservation Service
OCCD	Okanogan County Conservation District
PHS	Priority Habitats and Species
PUD	Public Utility District
RCW	Revised Code of Washington
RK	River kilometer
SASSI	Salmon and Steelhead Stock Inventory
TAC	Technical Advisory Committee
TMDL	Total maximum daily load
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WAU	Watershed Administrative Unit
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology
WDOT	Washington Department of Transportation
WFPB	Washington Forest Practices Board
WNF	Wenatchee National Forest
WRIA	Water Resource Inventory Area
YIN	Yakama Indian Nation

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SECTION 1: INTRODUCTION

This document summarizes information on aquatic species and their habitats in the four major tributaries to the mid-Columbia River in Washington State: the Wenatchee, Entiat, Methow, and Okanogan watersheds. The emphasis is on anadromous salmonids, yet the intent is to include analyses, where appropriate, of other aquatic biota and their habitats. The report reflects our current understanding of how habitat conditions affect the natural productivity and diversity of aquatic populations native to these watersheds. This report is based on the knowledge of local parties, fisheries and aquatic scientists, and from historical and recent studies.

1.1: Aquatic Diversity

It is reasonable to assume that salmonids in the Mid-Columbia Region exhibited more life history diversity than they do now. This is a result of loss of those habitats that allowed expression of those life history strategies. Habitat restoration would presumably increase diversity in life history strategies, and therefore, overall biological productivity of the watershed. This response is latent in the extant populations, and can be expressed once the appropriate habitats are made available. The general strategy of this report then, is to identify the historical and extant life history strategies, using an adaptation of the Ecosystem Diagnosis and Treatment method (Lichatowich et al. 1995), and to recommend means to allow this phenotypic response to watershed restoration. One does not know if all the possible life history types presented in the following sections were exhibited on a continuous basis. Regardless, it is valuable to consider all those that might have been present, in order to better reconcile extant life histories with historical estimates. (A more detailed description of the assumptions, uncertainties, and overall approach is presented in Appendix A). Four categories are presented in the following assessment:

Category I — Extant stocks that are persisting (progeny:parent ratios almost continuously above replacement), with continuous expression of a given life history strategy.

Category II — Stocks that are not persisting (progeny:parent ratios frequently below replacement), with infrequent expression of those life history strategies (Explained later in this document).

Category III — A life history strategy (or macrodistribution) within a given stock that is not currently in existence, yet there is reasonable likelihood that the strategy would develop once the habitat were made available.

Category IV — A stock that is extinct, or has low likelihood of phenotypic response to given restoration activity. Also, a stock that may respond to a given habitat restoration, but there is a low likelihood that sufficient habitat could be provided for the population to be viable.

We discuss three major evolutionary life history strategies of salmonids in the Mid-Columbia Region (ocean-type, stream-type, and inland), and assign each to the above categories. Species listed under these groupings are placed in each because of their dominant life history pattern. But crossover life histories are common and even expected as an evolutionary strategy to perpetuate the species (Allendorf and Leary 1988; Burgner 1991; Healey 1991). Species that adopt several life history patterns maximize the use of diverse habitats and vacant niches and have are robust to periodic dramatic environmental upheavals in a watershed (Gharrett and Smoker 1993; Ellner and Hairston 1994; Lichatowich et al. 1995). For the sake of convenience, our discussion of the effects of habitat alterations on various life history types were combined as much as possible. Some groups are not specifically discussed, but the impacts to these life history types can be inferred from the discussion of other life history types.

1.2: Affected Species

The majority of actions to be taken in a watershed restoration program are ostensibly to improve the productivity of anadromous salmonids, yet it is expected that other species dependent upon the riparian, wetland, or deepwater habitats will benefit (Wilson and Halupka 1995). It is likely that watershed restoration will benefit those species in the tributaries that are listed on the PHS list (WDFW 1995).

The species assessed in this document include anadromous runs of chinook salmon *Oncorhynchus tshawystcha*, sockeye salmon *O. nerka*, and steelhead *O. mykiss*. Inland species include kokanee (landlocked sockeye), bull trout *Salvelinus confluentus*, rainbow trout (a resident form of steelhead), and Westslope cutthroat trout *O. clarki lewisi*. Specific discussions of these species and their life history strategies are provided in each tributary assessment. For other species that may be affected by watershed restoration, such as Pacific lamprey *Entosphenus tridentatus*, mountain whitefish *Prosopium williamsoni*, and pygmy whitefish *P. coulteri*, little is known about their status in the specific tributaries, but a general discussion is provided on the known status of these species. Coho salmon *O. kisutch* were once present in some tributaries of the Mid-Columbia Region (Mullan 1984; ODFW and WDFW 1995), but are now considered extinct (Nehlsen et al. 1991). It has been proposed that non-native populations of coho salmon be introduced to the Mid-Columbia Region. A general discussion of coho salmon life history is therefore provided. White sturgeon *Acipenser transmontanus* is not discussed in this document, as we could find no evidence that their historical or current distribution includes the mid-Columbia River tributaries.

1.2.1: Ocean-type anadromous salmon

The primary ocean-type anadromous species in the Mid-Columbia Region is the summer or fall run of chinook salmon. Biologists have not detected significant genetic differences between the two runs; they are usually called summer chinook salmon or summer/fall chinook salmon (Chapman et al. 1994). Some have argued that, based on differences in timing (at multiple reference points) and spawning location, there are two discrete runs of ocean-type chinook salmon in the region, yet for the purposes of this document they are treated as one group. In 1995, NMFS concluded that summer chinook salmon in the mid-Columbia River are not a "distinct population segment" of a species (as defined by Waples 1991) or ESU as defined by the *NMFS Policy on the Definition of Species under the U.S. Endangered Species Act* (56 FR 58612-58618). Rather, they are part of a larger ESU that includes all late-run (summer and fall) ocean-type chinook salmon from the mainstem Columbia River and its tributaries (excluding the Snake River) between Chief Joseph and McNary dams (Waknitz et al. 1995). This conclusion was based primarily upon extensive protein electrophoretic data collections, which showed considerable genetic homogeneity within ocean-type chinook salmon in the region (Utter et al. 1995). This is likely a result of past and present interbreedings, broodstock management, and strayings over a continuous run (Waknitz et al. 1995).

The term "ocean-type" (Healey 1983) refers to the short period in freshwater (less than one year) before migrating to the ocean as subyearlings. Most of their life is therefore spent in the ocean. Spring chinook salmon are considered "stream-type" (spending one or more years in freshwater), and do not commonly show an ocean-type life history that can be verified from scale analysis. Conversely, summer chinook salmon can show extended freshwater rearing to late fall or through winter like "stream-type" fish. Based on limited snorkel observations, summer chinook salmon leave Wenatchee River in summer as expected for ocean-type fish, but some may rear in the mainstem Columbia

River for extended periods (Chapman et al. 1988). This phenomenon probably occurs on other tributaries to the mid-Columbia River, and suggests that mainstem reservoirs largely influence the success of ocean-type salmonids. Relative to other populations, ocean-type salmonids spend the shortest amount of their life in the tributaries. An important factor that separates this group from others is that juvenile fish have exited the subbasin prior to the lowest flows in fall and are not subject to harsh conditions in winter.

1.2.2: Stream-type anadromous salmonids

Spring chinook salmon

In the Mid-Columbia Region, juvenile spring chinook salmon generally spend one year in freshwater before they migrate downstream (Mullan 1987; Healey 1991); most spend two years in the ocean before migrating back to their natal streams (Mullan 1987; Fryer et al. 1992). The adults enter the tributaries to the mid-Columbia River from late April through July, and hold in the deeper pools and under cover until onset of spawning. They may spawn near their holding areas or move upstream into smaller tributaries. Spawning occurs from late July through September, usually peaking in late August (Chapman et al. 1995a). This extended period, both as adults and juveniles, makes spring chinook salmon typically more susceptible than ocean-type chinook salmon to impacts from habitat alterations. Water withdrawal in some areas has a deleterious effect upon stream-type salmonid spawning distribution, incubation survival, and late summer rearing habitat quality (Chapman et al. 1995a).

In the Mid-Columbia Region, stream-type chinook salmon exhibit a much more diverse manifestation of life history strategies than ocean-type salmonids, which is probably related to their extended freshwater residence. While the percentage of fish employing any particular strategy now or historically has not been determined, it is highly likely that the percentage shifted in response to varying environmental conditions (Stearns 1989). For example, juvenile fish that may have been inclined to overwinter in an upper tributary might instead migrate to the lower mainstem or nearby side channels and tributaries during a particularly cold winter (Bustard and Narver 1975; Beschta et al. 1987).

All stream-type chinook salmon discussed in this document are within the Upper Columbia River Spring Chinook Salmon GDU (Marshall et al. 1995). The White River population (a tributary to the Wenatchee River) has relatively distinctive allele frequencies among the stocks within this GDU. Also included in this GDU are the fish propagated at Leavenworth, Entiat, and Winthrop NFH, which was partially derived from Carson NFH, a nonlocal stock (MCHWG 1998).

Sockeye salmon

The life history of sockeye salmon is perhaps the most complex of any Pacific salmon. Although they share the same general life cycle as chinook salmon, multiple forms of the species are common and play important roles in its long-term survival (Burgner 1991). Kokanee, a resident form of sockeye salmon, occasionally migrate to sea and return as adults, however there is limited evidence that these fish contribute substantially to sockeye production (SRSRT 1994). A third form known as residual sockeye often occur together with sockeye salmon. Residuals are thought to be progenies of sockeye salmon, but are generally nonanadromous themselves. The distribution of sockeye salmon in the Mid-Columbia Region is limited to lakes Wenatchee and Osoyoos, in the Wenatchee and Okanogan watersheds, respectively. Limited numbers of adults and juveniles are periodically detected however, in the Methow and Entiat rivers (Carie 1996), Icicle Creek[1], and in isolated areas of the mid-Columbia River (Chapman et al. 1995b). Despite the considerable mixing of the Wenatchee and Okanogan sockeye salmon stocks during the Grand Coulee Fish Maintenance Project (Fish and Hanavan 1943), the two populations have a high level of distinction in allele frequencies (Winans et al.1996; BRT 1996).

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1 *Cates, U. S. Fish and Wildlife Service, Leavenworth, Washington.*

Steelhead

In general, steelhead adults migrate into the mid-Columbia River tributaries in both fall and spring after spending one to three years in the ocean (Wydoski and Whitney 1979). Spawning occurs primarily in late March, but may extend much later. Their eggs incubate from late March through June, and fry emerge in late spring to August. Fry and smolts disperse downstream in late summer and fall. Their use of tributaries for rearing is variable, depending upon population size, and both weather and flow conditions at any given time. Smolts typically leave Wenatchee River in March to early June, after spending one to seven years in freshwater, but most leave after two to three years (Peven et al. 1994). Some steelhead live their entire lives in fresh water. Historically, some steelhead spawned repeatedly over several years (making repeated migrations to and from the ocean), but this strategy was reduced by passage barriers on the mainstem Columbia River.

As a result of their varied length of fresh water residence, their variable ocean residence, and their spatial and temporal spawning distribution within a watershed, steelhead exhibit an extremely complex mosaic of life history types (Withler 1966, Peven et al. 1994). Such life history diversity is an effective strategy for ensuring the long-term viability of a population (Randall et al. 1987; Thorpe 1987). Conversely it also limits the population's ability to exploit favorably anomalous conditions (Reice et al. 1990). The status of mid-Columbia steelhead indicate that habitat degradation in the region is pervasive Moreover, spawner/ recruitment curves constructed by Mullan et al. (1992: H-295) indicate that factors outside these watersheds (primarily mainstem passage mortalities) have significant impacts to wild steelhead.

NMFS considers steelhead *O. mykiss* in the mid-Columbia River upstream of the Yakima River confluence to be one ESU, and warrant protection under the ESA (61 F.R. 960730210-6210-01). This ESU includes steelhead spawning in the Wenatchee, Entiat, Methow, and Okanogan watersheds, and smaller tributaries to the mid-Columbia River. Only anadromous forms of steelhead are listed due to uncertainties regarding the status of resident forms of *O. mykiss*, and their relation to the anadromous form. Steelhead produced from Wells FH are listed because NMFS considered them essential to the recovery of natural populations.

Rainbow trout is an inland (remains in freshwater) form of steelhead. Some rainbow remain in freshwater for most of their life but undergo a physiological change to a smolt and migrate to the ocean late in life. Inland rainbow and juvenile steelhead are not distinguishable from each other until the steelhead undergo smoltification. The mid-Columbia tributaries contain a mixture of full time resident rainbow and ocean migrating steelhead. The ability of *O. mykiss* to alternate life history strategies is an adaptive mechanism to variable environmental conditions.

Coho salmon

Coho salmon are considered extinct in the Mid-Columbia Region (Nehlsen et al. 1991). Mullan (1984) estimated the historical run size at 38,000 to 51,000 adults to the Wenatchee, Entiat, and Methow rivers. Spawning distribution was probably similar to that of steelhead. Adults probably ascended the tributaries in the late fall and spawned between late November and late December, although there is historical evidence of an earlier run of coho salmon (Mullan 1984). As cold water temperatures at that time of year probably preclude spawning in some areas, it is likely that coho salmon spawned in areas where warmer ground water up welled through the substrate. Juvenile coho salmon generally distribute themselves downstream shortly after emergence and seek out suitable low gradient tributary and off-channel habitats (Peterson 1982; Brown and Hartman 1988). Coho salmon prefer slower velocity rearing areas than chinook salmon or steelhead. They tend to overwinter in riverine ponds (Peterson 1982) and other off-channel habitats (Mason and Chapman 1965). Based on information on coho salmon habitat use in other streams, we presume that they employed the same six life history strategies as those listed for stream-type chinook salmon (for example, see Section 2.1.2). Classification of the potential for re-establishment of coho salmon is problematic. Certainly, habitat may be made available to outplanted juveniles, but it is not known whether the donor population would be adapted to re-establish naturally, and is therefore classified as *Category IV* (Section 1.2).

1.2.3: Inland fish

Bull trout

Four general forms of bull trout are recognized (anadromous, lacustrine, fluvial, and resident), each exhibiting a specific behavioral or life history strategy (Brown 1992; Pratt 1992). Bull trout are anadromous in coastal and Puget Sound river drainages (Leary and Allendorf 1991; Haas and McPhail 1991), yet are extinct in the Mid-Columbia Region (Nehlsen et al. 1991; *Category IV*). The lacustrine (adfluvial) form matures in lakes or reservoirs and spawns in tributaries where the young reside for one to three years (Fraley and Shepard 1989; Holton 1990; *Categories II and III*). Fluvial bull trout have a similar life history except that they move between mainstem rivers and smaller tributaries (*Categories II, and III*). Individuals of these three forms often make extensive migrations, are iteroparous, usually do not attain sexual maturity until ages five or six, and can reach sizes of 10 kg (Fraley and Shepard 1989; Holton 1990). The lacustrine and fluvial bull trout are of the most concern in the Mid-Columbia River tributaries (Brown 1992), as their habitat has been degraded more than that for resident forms. The stream resident bull trout spend their entire lives in smaller, high elevation streams, apparently moving very little, and seldom reaching a size larger than 30 cm (Brown 1994; *Category II*). It is likely that resident trout may have extensive seasonal movements (Young and Schmal 1994). It is also likely that bull trout change life history strategies (from resident to lacustrine) depending upon the current environmental conditions (Rieman and McIntyre 1993). This phenomenon may occur commonly for populations near Lake Wenatchee, where resident bull trout may migrate to the lake when stream flows (and attendant water temperatures) become intolerable. Habitat alterations that disrupt this capability to transmute may limit the population's stability (Scudder 1989).

The USFWS confirmed on 13 March 1997 that the Columbia River bull trout "population segment" warranted listing under the ESA. Critical habitat for bull trout will be designated by USFWS, after needed information is gathered to identify the appropriate critical areas. Juvenile bull trout, particularly young of the year, have specific habitat requirements (Goetz 1989; Rieman and McIntyre 1992). Small bull trout (less than 100 mm) are primarily bottom dwellers, often in shallow, slow backwater side channels. Adult and large juvenile bull trout are associated with deep pools, undercut banks, and debris jams (Shepard et al. 1984). They are strongly associated with woody debris at all life stages (Goetz 1989).

Westslope cutthroat trout

Westslope cutthroat trout are allopatric with rainbow trout, and have similar life histories. They are chiefly distributed in upper reaches of east slope Cascade Range, including the Wenatchee and Entiat rivers. Their status in Methow River is not fully known, although Behnke (1992) noted they were present in 19 of 27 streams sampled in that watershed. Many of these cutthroat trout showed some degree of hybridization with rainbow trout. Westslope cutthroat trout exhibit adfluvial and fluvial life history strategies (Andrusak and Northcote 1971; Averett and MacPhee 1971);

some may travel up to 150 km within a river system (Bjornn and Mallet 1964). Their habitat requirements are similar to that of both rainbow trout and bull trout (Behnke 1992), yet they may extend into colder habitats. Cutthroat and rainbow trout spawn at the same time and place, and considerable hybridization results when hatchery-produced rainbow trout are stocked in streams with natural cutthroat trout (Simpson and Wallace 1982). Similar to bull trout, cutthroat trout are highly susceptible to angling pressure (Behnke 1992).

1.2.4: Other species of interest

Pacific lamprey

Pacific lamprey is found in most coastal rivers of Washington State and inland in most tributaries to the Columbia River. Little specific information is known, however, on the life history or status of lamprey in the specific watersheds. In general, the adults are parasitic on fish in Pacific Ocean while the ammocoetes (larvae) are filter feeders that inhabit the fine silt deposits in backwaters and quiet eddies of streams (Wydoski and Whitney 1979). Adults enter the freshwater in late spring and early summer to spawn. Spawning occurs during June and July in nests formed as depressions in the small gravel of riffles. Adults die after spawning. Juveniles migrate from their parent stream to the ocean from March to July, with a peak in April. It is not known how long Pacific lamprey live in freshwater prior to migration, but it is assumed to be five to six years (Wydoski and Whitney 1979).

Mountain whitefish

The status of mountain whitefish is unknown. It is assumed to be in all small order tributaries to the Wenatchee, Entiat, Methow, and Okanogan rivers, and in larger lentic systems, primarily Lake Wenatchee. In streams they are mostly in riffles in summer, but prefer large pools in winter (Wydoski and Whitney 1979). Spawning usually occurs from October through December; generally in riffles, but also on gravel shoals of lake shores. Mountain whitefish feed primarily on instar forms of benthic aquatic insects. They also occasionally eat crayfish, fresh water shrimp, leeches, fish eggs, and small fish. In lakes, they feed extensively on zooplankton, particularly cladocerans. There is evidence that mountain whitefish historically spawned in lower reaches of some tributaries, but the mainstem hydroelectric dams inundated these habitats[2].

Pygmy whitefish

Pygmy whitefish is found in relic populations in western North America, and primarily in Columbia River (Wydoski and Whitney 1979). It inhabits lakes, typically staying deeper than 6 m. It resides in streams also, preferring habitats with moderate to swift current. Little is known about the pygmy whitefish; WDFW began surveys in Lake Wenatchee in 1996 to determine their status.

1.3: Geographic Scope

For a number of reasons, it is useful to look at each watershed (WRIA), in terms of its subwatersheds and WAU (Table 1)--both the number and drainage pattern of each. As its name suggests, each WAU should be managed as a unit, based upon geomorphic characteristics, drainages, timber or crop management. There is a direct relationship between the number of WAUs and the ease of constructing a habitat protection and restoration plan for that given watershed--the more units, the more complex the system is. If information was available, this report describes the salient features of each subwatershed within the major watersheds. Although not discussed in this assessment, Chelan River (WRIA 47), from the dam to the Columbia River confluence, and numerous streams which flow into the mainstem Columbia River (Crab, Red Rock, Sand Hollow, and Trinidad creeks) are suitable for habitat protection and restoration.

2 *Williams, Washington Department of Fish and Wildlife, Brewster, Washington.*

Table 1. Total area, Water Resource Inventory Area (WRIA) designation, number of subwatersheds, and Watershed Administrative Units (WAUs) for the major tributaries to the Mid-Columbia River.

Watershed	WRIA	Area (ha)	Subwatersheds	WAUs
Wenatchee	45	343,900	6	21
Entiat	46	108,500	2	6
Methow	48	464,100	5	16
Okanogan	49	647,500[a]	5	32

[a] *The area and number of units for the Okanogan are only for that part of the watershed in the United States. Triple that to get the total watershed area --2,123,800 ha.*

This assessment of the streams is broken into categories, which roughly follow that format used by the Washington Forest Practices Board (WFPB 1991) for watershed assessments. This format is revised somewhat to better fit the conditions seen in mid-Columbia streams, but in general, these categories are standard and all-inclusive: 1) mass wasting/surface erosion, 2) riparian and instream habitat, 3) stream channel, 4) water quality, and 5) water quantity.

1.4: River Processes

The basic components of a stream system are the stream channel and its floodplain. Floodplains are areas frequently covered by water when streams overflow their banks. Stream channels erode and meander across the floodplain as they flow downstream, with channel bends reducing the amount of energy and velocity of flowing water as they erode (Leopold 1994). The degree of meander can vary from almost straight with little erosion, to braided with numerous mid-channel bars and split channels.

Stream channels naturally change from year to year. Changes in flow and energy are compensated by bedload adjustments (sediment and gravel on the streambed). Most channels develop a balance between these factors. In an undisturbed, natural stream, the bedload becomes distributed between source (or transport) areas and deposit areas. A typical stream degrades (erodes) in the headwaters or upper elevation reaches due to its steeper slope and higher energy, aggrades (deposits) in areas of reduced slope and excess bedload, and meanders through transitional areas. During floods, a stream may both degrade and aggrade within the same stream reach. Aggradation and/or degradation may be influenced by local conditions such as large woody debris accumulations, bridge crossings, dikes, and channelized stream sections.

Stream channel function

The way a stream channel develops is governed by the laws of physics through observable stream channel features and related fluvial processes. The shape and actions of a stream are directly influenced by eight major variables: channel width, depth, slope, roughness of channel materials, sediment load, sediment size, water velocity, and discharge (Leopold et al. 1964). A change in any one of these variables sets up a series of channel adjustments which lead to a change in the others, resulting in channel pattern alteration. Numerous studies have demonstrated that the natural process of a river is to form a meandering channel (Inglis 1947; Leopold and Langbein 1966; Yang 1971).

Floodplain function

In a natural landscape, floodplains temporarily store flood waters during high runoff, reducing flood levels, rates of erosion, and water velocities. Floodplains store excess sediments. Those functions of floodplains can be impaired when a stream channel is cut off from its floodplain by rip rap or a bulkhead, or when the floodplain's characteristics are changed by removal of riparian vegetation. When a river is cut off from its floodplain and confined to a single channel, it flows more quickly. As its velocity increases, the water gains power and can increase bank erosion, streambed scouring, and damage to structures.

Floodplain characteristics also affect the river's behavior during floods. Riparian vegetation helps slow the water, allowing it to soak into the ground or move gradually back to the channel. Plant roots help control erosion by binding the soil. When this riparian vegetation is removed, water runs off more quickly, often taking valuable topsoil with it. Floodplains also help maintain water quality by filtering surface water runoff before it reaches the river. Natural floodplains help keep groundwater levels high.

Periodic flooding is critical for maintaining a river's floodplain ecological integrity and biological productivity (Rasmussen 1996). This important relationship has been well documented (Junk et al. 1989; Bailey 1991; NRC 1992; Bellrose et al. 1979). Natural hydrographs of most large floodplain rivers typically experience a spring rise in response to either high elevation snowmelt or seasonal rains. Native aquatic species evolved under these conditions and key critical life stages (spawning and migration) to coincide with high water events (NRC 1992). Waterfowl rely on spring rises to inundate feeding habitats encountered en route to summer nesting grounds (Bellrose et al. 1979). Floodplain pools, side channels, and sloughs, left behind when spring waters recede, provide important fish rearing areas. Many of these habitats have been eliminated or degraded.

Some watershed land use practices and flood control projects have increased the speed and volume of runoff in most east Cascade watersheds, leading to narrower (shorter duration), higher peaks in annual hydrographs (Bailey 1991). This phenomenon is most prevalent on the lower Entiat River. Levees along these rivers have all but eliminated connectivity between rivers and the remaining off-channel waters. These habitat areas functioned historically as water retention and nutrient spiralizing mechanisms (Bailey 1991; NRC 1992; Leopold et al. 1964). These backwaters and sloughs that remain are, in many instances, no longer able to exchange waters with the main river channel and are thus unable to function in their natural nutrient-spiraling mode (Rasmussen 1996). Instead, nutrients are simply flushed out of the system and downstream by swiftly flowing currents in the channelized river. River stages at high flows have increased through constriction of the channel because of levees and rip-rap dikes placed at the river bank. The uniform, trough-like nature of the channelized river eliminates areas where aquatic organisms can seek refuge from the swift current to attach, feed, and spawn (NRC 1992). All of these factors decrease productivity and species diversity, which are reflected in diminished populations of many native fish species (Brinson et al. 1981; Johnson 1992). In some situations, salmonid density and biomass adjacent to cover provided by rip rap can be higher than areas where no hiding cover is available. However, rip rap is not an adequate substitute for a properly functioning stream or a substitute for natural habitat complexity. The value of rip rap as habitat depends upon the material used, and how it is placed in the stream channel.

Upland function

The physical environment of streams in which fish live is intimately dependent upon the condition of terrestrial vegetative cover, soil mantle, and past history of land treatment (Platts and Rhinne 1985). After timber removal, more precipitation reaches the ground, and the soil mantle, where infiltration capacity has been reduced by logging, yields runoff sooner and faster (Chapman 1961). The complex relationships among infiltration capacity, compaction and retention capacity, transpiration and precipitation make it difficult to predict the effects of logging on stream flows and sedimentation in a certain area. Increased peak flows typically result in a higher rate of gravel movement in the streams, which may then cause scouring of redds, loss of LWD from the active channel, simplified channel configuration, and removal of benthic algae and invertebrates. Summer and winter stream temperature regimes following logging depend largely upon how riparian vegetation is managed during logging (Platts and Rhinne 1985).

Logging roads are also important sources of increased runoff contributing to higher peak flows (Waters 1995). There is some evidence that logging roads are greater sources of sediment than the actual process of timber harvest (Hoover 1952; Waters 1995). A high sediment load increases the proportion of fines present in the stream substrate, and if sufficiently severe, tend to fill the gravel interstices reducing incubation survival, hiding cover for emergent salmonids, and invertebrate production (Bjornn et al. 1977).

Stream system alterations

It is vitally important that natural stream hydrology and configurations be maintained wherever possible. Channelization, straightening, or altering a stream channel so the natural meander is removed generally results in bed scour, increased bedload movement, and both upstream and downstream bank erosion (Platts and Rhinne 1985; Leopold 1994). Although flood control projects can adversely affect aquatic habitat, careful consideration of habitat features and values during project design and construction can minimize these effects (NRC 1992). The desire to artificially alter instream fish habitat has resulted from a variety of reasons. In many instances, stream habitat degradation has proceeded to the point where one or more limiting factors, such as high water temperatures, excess sediment, lack of pools, insufficient cover have contributed to declines in fish populations.

When physical structures are installed in channels to improve fish habitat, the adjustment processes that occur sometimes create more damage than habitat (Hall and Baker 1982; Platts and Nelson 1985; Beschta and Platts 1986; Beschta et al. 1992; NRC 1992; Kauffman et al. 1993; Elmore and Kauffman 1994). Artificial stream restoration cannot be achieved via simple and artificial manipulations of selected components (NRC 1992). For example, habitat deficiencies associated with a low number of pools in a stream cannot be simply satisfied by digging more pools. Instead, the functional attributes of the entire system need to be re-established along with the appropriate physical, chemical, and biological processes (Beschta et al. 1992; Kauffman et al. 1993). Thus, habitat restoration is a holistic process not achieved through the isolated manipulation of individual elements (NRC 1992). In other words, artificial structures are not a suitable alternative or mitigating factor to land use practices which degrade riparian systems (Platts and Rhinne 1985). If inappropriate land use practices are disrupting this natural process, elimination of these practices is clearly the first and most important step in stream restoration.

1.5: Habitat Requirements of Riparian and Aquatic Species

Habitat needs of anadromous salmonids in the mid-Columbia River tributaries vary with season of the year and the stage of their life cycle. Upstream migration of adults, spawning, incubation of the eggs, juvenile rearing, and seaward migration of smolts are the major life stages for most anadromous salmonids. Insofar as possible, we have defined the range of habitat conditions for each life stage that will allow a population to sustain itself.

Upstream migration and spawning of adults

Adult salmonids returning to their natal stream must arrive at the proper time and in good health if spawning is to be successful. Unfavorable flow, temperature, turbidity, or water quality could delay or prevent fish from completing their migration. Manmade barriers such as impassible drops, improperly installed culverts, diversion dams, impoundments, and excessive velocities may also impede migrating fish.

Hiding and resting cover, clean substrate of appropriate size and composition, and water quality and quantity are important habitat requirements for anadromous salmonids before and during spawning. Cover for fish can be provided by overhanging vegetation, undercut banks, submerged vegetation, floating debris, and water depth and turbulence. Some anadromous fish--chinook salmon and steelhead for example--enter the tributaries months before they spawn, so cover is essential for them during this holding period. The suitability of a particular size gravel substrate for spawning depends mostly on fish size, and all require gravels relatively free of silt. Many salmonids prefer to spawn at the pool-riffle interchange. Streamflow regulates the amount of spawning area available. As flows increase, more gravel is covered and may become suitable for spawning. However, excessive water velocities may create unsuitable habitat conditions. The standard ranges of water temperature, depth, and velocity criteria for successful migration and spawning of those salmonids found in the Mid-Columbia Region are in Table 2.

Table 2. Water depth, velocity, temperature, and substrate size criteria for upstream migration and spawning of anadromous salmonids (adapted from Bjornn and Reiser 1991).

Species	Migration velocity (m/s)	Spawning velocity (cm/s)	Substrate size (cm)	Temperature (°C)	Depth (cm)
Chinook salmon	<2.44	30 - 109	1.3 - 10.2	5.6 - 13.9	>24
Sockeye salmon	<2.13	21 - 101	1.3 - 10.2	10.6 - 12.2	>18
Coho salmon	<2.44	30 - 90	1.3 - 10.2	4.4 - 9.4	>18
Steelhead	<2.44	40 - 91	0.6 - 10.2	3.9 - 9.4	>18
Trout and char	<1.22	11 - 91	0.6 - 5.2	2.2 - 20.0	>12

Incubation

Habitat requirements of salmonid embryos during incubation are different from, and less tolerant than, those of the spawning adults (Table 3). Successful incubation and emergence of fry is dependent upon conditions both inside and outside the gravels. Perhaps the most important criteria are those inside the gravel environment: permeability, porosity and apparent velocity in the gravel, dissolved oxygen, biochemical oxygen demand of material in the water and substrate, substrate size, and the percentage of fines in the substrate all affect incubation success, and, are affected by those factors outside the gravels. Factors which are outside the incubation gravels that play an important part are: channel gradient and configuration, water depth, surface water temperature, flow and velocity.

Table 3. General habitat needs for incubation of salmonid embryos (adapted from Bjornn and Reiser 1991).

Parameter	Recommended limit[1]
Dissolved oxygen	At or near saturation: lower threshold of 5.0 mg/l.
Water temperature	Threshold levels of 4°C to 14°C.
Permeability	More than 300 cm/h.
Sediment composition	Less than 20% by volume of fines smaller than 6.4 mm, and less than 12% by volume of fines smaller than 0.85 mm.
Surface flow	Sufficient to allow fry to emerge.
Surface velocity	Less than those which scour the redds and displace redd gravels.
Apparent velocity	More than 20 cm/h.

[1] *These data reflect general values in which salmonids can successfully incubate: Washington State and federal standards may differ from these values.*

Juvenile rearing

Habitat requirements of juvenile salmonids in the mid-Columbia tributaries vary with species, size, and time of year. Rearing period extends from fry emergence to seaward migration and can range from a few months for ocean-type chinook salmon to 3 or 4 years for steelhead (Peven et al. 1994). For fish that spend extensive time in the river, the quantity and quality of the habitat limits the number of fish that are produced. Important habitat components for juvenile salmon and trout are food production areas, water quality and quantity, cover, and space. Food for these salmonids comes primarily from insects produced in the surrounding riparian areas and from the substrate within the stream. The relative importance of terrestrial and aquatic insects varies with stream size, location, riparian vegetation, and time of year. In turn, these insects have specific habitat needs--depth: 0.46 - 0.91 m, velocity: 0.46 - 1.07 m/s, and substrate composed of coarse gravel and rubble (Bjornn and Reiser 1991).

Cover is perhaps more important to anadromous salmonids during rearing than at any other time, for this is when they are most susceptible to predation from other fish and terrestrial animals. Overhead cover--riparian vegetation, turbulent water, logs, or undercut banks--is used by most salmonids (Chapman and Bjornn 1969). Submerged cover--deep pools, large rocks in the substrate, aquatic vegetation, logs, and woody debris jams-- is also used by rearing salmonids, particularly in winter, when fish enter torpor (Everest and Chapman 1972).

Streamflow needs for juvenile salmonids are those which provide space and cover: adequate depth over riffles with velocities of 0.3 to 0.5 m/s, an areal riffle/pool ratio near 50/50, pool velocities of 0.1 to 0.2 m/s, and 60%of riffle area covered by flow (Bjornn and Reiser 1991). These values represent general preference ranges; seasonal differences in juvenile fish size and the physical characteristics of individual streams must be considered when determining habitat parameters (Sheppard and Johnson 1985). Changes in streamflow influence velocities and areas of riffles more than pools.

In summary, good rearing habitat for juvenile salmonids consists of a mixture of pools and riffles, adequate cover, water temperatures that average between 10ºC and 15ºC during the summer, dissolved oxygen usually at saturation, suspended sediment less than 25 mg/l, and riffles with less than 12% fine (<0.85 mm) sediment. Salmonids need diverse habitats that allow them to express a range of life histories as a means to adjust to changing environmental conditions.

There is substantial evidence (Bugert and Bjornn 1991, Bugert et al. 1991; Chapman and Knudsen 1980; Bisson and Sedell 1984; House and Boehne 1986; Heifetz et al. 1986; Lisle 1986; Bilby and Bisson 1987) that complex riverine environments have higher fish densities, more diverse biotic assemblages, and lower rates of emigration than relatively simple stream channels. Over the last century, flood control practices, as well as land and water uses, have resulted in a reduction in this aquatic habitat complexity. This has resulted in the reduced natural production capacity of waters where salmon have historically spawned and reared (Lichatowich 1989; Thomas et al. 1993; Moyle and Yoshiyama 1994). The way a stream is altered (streambanks armored with rip-rap, removal of riparian and instream cover, reduction in floodplain function, and stream channel alignment) has direct adverse effects upon its biological productivity.

1.6: Recommended Approach to Increase Aquatic Productivity and Diversity

The following recommendations are based upon a biological assessment of the habitat needs and life histories of aquatic species in the tributaries to the mid-Columbia River, although we discounted certain recommendations that we deemed unfeasible. We expect the relative priorities of these recommendations may be modified when feasibility considerations are made. Many of these measures require participation from private land managers, irrigation districts, and public entities.

1.6.1: General Strategy

Our recommendations to increase biological productivity and diversity follow a triage approach in which Habitat Protection is the top priority, particularly for life history types that are extant and performing well (*Category I*), Habitat Restoration is focused on existing but poorly performing or extinct phenotypes that would re-establish readily following treatment (*Categories II and III*), and little or no effort is targeted at more problematic extinct life histories (*Category IV*) until the needs of the first three categories are satisfied. Hatchery outplants should be used as an ancillary tool to augment biological diversity, and will target *Categories II and III*.

Habitat conservation measures in the tributaries should contain both Protection and Restoration elements. Examples of protection measures would be cooperative agreements with, or easements and purchases from, willing landowners of important habitat. Examples of restoration measures would include, but not be limited to:

1) to open fish passage to blocked stream sections or oxbows,
2) to change the points of origin for problematic irrigation withdrawals to less sensitive site(s),
3) to purchase, on a willing buyer/seller concept, water shares for the Trust Water Rights Program,
4) to provide alternative sources of irrigation and domestic water to mitigate impacts of problematic surface water diversions,
5) to remove dams or other passage barriers on the tributaries,
6) to use mechanical means to encourage natural development of riparian areas, and
7) to use engineering techniques which increase complexity of permanently altered habitats.

These actions are based on a fundamental emphasis on protecting and promoting habitat diversity throughout the watershed. Specific recommendations for each watershed are provided in the individual watershed assessments.

The simple alteration of physical features in the stream channel does not necessarily restore biological productivity when riparian management practices continue to exert their effects on the aquatic ecosystem. Attempts to restore habitat will fail if we place structures in the stream channel without addressing those activities that are causing habitat degradation. For example, some *short-term* habitat benefits might be achieved by adding LWD to streams, but the benefits can only be temporary from an ecological perspective unless riparian management practices ensure the *long-term* recruitment of LWD from the riparian zone. Some restoration projects may be best suited with both short-term and long-term objectives. For example, LWD may be secured (with cable for example) to stabilize erosive banks, allowing interim streambank protection and salmonid hiding cover, while passive restoration and revegetation will ensure proper functioning riparian conditions for the long term.

Some general watershed management initiatives have less tangible benefits, but would invariably improve the aquatic/riparian/wetland/ecosystems of the Mid-Columbia Region. Examples of these efforts are: (1) to support a *Chelan Agreement* style water planning process to explore options for resolving competing instream and out-of-stream uses; and (2) the use of matching funds to accomplish protection and restoration projects.

1.6.2: Habitat Protection

The highest priority for maintaining biological productivity will be to allow unrestricted stream channel diversity and flood plain function. The principle means to meet this objective is to secure riparian habitat--anywhere in the watershed--either in conservation agreements, easements, or direct purchases from willing landowners. Predetermined riparian protection measures (i.e., buffer strip widths) for each site should not be used. Riparian buffer widths should be determined based on site-specific considerations including channel type, floodplain character, presence of wetlands or off-channel features, and the potential for channel migration. These site-specific conditions and landscape-level considerations can provide landowners with some management flexibility. A field-based process should be used to establish protected areas, but a minimum performance standard will be to maintain channel/floodplain interaction and function. The size, configuration, and composition of the protected area will be negotiated between the willing landowner and the fish managers. The fish managers will attempt to accommodate the landowner's management objectives, but will not participate in projects that do not provide adequate fish habitat benefits. Obviously, some areas have more acute needs, because of their importance for existing life history strategies, and should be given greater emphasis.

1.6.3: Habitat Restoration

A range of strategies is recommended for habitat restoration in the mid-Columbia tributaries. Like the *Habitat Protection* strategy, most strategies center on efforts to maintain or increase the complexity of the stream channel and floodplain. Most of these efforts are on lower reaches and aggradation zones, and would benefit both ocean-type and stream-type salmonids. Recommended strategies in this section proceed along two major pathways: *Passive Restoration* and *Active Restoration* (Kauffman et al. 1993). In *Passive Restoration*, amelioration of the deleterious management practice is all that is necessary. *Active Restoration* would eliminate the activities that are causing degradation, yet also require mechanical actions to accelerate natural recovery.

1.6.4: Hatchery Production

Hatchery outplants should be used in conjunction with watershed restoration, if they can be done in a manner that is consistent with the supplementation concept (Cuenco et al. 1993) and the basic philosophy for mid-Columbia River hatchery management (MCHWG 1998). At a minimum, these supplementation programs would incorporate the following strategies: (1) use local (or most appropriate) broodstock, (2) promote natural spawning of hatchery-reared salmon, (3) acclimate smolts on surface waters proximal to areas to be seeded, and (4) avoid potential for impacts to natural production. The authors believe that carefully considered outplants of native (or otherwise appropriate) anadromous salmonids at selected life stages into off-channel and tributary habitats would substantially increase natural productivity. Moreover, hatchery outplants can be an effective strategy in developing partnerships with local land owners and managers (Rottier and Redell 1993; Budhabhatti and Maughan 1994). However, there is sufficient evidence from preliminary evaluations of supplementation programs (Mendel et al. 1993; Busack and Currens 1995) for the authors to recommend a cautious, limited strategy for increased hatchery production.

Hatchery outplants must be based upon the premise of increasing biological diversity in the watershed, rather than productivity. In general, we recommend that all facilities and infrastructure for additional supplementation should be highly flexible and responsive to changes. They should not necessarily operate every year. Adaptive management and research should be integral to the guiding principles for these programs.

THE WENATCHEE WATERSHED

SECTION 2: ASSESSMENT OF AQUATIC SPECIES IN THE WENATCHEE WATERSHED

2.1: Commercially and Culturally Important Fish Species

The Wenatchee River supports several populations of economically and culturally important fish species. The watershed currently supports anadromous runs of chinook salmon, sockeye salmon, and steelhead. Coho salmon were once present in the Wenatchee Watershed (Mullan et al. 1992), but are now considered extinct (Nehlsen et al. 1991). Important inland species include mountain whitefish, kokanee (landlocked sockeye), bull trout, rainbow trout (a resident form of steelhead), and Westslope cutthroat trout. A discussion of three major evolutionary life history strategies (ocean-type, stream-type, and inland) of Wenatchee River fish populations are provided below.

2.1.1: Ocean-type anadromous salmonids

Ocean-type chinook salmon return to the Wenatchee River primarily in July and August, but may enter the river into early October. They spawn in the mainstem Wenatchee River from the outlet of Lake Wenatchee downstream to its confluence with the Columbia River (87 km). Spawning begins in late September upstream from Leavenworth, and ends in early November in the lower river (Peven and Truscott 1995). Juveniles generally emigrate to the ocean as subyearling fry, leaving the Wenatchee River from one to four months after emerging from the gravel in April. Ocean-type salmonids are most dependent on habitat in the mainstem Wenatchee downstream of Plain. From 1960-1994, the average escapement of ocean-type chinook salmon was 8,826 (based on differences in adult and jack counts at Rock Island and Rocky Reach dams), with a range from 3,394 to 13,625. To minimize redundancy with the stream-type chinook section, only two general life history types are presented here, which express the presumed historical life history strategies for ocean-type anadromous fish: 1) spawn in the upper mainstem (Tumwater Canyon and upstream) and leave the system in summer and fall as subyearlings, and 2) spawn in the lower mainstem and leave the system in summer and fall as subyearlings. Both these phenotypes would be classified as *Category I*. We presume that some cohorts also rear in the mainstem, Lake Wenatchee, or tributaries through winter when conditions are favorable to this strategy (*Categories I and II*).

2.1.2: Stream-type anadromous salmonids

Spring chinook salmon

Stream-type chinook salmon (often referred to as “spring run") return to the Wenatchee River from late April through June. The primary spawning areas are the Chiwawa River between Grouse and Phelps Creeks, Nason Creek between Kahler and Whitepine Creeks, the Little Wenatchee River between RK 1 and 11, the White River between Sears Creek and White River Falls, and the mainstem Wenatchee River between Chiwaukum Creek and Lake Wenatchee (Peven and Truscott 1995). Spawning is observed annually in Icicle Creek as well, but it is likely that most of the fish that spawn here are of hatchery origin (WDF et al. 1993). A limited amount of spawning has also been reported in Peshastin, Chumstick, and Mission creeks (WNF 1994), and are classified as *Categories II and III*. Spawning begins in early August in the upstream reaches of the tributaries, and continues downstream through September. The average estimated natural escapement to the Wenatchee River (based upon redd count expansions) is 2,929 for the period 1960-1969, 2,354 for the period 1970-1979, 1,838 for the period 1980-1989, and 509 for the period 1990-1995[3]. 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.

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[3] *LaVoy, Washington Department of Fish and Wildlife, Wenatchee, WA.*

The peak of spring migration is late April through May, but downstream movement from the tributaries may be continuous, and not always associated with parr/smolt transformation (Petersen et al. 1995).

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

a. Spawn, rear, overwinter in upper reach tributaries --above Tumwater Canyon *(Categories I and II)*.
b. Spawn, rear, overwinter in lower reach tributaries--below Tumwater Canyon (*Category III*).
c. Spawn, rear in tributaries; overwinter in upper mainstem Wenatchee (*Category I*).
d. Spawn in tributaries, rear and overwinter in Lake Wenatchee *(Categories I and II)*.
e. Spawn, rear, overwinter in mainstem Wenatchee above Tumwater (*Category I)*.
f. Spawn, rear, overwinter in mainstem Wenatchee below Tumwater (*Categories II and III)*.
g. Spawn in tributaries or mainstem Wenatchee, rear or overwinter in accessible side channels (*Category III)*.
h. Spawn, rear in upper tributaries, overwinter in lower tributaries (*Category III*).
i. Spawn, rear in lower tributaries, overwinter in lower mainstem (*Category III*).
j. Spawn, rear in upper reach tributaries, outmigrate in fall/winter (*Categories I and II*)
k. Spawn, rear in lower reach tributaries, outmigrate in fall/winter (*Category III*).

Sockeye salmon

Although not generally referred to as such, sockeye salmon are "stream-type" in the sense that they reside in freshwater (nursery lake) for more than a year. The principle spawning areas for Wenatchee River sockeye salmon are RK 0 to 8 on the Little Wenatchee River, from RK 9 to 15 on the White River, and from RK 0 to 2 on the Nepeequa River (WDF et al. 1993). Sockeye salmon are known to spawn on shoals and in shallow water areas in their nursery lakes (Burger 1991). We have not verified this in Lake Wenatchee but some fish may spawn along the shoreline at the upper end of Lake Wenatchee (*Category II*). As such, sockeye are vulnerable to bulkhead construction because of mechanical damage to redds, altered gravel composition, and reduced nutrient input. Unauthorized filling and disruption of springs and groundwater seeps, and removal of riparian vegetation also would affect these spawners, and decrease fry production. Spawning occurs from mid-September to mid-October. Juveniles move downstream from the rivers to Lake Wenatchee immediately after they emerge from the gravel (March through May). Most of the juveniles (about 82%) spend one year in Lake Wenatchee (Shaklee et al. 1996; *Category I*), yet some spend two years in the lake prior to emigration (*Category I*). A small percentage of sockeye salmon remain in Lake Wenatchee their entire life as kokanee (*Category II*). Historical life history strategies follow that of spring chinook salmon, with the notable addition of residency by kokanee, which would follow an adfluvial strategy (Section 2.1.4). Wenatchee sockeye salmon is the most robust GDU in the mid-Columbia River (Shaklee et al. 1996), and are electrophoretically and demographically distinctive. This population is entirely dependent however, upon relatively small reaches within the White and Little Wenatchee rivers for spawning, incubation, and initial rearing.

Steelhead

Steelhead use the mainstem Wenatchee River and eight of its tributaries: lower Mission Creek, Sand, Brender, Peshastin, Chumstick, Icicle, Chiwaukum, and Nason creeks, and the Chiwawa, Little Wenatchee, and White rivers. Some fry and parr rear in the mainstem Wenatchee all year. Listing all of the possible steelhead life history types will not be attempted here. They probably exhibit all of the types listed for stream-type chinook salmon, compounded by variable fresh water residence, and penetrate deeper into most of the tributaries than stream-type chinook salmon do.

Categorization of steelhead robustness can be better done by analysis of their distribution, rather than phenotypic diversity (Table 4). Those individuals using upper reaches of tributary habitats (Peshastin and Mission Creeks, for example) have probably been more heavily impacted by forest practices, improper grazing practices, stream channel alterations, and unauthorized water withdrawals than have stream-type chinook salmon. Again, riparian and shoreline impacts are a major problem.

Table 4. Categorization of steelhead macrodistribution in the Wenatchee Watershed, based upon likelihood of protecting or restoring their habitat. Refer to Section 1.2 for a description of categories.

Category	Locations
I	Chiwawa River, White River, Little Wenatchee River, Nason Creek, Chiwaukum Creek
II	lower Icicle Creek, lower Peshastin Creek (Ingalls Creek downstream), lower Mission Creek (Yaksum Canyon downstream), Sand Creek, upper mainstem Wenatchee River
III	Chumstick Creek and tributaries, upper Mission Creek and tributaries, Brender Creek, upper Peshastin Creek and tributaries, lower mainstem Wenatchee River

2.1.3: Inland fish

Resident rainbow trout, bull trout, and westslope cutthroat trout use the Wenatchee River and tributary habitat most or all their life. Although little is known about their specific population dynamics or demographics, their presumed status and life history patterns for these inland fish are:

a. Spawn and rear in the Wenatchee River and tributaries (*Category I*).
b. Spawn in lower order tributaries, rear in higher order tributaries (*Category II*).
c. Spawn, rear in tributaries, temporarily rear in Lake Wenatchee (*Categories I and II*).
d. Spawn in tributaries, rear in mainstem Wenatchee (*Categories I and II*).
e. Spawn in tributaries, rear in Lake Wenatchee (*Categories I and II*)
f. Spawn in intermittent side channels, rear in mainstem Wenatchee (*Category III*)
g. Spend some or all the life history in perennial side channels (*Category III*).

Bull trout

The principal spawning areas for bull trout in the Wenatchee River are in Panther Creek (tributary to White River), and the Chiwawa River and selected tributaries (Rock, Chikamin, Phelps, Alpine, James, and Buck creeks; Brown 1992). Other lesser populations are known to occur in Nason Creek, Chiwaukum Creek, Eightmile and French Creek (tributaries to Icicle Creek), and Ingalls Creek (a tributary to Peshastin Creek). Bull trout occur through the mainstem Wenatchee River from the Columbia River to Lake Wenatchee, but their numbers appear to be low--mostly upstream of Tumwater (Brown 1992). A winter fishery for large adults had persisted for years on the mainstem, presumably on fluvial stocks which spawned in upper tributaries. The lacustrine form principally spawns in the White River drainage, whereas those bull trout that spawn in the Chiwawa drainage exhibit more of a fluvial life history strategy (Brown 1992). The lacustrine populations in the Wenatchee River would conceivably be more vulnerable--both to angling harvest and habitat loss, since they spent some of their lives outside of public lands. With the exception of high levels of sediment in some spawning areas, the existing USFS prescriptions for managing stream corridors and riparian habitat should be adequate for protection of bull trout in public lands (Brown 1992). Fishing pressure is a major factor in their declines in the Wenatchee Watershed (Brown 1992).

In 1992, harvest of bull trout was prohibited in the Columbia River and most tributaries of Washington State, including the Wenatchee Watershed.

Westslope cutthroat trout

Several genetically "pure" and "essentially pure" populations occur in the Wenatchee Watershed. These populations include: Chiwawa River (Phelps, Rock, Buck, and the mainstem headwaters), Little Wenatchee River (Rainy, Lake, and Snowy creeks, and the mainstem headwaters), White Rivers (Napeequa River and mainstem headwaters), Nason Creek (Smith brook and Gill creeks and the mainstem headwaters), Icicle Creek (Jack, French, and mainstem headwaters), and Negro Creek in the Peshastin drainage[4]. Other creeks may have genetically pure or essentially pure stocks, but these populations have not been sampled.

SECTION 3: ASSESSMENT OF HABITAT CONDITION IN THE WENATCHEE WATERSHED

3.1: Basin Setting and Demographics

The Wenatchee watershed drains a portion of the east Cascade Mountains in north central Washington within Chelan County. The Wenatchee River enters the Columbia River at RK 757. The watershed covers 343,900 ha, with 372 km of major streams. Wenatchee River has about 262 lineal km of stream accessible to anadromous salmonids. The watershed originates in the Cascade Mountains, including the Alpine Lakes and Glacier Peak wilderness areas. The Little Wenatchee and White rivers flow into Lake Wenatchee, the source of Wenatchee River. From the lake outlet and confluence of Nason Creek (RK 87.6), the river joins Chiwawa River (RK 78.2), passes rapidly in Tumwater Canyon and meets Chiwaukum Creek (RK 58.0), before dropping into a lower gradient section near Leavenworth and Icicle Creek confluence (RK 41.4). Major tributaries in the lower valley include Chumstick Creek (RK 40.0), Peshastin Creek (RK 28.4), and Mission Creek (RK 17.0).

3.1.1 Basin ownership and land use

The federal government is the largest landowner in the watershed. More than 99% of federal land, some 271,670 ha (72% of the total watershed area), is managed by WNF. The largest part of this total (128,110 ha) is designated as wilderness, 98,323 ha are managed for multiple resource use (including timber harvest), and 45,205 ha are managed as "non-harvest" areas. Longview Fibre owns and manages 18,211 ha in the watershed, WDNR manages 3,520 ha, and the remainder of the forest land (8,306 ha) is privately owned by commercial and non-commercial managers. Private ownership is limited to less than 25% of the total watershed area, but nearly two thirds the lineal area of the anadromous streams, primarily lower gradient sections, are bordered by private lands. Approximately 8,700 ha of land are irrigated with water diverted from the Wenatchee River, although only 5,000 ha are actually within the basin. Most of these irrigated lands are in orchard production. All of the known large diversions are screened, and by the end of 1996, all diversions will be equipped with modern fish screens. Many unauthorized smaller intakes may be operating without screens, however.

Timber culture and harvest

The water quality impacts related to forest practices on private lands are regulated by the Washington Forest Practices Act (RCW 76.09). Forest practices impacts are minor in the Icicle drainage, but they are significant in the other tributaries. Forest roads in the Peshastin, Mission, and Chumstick watersheds are typically located in the narrow floodplains of the mainstems and their tributaries. This road location practice can result in multiple habitat impacts, including reduced riparian canopy, increased fine sediment loads, reduced pool habitat, and lost off-channel habitats.

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[4]*Noble, U.S. Fish and Wildlife Service, Leavenworth, WA.*

Such roads also directly reduce watershed storage capacity by rapidly routing run off into stream channel and by compacting floodplain soils, and also indirectly by discouraging beaver pond construction (Waters 1995). Ground-based skidding is still a common practice on the private lands in these watersheds, and is a significant fine sediment source[5]. Sediment levels are above the USFS standard (20%) as directed by the NFP in Mission, Peshastin, and Tronsen creeks. Many of the timber harvests that occurred in these watersheds prior to 1988 left no buffer along the channels. Subsequent harvests have incorporated riparian buffers on fish-bearing streams. These buffer areas however, are the minimum required by the state do not necessarily provide adequate shade or large woody debris recruitment.

Agriculture

Irrigated tree-fruit production is the primary commercial agricultural practice in the Wenatchee Watershed. Alfalfa and grass hay, winter wheat, and Christmas trees are also produced to a much lesser degree. The number of small non-commercial farms in the watershed is increasing as large commercial orchards are divided. There are roughly 5,000 ha of agricultural lands in the basin, most of which are in the low-lying areas adjacent to the mainstem Wenatchee, and the Icicle, Chumstick, Peshastin, and Mission watersheds.

Grazing

Grazing, with the exception of small parcel hobby farming or ranching, is not a significant component of the watershed, and therefore not considered a problem at this time. Commercial level grazing is minor in the Wenatchee Watershed. Historically Mission Creek was extensively grazed to the near total destabilization of the watershed. These early grazing practices may have affected the current hydrologic and sediment transport conditions in that watershed. While smaller in scale, hobby farm operations can result in significant localized impacts, and contribute to cumulative effects in the watershed.

Mining

No attempt has been made to quantify the effects of mining in these watersheds, but they appear to be significant enough in Peshastin Creek to warrant discussion. The watershed was extensively placer mined between the 1860's and about 1940. Small-scale placer mining still occurs in the mainstem and several of its tributaries. In addition to the direct disruption of the benthos, the modern miners and their campsites have had heavy local impacts on riparian zones along several of the tributaries. We believe that recreational dredging has increased in recent years, yet little is known about the impacts of these actions to the aquatic ecosystem. The authors are unaware of any sampling for toxic metals in fish tissue in the basin, or any attempt to identify possible food web effects.

Recreation

Although no attempt has been made to quantify the impacts of recreation, local biologists have observed evidence of poaching and have found campers harvesting substantial amounts of LWD in the White and Chiwawa watersheds. Spring chinook and sockeye salmon and adfluvial bull trout, by virtue of their high visibility and low water conditions at spawning are very vulnerable to poaching. To protect stream-type chinook salmon, WDFW recently imposed selective resident fishery regulations throughout much of the anadromous fish zone that should significantly reduce juvenile hooking mortality. Portions of the zone however, remain open to bait fishing. The recently abandoned practice of planting catchable hatchery rainbow trout in this portion of the sub-basin probably has reduced incidental

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[5] *Bambrick, Yakama Indian Nation, Toppenish, WA.*

harvest of steelhead and chinook salmon smolts. New roads built to accommodate timber harvest open new areas to outdoor enthusiasts. Associated with this increased access is a potential for legal and illegal fish harvest and the introduction of exotic fish species through unintentional and intentional plantings.

3.1.2: Water resources and management

Wenatchee Watershed is the third largest (343,900 ha) of the four major mid-Columbia tributaries, but it yields the greatest average annual discharge (2.3 MAF). As in the other mid-Columbia tributaries, the highest average daily flows occur in May and June (7000 -10,000 cfs at Monitor, RK 11). Peak instantaneous flows for the year (10,000 - 15,000 cfs) usually occur from mid-May through mid-June, although rain-on-snow events in November and December have produced the highest recorded discharges (40,000+cfs). Average flows during the months of August (about 1,500 cfs) and September (about 800 cfs) are but 16.7%and 9.2%, respectively, of average June flows. In dry years, September flows have averaged as low as 406 cfs. Winter flows are generally nearly double that of September flows, but they occasionally dip below 300 cfs.

Water quantity

There are four major irrigation districts in the Wenatchee Watershed: 1) Wenatchee Reclamation District, 2) Icicle and Peshastin Irrigation Districts, 3) Cascade Irrigation District, 4) Chiwawa Irrigation District, and two smaller irrigation groups (Jones-Shotwell and Pioneer-Gunn). These districts have about 68% of the total water rights; other users are (in order): domestic (10%), commercial and industrial (8%), municipal (6%), fish hatcheries (3%) and all others (4%). Combined, these users have 420 cfs water rights (357 surface, 63 ground). The largest user is the Wenatchee Reclamation District, which serves over 9,000 users (many of them are residential) by diverting up to 200 cfs at Dryden Dam. The Icicle and Peshastin Irrigation District is second largest, serving 937 growers on 8,000 acres of orchard land.

Water withdrawals are not a large problem in the upper watershed, but development pressure could change that. A significant water-withdrawal impact in the upper watershed is the Wenatchee-Chiwawa Irrigation District’s withdrawal of up to 25 cfs from the Chiwawa River. The diversion amounts to approximately 25% of the average September Chiwawa flow in a drought year (example: 1994) and approximately 13% of September flow in an average year. The adopted minimum instream flows for the Wenatchee River (Table 5) are lower than those recommended by the Washington departments of Fisheries and Wildlife at the time of adoption. The WDOE continues to issue water rights conditioned to those minima. No minimum instream flow protection levels have been established for the upper watershed tributaries. At this time, we do not know if the diversion dams affect upstream or downstream migration.

Chapter 90.54 RCW requires WDOE to maintain “base flows” for the protection and preservation of instream values, which among other parameters, include fish and wildlife habitats. The WDOE has established instream flow requirements for the Wenatchee Watersheds (Chapter 173-545 WAC). These flows are used to condition new water rights, but do not affect water rights acquired prior to adoption.

Table 5. Statutory instream flows (instantaneous cubic feet per second) for five stream management units in the Wenatchee River. To make this table readable, we provide a simplified version of the flow standards set in the Washington Administrative Code.

Time period	Wenatchee R. at Plain	Icicle Creek at Leavenworth	Wenatchee R. at Peshastin	Wenatchee R. at Monitor	Mission Creek at Cashmere
October 1 to March 15	550	150	750	800	6
March 16 to April 15	910	200	1,300	1,350	22
April 16 to June 15	2,000	660	3,000	2,800	30
June 16 to Sept. 30	800	140	1,200	2,000	5

In years of low snowpack, water withdrawals for irrigation and domestic use impact salmonid spawning and rearing habitat downstream of Dryden Dam. While the percentage of flow diverted is small in June and July, it may be significant in August through mid-October of average water years, and may have lethal impacts to juvenile salmonids in the fall of a dry year (1994 for example). The actual instantaneous demand throughout the irrigation season for the tree-fruit industry in the Wenatchee Valley is not known--yet estimates vary considerably, depending upon the assumptions used. We used available data and the following assumptions to calculate the percentage of stream flow withdrawn in a given irrigation season:

> The sum of the maximum contractual entitlements of the basin's six irrigation districts is 371 cfs. This value was adjusted for an assumed rate of return flow (25% for lands within the basin, 0% for those outside the basin), then added to ground water rights for irrigation (also adjusted for 25% return flow), and to all other rights (which were adjusted for 50% return flow rate). Based upon these assumptions, the cumulative withdrawal may reach approximately 400 cfs. However, the instantaneous rates of withdrawal may not reach the maximum entitlement, and may vary substantially depending upon fruit harvest, ditch and diversion maintenance, and other factors. We therefore assumed that the cumulative instantaneous rate of withdrawal ranges from 50% to 100% of the cumulative maximum entitlement in a given year. The 30-year average Wenatchee River flows (1963 to 1992, measured at Monitor: USGS Station 12452500) for the months of August, September, and October are 1,545.2 cfs, 848.5 cfs, and 1,037.8 cfs, respectively (Montgomery Water Group et al. 1995). Flows in September and October have been recorded at less than 500 cfs (although we believe that the stream gauge may not provide accurate estimates at nadir flows). Weighing these variables, we therefore estimate the range of water withdrawal to be 13% to 47%, depending upon the instantaneous rate of diversion and the flow. Regardless, these calculations do not include all registered claims and makes no adjustment for unauthorized water use or for exempt wells.

Water quality

Water quality is generally good in Wenatchee River but water temperatures are above those preferred by salmonids in July, August, and September (Ehinger 1993). The mainstem Wenatchee River has occasional exceedences of state 303(d) water quality standards for dissolved oxygen, pH, and temperature criteria[6]. The land use practices listed above have increased summer water temperatures above what they would be under natural conditions, and conversely, have probably decreased winter temperatures.

[6] *Hall, Washington Department of Ecology, Yakima, WA.*

Wenatchee River meets Washington State Water Quality Standards in most of the watershed. The river is rated a *Class AA* (extraordinary) status from the headwaters to WNF boundary near Leavenworth (Montgomery Water Group 1995), although temperature standards are occasionally exceeded (WNF 1995). The remainder of the river, to its confluence with the Columbia River, is designated *Class A* (excellent) status. Water quality problems are evident in smaller drainages such as the Mission, Peshastin, and Chumstick creeks. The mainstem Wenatchee River on occasion does not meet water quality standards for temperature, dissolved oxygen, and pH (Montgomery Water Group 1995). Temperature exceedence has occurred at virtually all sampling points in the mainstem on low-flow years (Ehinger 1993; Hindes 1994; CCCD 1997).

Documented water quality problems include occasional exceedences of state standards for dissolved oxygen (Wenatchee River and Brender, Icicle, and Chumstick creeks), pH (Wenatchee River and Icicle and Chumstick creeks), fecal coliform (Chumstick, Mission, and Brender creeks), and DDT (Mission Creek). The only temperature data available for each of the lower tributaries were those provided in Hindes (1994). Only minor exceedences of water temperature criteria are documented in that report, but the individual(s) who collected the data did not indicate at what time of day the data were collected. If temperatures were measured in the morning then it is highly likely that daily maximum water temperatures in these lower tributaries significantly exceed criteria. Diel fluctuations of 6^{o} C are common in central Washington streams[7]. Isolated fish kills resulting from chemical contamination of open waters have been reported in the Wenatchee Watershed. This risk remains. It is probable that storm water also delivers significant accumulated pollutants to Mission, Chumstick, and Peshastin Creeks, given the amount of impervious surfaces draining into them.

Fecal coliform pollution is a problem for Mission, Peshastin, and Chumstick creeks (Hindes 1994; CCCD 1997). Brender Creek, a tributary of Mission Creek, never tested below the state standard for fecal coliform during the test period (Hindes 1994). To date, the exact sources of the elevated levels are not known. The CCCD received two Centennial Clean Water grants from WDOE to identify nonpoint sources, and to plan and implement BMPs to prevent non point source pollution. At this time, the primary sources appear to be failing domestic septic systems along these streams, yet agricultural runoff, forestry practices, and municipal stormwater management are also being examined (CCCD 1997). Another source of water degradation in Mission and Chumstick Creeks is nitrogen, found in several forms, and probably a by-product of septic systems.

3.1.3: Regional and local considerations

The basin is experiencing a demographic shift from a natural resource based economy reliant on agriculture, forestry and mining to an economy more dependent on tourism, recreation and general goods and services industries. The population of the Wenatchee Watershed grew from 11,736 in 1970 to 14,829 in 1990--a 26% increase. By the year 2010, the population is projected to reach 22,416--a change of 51%. Most of the growth is in the Leavenworth and Lake Wenatchee areas[8]. Although the economy of the valley remains heavily dependent on the tree fruit industry, the growth locally is not in orchard development but instead in tree fruit processing and storage. Smaller parcels in tree fruit production are being converted to nonagricultural use including housing, retail businesses, and small manufacturing. As land in the valley bottoms has shifted from agriculture to other uses, somewhat different landscape alterations have

[7] *Bambrick, Yakama Indian Nation, Toppenish, WA.*

[8] *Chelan County Planning Department, Wenatchee, WA.*

emerged. These alterations are commonly clearing vegetation and installing bank protection (rip-rap) for "view" property, and home construction in the jurisdictional shorelines and flood zones.

Conversion of timber areas into other uses such as residential subdivisions has occurred in White River, Nason Creek, and the upper mainstem Wenatchee River. This conversion on private lands is not regulated by the Washington Forest Practices Rules and Regulations. However, Chelan County is involved in regulation of the forest conversion process through local land use planning and zoning authority (RCW 76.09.060 and 76.09.240).

Although fish habitat protection is of primary concern to fishery managers, they have only limited jurisdiction over land and water use that impact habitat. Land and water use activities are regulated by a patchwork of federal, state, and local laws and ordinances. Even when it appears that fish habitat is adequately protected through written statutes, agreements, guidelines and other documents, on-site observations may show differently. Successful protection of habitat is most likely to occur when both the citizens and the jurisdictions recognize the legitimacy and the worth of the policies, standards, and guidelines involved.

Urban and suburban development and road construction (forest and highway) impacts are significant in these systems as well. The Peshastin Creek channel is largely defined by Highway 97. Chumstick and Mission Creeks have been straightened and realigned along much of the historical anadromous zone. While the portion of Icicle Creek still accessible to anadromous fish remains highly sinuous, its banks have been rip-rapped along much of this reach, and its historical maze of side channels and oxbows have been filled in, or cut off from the main channel.

3.2: Historical and Existing Aquatic Habitat Conditions

3.2.1: Riparian and stream channel condition

Mainstem Wenatchee River

Chelan PUD funded a stream reach classification on Wenatchee River from Icicle Creek confluence downstream to its mouth at the Columbia River. The extent of the stream channel with woody vegetation, rip-rapped banks, or actively eroding banks was determined from digitized 1991 aerial photographs. The total measured stream length was 92 km, of which 5% were actively eroding (note however, that the extent of bank erosion has increased considerably since these photographs were taken in 1991). Of the 4,256 linear m of eroding banks, 2,241 m had no woody vegetation present, 220 m had a narrow woody fringe, 1,030 m had intact natural woody vegetation, and 585 m were armored with rip rap. Of the 91,548 m of digitized stream length, 31% (27,929 m) had no woody vegetation, 35% (31,865 m) had only a narrow woody fringe, 19% (17,144 m) of the stream banks were armored with rip rap, and the remaining 16% (14,590 m) had intact natural woody vegetation.

Most alterations of the stream channel have been the result of construction of the major railroads, highways, and arterials that are adjacent to the mainstem Wenatchee River, and Nason, Peshastin, and Chumstick creeks. On the mainstem Wenatchee, extensive floodplain habitat was lost to highway placement, particularly near the Mission Creek confluence. Extensive use of rip rap to stabilize streambanks in the lower reach decreased the sinuosity of the stream and LWD recruitment. Also, the highway caused reduced access to off channel juvenile rearing habitat in the Sleepy Hollow reach of the lower Wenatchee River. These off-channel habitats may be connected, if practical and consistent with other priorities to protect, restore, and enhance aquatic/riparian/wetland habitats impacted by transportation facilities. Project feasibility, long-term maintenance, and potential liabilities for WDOT must be considered in restoration of these off-channel habitats. Currently, and to the extent practical, WDOT employs bioengineering techniques, revegetation technologies, and other BMPs in highway maintenance and construction work to restore riparian areas.

Low-head berms were built in the 1950s near the communities of Cashmere and Monitor as flood protection. These berms were constructed with some relatively large boulders, which formed lateral scour pools in some reaches, and therefore created some instream habitat. In general however, the lower mainstem river channel has lower incidence of banks stabilized with rip-rap (Table 6). This reach falls under the Rosgen (1994) classification of stream type B, which would be described as a moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools and stable banks. The upper mainstem Wenatchee River (from Chiwaukum confluence upstream) would probably be classified as stream type C: low gradient, meandering, point bar, riffle/pool, alluvial channels with broad, well defined floodplains (Rosgen 1994).

The upper Wenatchee River between from the lake downstream to Leavenworth is impacted less than the reach downstream of Leavenworth. Some rip-rap and general bank protection projects exist in the Plain area along with riparian clearing near some homes along the river. Downstream from Leavenworth, orchards and homes now occupy much of the river's riparian area. Several homes were recently constructed close to the river (<25 feet) and the homes will likely soon require additional bank protection. Such close proximity to the river effectively precludes employing bioengineered bank protection techniques, and limits bank protection options to those that result in the additional degradation of salmonid habitat.

White River

The lower White River is the principal spawning area for sockeye salmon and adfluvial bull trout. In 1992, the White River was surveyed from the Sears Creek confluence upstream to within the Glacier Peak Wilderness, using a modified Hankin and Reeves method (USFS 1992). The lower reach (Reach I), up to approximately the Napeequa River confluence, lies within private lands. The lower White River stream channel has an average slope of 1% and has shallow entrenchment within a wide flat-floored glacial valley. The valley floor within this reach is flat and relatively wide (more than 200 m), making it of high value for residential development. In Reach I, the average wetted stream width is 28 m, and the channel is dominated by pools (48%), with glide habitat of 29.5%, riffle habitat of 19.2%, and 3.3% side channels (Dambacher and Eason 1992). The stream canopy closure is relatively low--less than 20%. The stream substrate is embedded 35% and more with fine glacial sediment. Average woody debris is 60 pieces per km. Reach II extends from Napeequa confluence to White River falls (5.5 km)--all within WNF. The average wetted width is 22 m, with 57.4% riffle habitat, 26.5% glide habitat, 11.1% pool habitat, and 3.8% side channels (Dambacher and Eason 1992). Pool habitat is considerably less than Reach I, but still within USFS standards. There are an average of 40 pieces of woody debris per km. Stream canopy closure is rated at less than 20%. Reach III extends from White River Falls to Indian Creek confluence (5.9 km). The average wetted width is 17.7 m, with 41.7% riffles, 30.3% pools, 26.7% glides, and 0.7% side channels. Stream canopy closure is 31-60% (Dambacher and Eason 1992).

Nason Creek

Nason Creek flows through a sedimentary glacial canyon, and is relatively unconfined. There are areas of excessive scour occurring, a result of both natural events and human alterations. The average gradient in lower Nason Creek is 0.23%. Some side channels and oxbows have been cut off from the main channel by construction of Highway 2. Over 5% of the lower Nason Creek channel has been altered by rip rap placement.

Chiwawa River

The Chiwawa River is a fourth order stream, and the largest tributary to the Wenatchee River. The watershed is 47,350 ha; 17% of which in Glacier Peak Wilderness. In general, the river does not meet the USFS standards for wood or pools per unit stream length in any reach, while temperature and sediment levels fluctuate between the reaches (WNF 1992). Private homes and property are adjacent to Chiwawa River for the first 8 km, near the confluence of Chikamin Creek and in several other sections of tributaries. Timber harvest in the watershed has been moderate, with most of it having been in the Meadow Creek drainage. There are numerous roads throughout the watershed. A water diversion is located at RK 7, and has a capacity of diverting 30 cfs. A satellite to the Rock Island Fish Hatchery Complex is located at RK 1.

The USFS surveyed 47 km of Chiwawa River in 1992, using the Hankin and Reeves (1995) method (Table 7). In the lowest reach (Reach I; generally in the Shugart Flats and Chiwawa Pines developments), the riparian vegetation was 3 m to 10 m wide; in some places the riparian vegetation is non-existent. Average canopy closure was 35%, with a range of 15% to 50% (WNF 1992). Cleared private property and the relatively high wetted width (17 m average), may account for the low canopy closure in this reach. The USFS rates this reach in poor to moderate condition; it is well below the USFS standard for pool frequency (WNF 1992). In Reach II, the average riparian width is 16 m. Average canopy coverage is 53%. The riparian habitat is in moderate to fair condition (WNF 1992). In Reach III, there are numerous meanders and oxbows that create wetlands and extensive riparian vegetation. The average riparian width is 20 m, with canopy closure of 64%. The riparian habitat is rated as good. In Reach IV, the average riparian width is 13.7 m, yet in some places extend to 60 m, because of beaver activity and oxbows. The average canopy closure is 60%. The riparian vegetation is considered good (WNF 1992). In Reach V, riparian width fluctuated from 5 m to 14 m, with an average of 8 m. Average canopy closure is 68%. In general, the riparian condition is good, yet there are two campgrounds adjacent to the Chiwawa River in this reach (WNF 1992). For the river in general, the habitat is riffle dominated, with pools associated with logjams and meanders. No fish passage barriers were located in the survey. Temperatures in the surveyed reach ranged from 9.4 ºC to 20.0 ºC, taken on 10 August 1992.

Table 7. Fish habitat parameters identified in the Chiwawa River in 1992.

Reach	Percent riffle	Percent pool	Effective fish cover (%)	LWD per mile	BFCW per pool
I	95	4	0 - 5	34	29.3
II	49	29	6 - 19	44	9.3
III	44	36	6 - 20	92	11.6
IV	65	29	6 - 20	75	6.7
V	62	33	6 - 20	50	3.9

Icicle Creek

Lower Icicle Creek is an unconfined alluvial stream, with a relatively low gradient. Based upon analysis of aerial photographs, Chapman et al. (1994a) found that 11.2% of the stream had riparian vegetation removed, principally from housing development. An unquantified, but substantial amount of streambank has been altered with rip rap in recent years. The barrier dam at Leavenworth NFH blocks access to more than 30 km of historical habitat. Free (1995) surveyed Icicle Creek upstream of the dam and two tributaries (Trout and Jack creeks) and found viable populations of rainbow trout, bull trout, cutthroat trout, and brook trout.

Chumstick Creek

This system probably produced coho salmon, steelhead, and stream-type chinook salmon. We speculate that coho salmon were the most populous, yet no data are available to support this. A large culvert under the North Peshastin Road (near the mouth of Chumstick Creek) is a passage barrier for adult salmonids. Several smaller culverts on the lower Chumstick Creek are suspected to hinder upstream passage of salmonids at certain times. Summer flows, at least in drier years, appear to be low enough to prevent adult salmon staging and spawning. The high percentage of silt substrate in the lower 15 km would likely result in high pre-emergence mortality. Juvenile salmonids have been observed in lower Chumstick Creek, closely associated with the patchy riparian cover.

Peshastin Creek

Stream-type chinook salmon still use this system, and probably many more used it historically than do today. Steelhead were likely the more populous anadromous species spawning in this system, however. Coho salmon may also have been more abundant than chinook salmon here. It has not been determined if the irrigation diversions actually block adult migration, but they have been offered as one explanation as to why no chinook salmon spawn in Peshastin Creek in some years. Some local biologists believe it is still accessible in average or better water years, and in low water years, to only the earliest migrants. Others think that adults can access the creek in all years. Juveniles rear in the section below the diversions, but it is not known if they exit the system before it goes dry or if they remain there and perish. Given the amount of bedload movement observed in this system, gravel scour is likely a significant source of pre-emergence mortality for any fish that do spawn here.

Riparian vegetation along the mainstem, where it has not been totally cleared, is primarily deciduous trees and shrubs. As a result, the mainstem channel receives a very limited supply of the large diameter conifers capable of persisting in this flashy system. Currently in-channel conditions appear to be hostile for stream-type chinook salmon overwintering above the U.S. Highway 2 crossing. Below the crossing gradient flattens considerably, but the lack of riparian vegetation also makes for poor rearing and overwintering habitat. The stream channel in Peshastin Creek has been altered and straightened by construction of Highway 97 from the mouth to Scotty Creek. As a result, water velocities (and resultant bedload) are very high, making this stream virtually unusable by salmonids at all life stages.

Mission Creek

The Mission Creek watershed amounts to 6% of the area of the Wenatchee Watershed, yet it contributes less than 1% of the mainstem flow. Mission Creek however, is one of the two major sources of sediment to the Wenatchee River (Hindes 1994)--the other is Chumstick Creek. The predominant rock formation is Swauk sandstone, which makes soil conditions in the watershed extremely unstable. Grazing was a major factor in destabilizing the watershed. In 1931, 7,200 sheep grazed the Mission Creek watershed, and five times this number were trailed through this area (Ciolek 1975).

Adult stream-type chinook salmon cannot get above the irrigation diversions (steelhead can in wet years), and the spawning conditions in the lower creek are unsuitable for them. High sediment loads, high peak flows, high pre-spawning water temperatures and limited adult resting habitat are all problems for stream-type chinook salmon in this watershed. Juvenile chinook salmon and rainbow/steelhead overwinter in lower Mission and Brender Creeks, however. It is possible that toxic storm water discharges cause sporadic fish kills, although there are no data to substantiate this premise.

3.2.2: Lake Wenatchee

Lake Wenatchee is the only nursery lake for sockeye salmon in the Wenatchee Watershed. It is a typical oligotrophic lake (Mullan 1986), being relatively clear with low productivity (Allen and Meekin 1980). Mullan (1986) classifies Lake Wenatchee as classic sockeye rearing habitat: cold, clear well-oxygenated, but infertile water. He concludes that the lake has a low nutrient base but high efficiency in energy conversion to sockeye production. The lake is approximately 8 km in length and has a surface area of about 989 ha. Average depth is about 55 m. The White and Little Wenatchee rivers deliver most of the inflow, as the catchment basin is relatively small, and the Wenatchee River is the outflow. The average turnover rate is 2.2 times per year.

Lake Wenatchee is highly susceptible to housing development. The amount of shoreline development that has occurred along the lake has increased in the past fifteen years. Many bank hardening and dock construction permits have been issued in that time. Such activities disrupt sediment dynamics and decrease the productivity of littoral zones. The construction of bulkheads, removal of riparian vegetation, and shoreline clearing on Lake Wenatchee is a departure from natural condition. This practice reduces wood and nutrient recruitment to the lake and downstream. The average annual phosphorous budget is 10,600 kg/yr, which is relatively low. The development of homes within the basin without adequate sewage treatment may increase this input, and could change the oligotrophic character of the lake.

3.2.3: Wetland Resources

As is typical in a landscape with steep slopes and rocky terrain, most of the wetlands in Wenatchee Watershed are closely associated with stream systems. Based on 1983, 1984, and 1990 aerial photographs, roughly 2.6% of the watershed is classified as wetland (defined in Appendix A.1) under the USFWS National Wetland Inventory (Table 8). As to be expected, the majority of wetlands are in the relatively undisturbed Chiwawa drainage. Two of the notable wetland complexes in Wenatchee Watershed are: 1) Fish Lake, which is a 73 ha sphagnum bog near the confluence of the Wenatchee and Chiwawa rivers, and 2) Camus Meadows, which is a large seasonal wetland containing several rare plants, including *Delphinium viridescens*, which is on the Washington State endangered plant species list.

Table 8. Wetland habitat in the Wenatchee Watershed and tributaries, which were identified in the USFWS National Wetland Inventory.

Subwatershed	Total upland area (ha)	Total wetland area (ha)	Percent wetland
Chiwawa	55,766	2,926	5.2
Chumstick	26,576	159	0.6
Icicle	54,443	854	1.6
Little Wenatchee	25,965	416	1.6
Mission	26,028	23	0.1
Nason	27,133	314	1.2
Peshastin	35,601	124	0.3
Wenatchee	57,300	1,102	1.9
White	39,249	1,053	2.7
Totals	295,450	6,971	2.4

3.3: The Relationship of Existing Aquatic Habitat Conditions to Biological Productivity

Ocean-type chinook salmon

These fish encounter habitat that has been heavily impacted by development in the valley bottomlands. The lower mainstem Wenatchee was not a highly meandered, unconfined system with an extensive off-channel habitat network when development began, but it soon lost most of what it had. Flood control dikes, gravel mining, and channel straightening associated with rail lines and roads have dramatically simplified habitat in this section of the river. Wood removal, and the loss of wood recruitment resulting from these and other actions exacerbated conditions. Today, the lower mainstem is almost entirely devoid of large woody debris, and there is virtually no remaining riparian vegetation. These practices in combination constitute the greatest impact to salmonid habitat in the mainstem Wenatchee downstream of Leavenworth.

It is believed that summer chinook salmon spawning in the lower Wenatchee River (downstream of Mission Creek confluence) do not enter the river until shortly before they spawn. By so doing they avoid warmer water and usually encounter higher flows than earlier spawners. Flows during the second half of October are on average 25% higher than those in the latter half of September. Again, risks to emergence success are noteworthy, although here anchor ice does appear to be a problem.

These earlier migrants avoid the higher water temperatures present in lower Wenatchee River during August. In drier years, later migrating fish may have difficulty getting above Leavenworth. One author observed fish laboring to cross (several were observed falling back), a bar above the mouth of Icicle Creek in the fall of 1986. Sedimentation, gravel scour and anchor ice are potential sources of pre-emergence mortality. The authors are unaware of the extent to which this area is prone to anchor ice, however.

The early rearing environment is fairly hostile. The combination of natural and artificial channel confinement severely limits the availability of suitable early rearing habitat. Velocity refugia are primarily associated with rip-rap and afford little cover from avian or piscine predators. Habitat enhancement efforts should include creating additional velocity refugia and better cover. Late rearing habitat quality also suffers from the lack of in-channel diversity. The lack of cover, particularly as flows drop in the summer and fall, may be limiting the success of this group of fish through both depensatory (fish avoid areas with poor cover and crowd into the few suitable areas) and compensatory (fish use these habitats but are subjected to high predation rates) mechanisms. Overwinter habitat quality was also severely reduced by the actions described above. Winter water temperatures often hover near freezing (Ehinger 1993, Hindes 1994). Frazil and anchor ice are common winter phenomena[9] and can occupy most of the substrate in this reach in a cold winter with low flows.

Stream-type salmonids

Based on stream survey information (from USFS, WDFW, and Chelan PUD) and the observations of fish biologists familiar with the basin, most Wenatchee River stream-type anadromous fish spawn in habitats least modified by land use practices. Early rearing also occurs in these more pristine areas (Hillman and Miller 1994). A portion of the juvenile population may move downstream gradually during summer, fall, and winter rearing (Hillman and Chapman 1989; Petersen et al. 1995). Here they encounter increasingly altered conditions where recruitment of shelter habitat (primarily LWD) and food supply is reduced because of loss in riparian areas. Conditions in the upper Chiwawa and

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[9]*Hays, Chelan County Public Utility District, Wenatchee, Washington.*

White rivers are particularly good. Nason Creek, however, has been extensively straightened and contains few LWD in most of the anadromous zone. Similarly, the mainstem Wenatchee River in and around Plain and lower Chiwawa River have lost considerable LWD and in-channel diversity as a result of shoreline development.

Forest practice impacts to this life history type are expected to improve if the riparian buffers required by the NFP remain in effect, and if forest road construction techniques and maintenance standards continue to improve. The Little Wenatchee River and Nason Creek each experience very low flows during the late summer, but we do not know to what extent this phenomenon results from forest management. The current forest hydrology models that have been applied to these watersheds indicate only slight exacerbation of peak and summer low flows. No data regarding spawning gravel condition are available, but USFS estimates that sediment production from forest practices is minor (<10% of background; USFS 1990). The upper mainstem Wenatchee River still suffers from the scouring effects of historical in-channel log drives.

Shoreline development is the greatest in-basin habitat problem and probably the greatest threat to this life history type, especially in the lower rearing and overwintering zones. Chelan County currently allows construction to within 25 feet of Class I, II, and III streams (CCPD 1994), and permits construction within the floodplains of streams under its jurisdiction. Denuded stream banks, channel straightening, and bank armoring are the results of these policies. The areas most threatened by potential additional development are the White River below the Nepeequa River, the Chiwawa River below Deep Creek, most of the anadromous portion of Nason Creek, and the Wenatchee River mainstem between Lake Wenatchee and Tumwater Canyon. The areas already impacted were mentioned earlier.

Stream-type anadromous salmonids that spawn or rear in the middle and lower sections of main tributaries encounter conditions dramatically different than those that existed before development. Water withdrawals are very significant problems in all of the lower river tributaries. Portions of Peshastin and Mission Creeks are often dewatered by irrigation withdrawals. Icicle and Chumstick Creeks may also be heavily diverted.

Sockeye salmon spawning habitat is limited to the lower gradient riffles within the accessible portions of the White, Little Wenatchee and Nepeequa rivers. Redds are constructed in substrate roughly half the size of that used by stream-type chinook salmon. Suitable spawning areas exist primarily where the rivers and their floodplains are unconfined -- two conditions necessary to retain the smaller gravels preferred by Wenatchee sockeye salmon. The status of and recommendations for habitat in this area are detailed in the stream-type chinook salmon section, but shoreline development warrants additional discussion here. About half of the spawning habitat in the White River is bordered by private property. As people build and begin to clear vegetation, stream banks begin to erode; people usually then want to compound their original mistake by trying to “control” the river. If this situation continues on the White River, sockeye salmon production will decline.

Large wood material and higher flows provide protection from poaching, harassment, and predation for mature stream-type anadromous salmonids in the summer and fall. Importance of shelter habitat increases as forest road construction provide easier fishing access and vulnerability to legal and illegal harvest.

Inland fish

Many of the key habitat factors that apply to anadromous salmonids also apply to resident 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 bottomland development (bank protection, channelization, water withdrawal). Key habitat conditions for resident fish, in particular rainbow trout, westslope cutthroat trout, and bull trout revolve around minimizing sedimentation, gravel scouring, and providing needed cool water temperatures and adequate cover.

SECTION 4: RECOMMENDED STRATEGIES FOR THE WENATCHEE WATERSHED

4.1: Habitat Protection

The highest priority for maintaining biological productivity will be to allow unrestricted stream channel migration, complexity, and diversity and flood plain function (Section 1.6.2). Obviously, some areas have more immediate needs, because of their importance for existing life history strategies, and should be given greater emphasis. The following list identifies stream reaches which should receive protection, and is therefore ranked in biological priority. This list is not comprehensive, but provides a general indication of the types of protection measures required.

1) The Lower White River, from the mouth to RK 15. Protection of this reach is crucial for the long-term viability of sockeye salmon, as RK 9 to 15 is their principle spawning area, and lower 9 km contain important chinook salmon adult holding and juvenile rearing areas. It is also highly vulnerable to alterations in stream channel function due to residential development. This reach has relatively unstable alluvial materials, requiring extensive vegetative cover to maintain stability during normal flood events. The extent of riparian vegetation necessary for adequate protection would be determined from field review, but would likely be a perpendicular distance of three to seven times the bankfull width of the stream channel. This action requires both protection and restoration actions.
2) The lower Chiwawa River near the Chikamin Creek confluence (RK 24). This reach provide critical rearing and overwinter habitat for spring chinook salmon, steelhead, mountain whitefish, and bull trout.
3) The Little Wenatchee River, from the mouth to RK 8. This reach is the second most important spawning habitat for sockeye salmon.
4) Shorelines along Lake Wenatchee, particularly at the west end, near the outlets of the Little Wenatchee and White rivers. This area has several wetland complexes that are vulnerable to encroachment. Moreover, it is likely that sockeye salmon spawn in those lakeshore areas. This action involves both protection and restoration.
5) Selected sites along the upper mainstem Wenatchee River, from Lake Wenatchee (RK 88) to Deadhorse Canyon (RK 62). This reach is important spawning habitat for ocean-type chinook salmon, and overwinter habitat for numerous life history types. Recruitment of LWD into the stream channel at this reach should be encouraged.

Salmonids which exhibit stream-type life history strategies will benefit most from these efforts. *Category I and II* phenotypes were targeted, and some *Category III* phenotypes may benefit. In addition, protection of these habitats would presumably benefit many non-salmonid species that are identified on the WDFW PHS list.

4.2: Habitat Restoration

A range of strategies is recommended for habitat restoration in the Wenatchee Watershed. Like the *Habitat Protection* strategy, most strategies center on efforts to maintain or increase the complexity of the stream channel and floodplain (Section 1.6.3). Most of these efforts are on the lower reaches and aggradation zones, and would benefit both ocean-type and stream-type salmonids. These recommendations are not comprehensive and not listed in order of biological priority.

1) Restore flood plain function on the lower Wenatchee River, particularly from the Mission Creek confluence (RK 17) downstream to the Columbia River confluence. This would require only passive restoration. Since this reach has the highest discharge, the extent of riparian vegetation required to restore flood plain function would be larger than the tributaries (NRC 1992). This action would likewise require some agreement with the affected land managers to maintain the restored habitat, or through easement or purchase of the habitat. The authors recognize that this recommendation is exceptional--and exceptionable--as it would be politically and economically expensive. However, if done properly (using well-defined incentives that are consistent with market forces) this action would serve as a model for the other mid-Columbia tributaries of land management that is conducive to economic and environmental sustainability. Benefits of this action would be numerous to anadromous and inland salmonids, as well as a myriad of PHS species.
2) Move the point of diversion for the East Wenatchee portion of Highline Canal (Wenatchee Reclamation District) to the Rock Island Pool (Columbia River). This action would increase late summer instream flows by 42 to 45 cfs for 28 km. Benefits would be seen for rearing steelhead, stream-type anadromous salmon, inland fish, and for ocean-type chinook salmon during upstream migration and spawning. Prior to implementation of this recommendation, an assessment would be required of the impacts of pumping water from the Columbia River on fish and other aquatic species.
3) Provide year-round passage to and from the wetlands that were cutoff from the lower Wenatchee River because of Highway 2 placement, from Fairview Canyon (RK 12) downstream to Sleepy Hollow (RK 6). A cooperative agreement with WDOT would be required.
4) Develop riparian habitats in the rights-of-way lands along the highways. This work can be done on the lower Wenatchee River, lower Peshastin Creek, and lower Nason Creek. Again, a cooperative agreement with WDOT would be required. Beavers should be allowed to establish into these reaches, if done in a manner that minimizes risk, maintenance, and liability to affected landowners.
5) Modify the diversion dams operated by Leavenworth NFH and Icicle Irrigation District to allow anadromous passage to the upper Icicle Creek. Cooperative agreements with the USFWS and Icicle Irrigation District would be required.
6) Provide fish passage from the wetlands and oxbows to Nason Creek that were cutoff because of Highway 2 placement, from White Pine Creek (RK 25) downstream to Kahler Creek (RK 6).
7) Modify the North Road culvert on Chumstick Creek (RK 1) to allow upstream passage to Chumstick Creek for anadromous salmonids. Several smaller culverts in Chumstick Creek from the mouth to Merry Creek confluence (RK 10) are suspected barriers also, and would require modifications.
8) Several riparian restoration projects would benefit stream-type and inland salmonids, increase species diversity, improve water quality, increase late-summer instream flows, and desynchronize flood events. The recommended locations include: lower and upper Icicle Creek, Chumstick Creek, lower Peshastin Creek, Ingalls Creek, Negro Creek, Camas Creek, Mission Creek, and Brender Creek.
9) The lower Chiwawa River requires restoration, particularly from the mouth to Deep Creek confluence (RK 7).
10) The lower Icicle Creek requires restoration, from Leavenworth NFH (RK 5) downstream to the Wenatchee River confluence. Re-establishment of fur-bearing mammals (and other ecological keystone species) into this reach should be encouraged, as a means to increase habitat and species diversity.

11) Upper Icicle Creek, from Icicle Irrigation Diversion Dam (RK 9) downstream to Leavenworth NFH.
12) In a cooperative venture with irrigation districts, modify selected irrigation canals for off-channel juvenile salmonid rearing habitat.

THE ENTIAT WATERSHED

SECTION 5: ASSESSMENT OF AQUATIC SPECIES IN THE ENTIAT WATERSHED

5.1: Commercially and Culturally Important Fish Species

The Entiat River supports several populations of economically and culturally important fish species. The watershed currently supports anadromous runs of chinook salmon and steelhead. Coho salmon were once present in the Entiat Watershed (Mullan et al. 1991), but are now considered extinct (Nehlsen et al. 1991). Passage barriers on the Entiat River at the turn of the century probably contributed to their extinction. Important inland species include mountain whitefish, bull trout, westslope cutthroat trout, and rainbow trout (a resident form of steelhead). A recreational fishery exists for steelhead, resident rainbow, and brook trout. No sport fishing for bull trout or salmon is allowed on the Entiat River. The spring and summer chinook salmon and steelhead populations are listed as depressed in the SASSI (WDF et al. 1993). Fish passage into the Entiat River was significantly impeded for several years by a log mill dam built across the river near Ardenvoir (Chapman et al. 1994a), and a power generation dam in the lower river (WNF 1996a). Salmon and steelhead pass eight major hydroelectric dams on the mainstem Columbia River. In general, spawning and rearing habitat in the upper reach of the Entiat (from Potato Creek confluence to Entiat Falls) are considered to be in very good condition for salmon and steelhead, and poor in the lower Entiat (WNF 1996a).

5.1.1: Ocean-type anadromous salmonids

It is suspected that ocean-type chinook salmon were not a dominant life history strategy in the Entiat River system (Craig and Suomela 1941). Ocean-type chinook salmon return to the Entiat River primarily in July and August, but may enter the river into early October. They spawn in the mainstem Entiat River from the Preston Creek confluence downstream to its confluence with the Columbia River (37 km; Carie 1996). Spawning begins in late September in upstream reaches, peaks on 13-20 October, and ends in early November in the lower river (Peven 1992). Juveniles probably emigrate to the ocean as subyearlings, leaving the Entiat River from one to four months after emerging from the gravel in April.

Based upon redd count expansions, the ocean-type chinook salmon escapement to the watershed averaged 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. In 1995, 40 ocean-type chinook salmon redds were observed in the mainstem Entiat River downstream of RK 32. From this count, Carie (1996) estimated that 110 ocean-type chinook salmon used Entiat River for spawning that year. No summer chinook salmon spawn in the tributaries of Entiat River, and virtually all ocean-type chinook salmon spawn downstream of Preston Creek confluence. Emergence timing is probably January through April. Juveniles may rear from a few months to a year before migrating downstream. Two general life history types are presented here, which express the presumed historical life history strategies for ocean-type anadromous fish: 1) spawn in the mainstem and leave the system in late spring/summer as subyearlings, and 2) spawn in the mainstem and leave the system in fall as subyearlings. Both these phenotypes are classified as *Category II*. Some cohorts rear in the Entiat River through winter when conditions are favorable to this strategy (*Categories II and III*).

5.1.2: Stream-type anadromous salmonids

Spring chinook salmon

Stream-type chinook salmon return to Entiat River from late May through July. The primary spawning areas are the mainstem river upstream of the terminal moraine (RK 26) to Fox Creek confluence (RK 45; Carie 1996), and would be classified as *Category II*. Spawning begins in early August in the upstream reaches, and continues downstream through August and September. The average estimated natural escapement to Entiat River (based upon dam count turnoff estimates) is 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[10]. However, some of these escapment values are not corroborated by redd count expansions, done recently by USFWS. The authors feel the later technique provides a more reliable estimate of stream-type chinook salmon escapement. 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 the spring migration is late April through May, but downstream movement from the tributaries may be continuous, and not always associated with parr/smolt transformation.

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

1) Spawn, rear, overwinter in upper reach tributaries --above terminal moraine *(Categories II and III)*.
2) Spawn, rear, overwinter in lower reach tributaries--below terminal moraine (*Category III*).
3) Spawn, rear in tributaries (Mad River, Roaring Creek); overwinter in lower mainstem Entiat (*Category III*).
4) Spawn in tributaries or mainstem Entiat, rear or overwinter in accessible side channels (*Categories II and III)*.
5) Spawn, rear in tributaries, outmigrate in fall/winter (*Category III*).

Sockeye salmon

Sockeye salmon are not indigenous to the Entiat River (Craig and Suomela 1941). After they were propagated at Entiat NFH between 1941 and 1969, small numbers of sockeye salmon adults were observed on a discontinuous basis in the Entiat River during spawning ground surveys for chinook salmon (Carie 1996). The most recent observation was one fish in 1995. These fish are either strays from the Wenatchee and Okanogan stocks, or they may be artifacts of the Entiat NFH releases (Mullan 1986). Little is known about the life history of Entiat sockeye salmon; they are assumed to rear primarily in the impounded lower reach of the Entiat River and the Columbia River reservoir (Chapman et al. 1995a). Spawning occurs from mid-September to mid-October. It is assumed that juveniles move downstream from Entiat River to the Columbia River reservoir immediately after they emerge from the gravel (March through May). These fish are classified as *Category III* because of their small population size.

Steelhead

Steelhead spawn in upper Entiat River and some tributaries from 15 March to 31 May. Most steelhead spend one to two years rearing in the mainstem or its tributaries, and a given year class undergoes an almost continuous outmigration from the river during this period. Movements are complex and not fully explainable. After nearly 14 months of rearing in a hatchery (Chelan, Wells and Eastbank FH), smolts are planted into the mainstem Entiat River from 20 April until 20 May. Almost 10% of these hatchery fish are believed to spend an additional year in residence prior to emigration. Natural steelhead stock/recruitment relationships from several reports show little or no replacement[11]. Most steelhead smolts leave the system at age 2 or 3, depending upon stream temperatures. Most adults spend two years at sea, so the dominant age in the Entiat River system is 2.2 and 3.2. Females tend to stay longer at sea. Currently, and for at least the last twenty years, steelhead spawning in the rivers are, and have been, predominantly hatchery origin fish.

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[10]*LaVoy, Washington Department of Fish and Wildlife, Wenatchee, WA.*

[11]*Brown, Washington Department of Fish and Wildlife, Wenatchee, WA.*

Listing all of the possible steelhead life history types will not be attempted here. They probably exhibit all of the types listed for stream-type chinook salmon, compounded by variable fresh water residence, and penetrate deeper into most of the tributaries than stream-type chinook salmon do. Categorization of steelhead robustness can be better done by analysis of their distribution, rather than phenotypic diversity (Table 9). Those individuals using the upper reaches of tributary habitats have probably been more heavily impacted by forest practices than have stream-type chinook salmon. Again, riparian and shoreline impacts are a major in-basin problem.

Table 9. Categorization of steelhead macrodistribution in the Entiat Watershed, based upon likelihood of protecting or restoring their habitats. Refer to Section 1.2 for a description of categories.

Category	Locations
I	Preston Creek, Brenegan Creek, upper Entiat River (above Fox Creek confluence), Mad River, Roaring Creek
II	Stormy Creek, Potato Creek, middle Entiat River (terminal moraine to Fox Creek)
III	Mud Creek, Crum Creek, lower mainstem Entiat River (below terminal moraine)

5.1.3: Inland fish

Resident rainbow trout, bull trout, and westslope cutthroat trout use Entiat River and tributary habitat most or all their life. Although little is known about their specific population dynamics or demographics, their presumed status and life history patterns for these inland fish are:

a. Spawn and rear in the upper Entiat River and tributaries (*Category I*).
b. Spawn in lower order tributaries, rear in higher order tributaries (*Category II*).
c. Spawn, rear in tributaries, temporarily rear in mainstem Entiat River (*Category II*).
d. Spawn in tributaries, rear in middle mainstem Entiat River (*Categories I and II*).
e. Spawn in tributaries, rear in lower mainstem Entiat River (*Category III*).
f. Spawn and rear in the lower Entiat River and tributaries (*Category III*).
g. Spawn in intermittent side channels, rear in mainstem Entiat River (*Category III*)
h. Spend some or all the life history in perennial side channels (*Categories II and III*).

SECTION 6: ASSESSMENT OF HABITAT CONDITION IN THE ENTIAT WATERSHED

6.1: Basin Setting and Demographics

6.1.1 Basin ownership and land use

The smallest watershed of the four considered in this assessment, the Entiat is probably also the simplest ecosystem. A substantial portion of the watershed lies within public lands, primarily WNF, but there are also lands held by BLM, WDNR, and WDFW. The drainage area is one fourth of the Methow--about 108,500 ha--yet 90% of the watershed is in public ownership. This condition lends itself well to implementation of restoration plans, but it substantially reduces the chances for creativity, since many landscape management decisions are set by the NFP and Record of Decision. Less than 10,000 ha of the watershed is privately owned, most of it is in the valley bottom. More than 75%of the riparian habitat for anadromous salmonids in the mainstem Entiat River is privately owned, however.

The Entiat Basin suffered four major burns within the last 25 years--the Entiat Fire in 1970 (burned 22% of the watershed), the Crum Canyon Fire in 1976 (4%), the Dinkleman Fire in 1988 (20%), and the Tyee Fire in 1994 (36%). To allow salvage logging to begin after the 1994 Tyee fire, the USFS was obligated to produce a “fast-track” watershed assessment for the Entiat Watershed. They were required to do this assessment prior to letting out bids for two reasons: 1) most of the upper drainage lies within northern spotted owl range, and are therefore subject to the *Record of Decision* for that recovery plan, and 2) most of the upper drainage is considered a federal key watershed for bull trout, salmon, and steelhead (USFS et al. 1994). As a result, an assessment of the public lands in the Entiat Watershed is available that may meet most criteria for a conservation assessment in a Conservation Plan under Section 7 of the ESA.

In September 1995 the Entiat TAC completed a multidisciplinary survey on the lower 40 km of the Entiat River. This survey's objectives were to inventory existing stream channel conditions, identify suitable rehabilitation efforts, and collect baseline information for long-term monitoring. Similar work was also done in the late 1970s, by another technical group, sponsored by landowners and the Soil Conservation Service (now called NRCS).

The Entiat River has two subwatersheds (reaches would be a better term in this case). There is a terminal glacial moraine near the Potato Creek confluence (RK 24), which changes the river characteristics (gradient, sinuosity, entrenchment) considerably. There are not sufficient data to have a good flow profile for the lower reach. To address this information need, the Entiat TAC placed a stream gauge in the lower reach (near Keystone) in 1995.

Timber culture and harvest

The water quality impacts related to forest practices on private lands are regulated through the WFPA (RCW 76.09). Riparian buffers for federal land are guided by the NFP. Forest practices impacts are minor in the Roaring Creek drainage, but they are significant in some smaller tributaries (Burns, Preston, Brenegan, McCree creeks). Forest roads in the Potato, Mud, and Crum watersheds are typically located in the narrow floodplains of the mainstems and their tributaries. This road location practice can result in multiple habitat impacts including reduced riparian canopy, increased fine sediment loads, reduced pool habitat, and lost off-channel habitats. Such roads also directly reduce watershed storage capacity by rapidly routing run off into stream channel and by compacting floodplain soils, and also indirectly by discouraging beaver pond construction. Recently, there have been extensive road obliteration and re-construction projects in the WNF--primarily for riparian restoration[12]. Ground-based skidding is still a common practice on the private lands in these watersheds, and can be a significant fine sediment source. Subsequent harvests have left buffers on fish-bearing streams, but the state's minimum requirements do not always result in adequate shade or LWD recruitment.

Conversion of privately-owned timber areas into other uses such as residential subdivisions is not regulated by the Washington Forest Practices Rules and Regulations. However, Chelan County is involved in regulation of the forest conversion process through local land use planning and zoning authority (RCW 76.09.060 and RCW 76.09.240).

The WNF and NRCS have done extensive studies of erosion in the Entiat Watershed (ERCC 1979; WNF 1996a). These studies were done to address the increased potential for erosion resulting from the extensive sheep grazing in the watershed during the 1930s and the series of fires over the last three decades. The following is a *rough and simplified* synopsis of a fairly complicated analysis of erosion hazards in the Entiat Watershed:

[12] *MacDonald, U.S. Forest Service, Wenatchee, WA.*

Criterion	Upper reach	Lower reach
Surface erosion hazard	high	high
Debris slide hazard	high	moderate
Sediment delivery hazard	high	high
Soil compaction hazard	low/moderate	high
Soil moisture stress	low	high
Surface runoff	high	moderate
Subsurface water storage	high	moderate
Regulation of stream flow	high	low/moderate

Relative to hazards from forest land erosion and fluvial sedimentation, streambank erosion is not a significant problem on the Entiat River--mostly because the riparian vegetation in the upper reach is in good shape, and the Corps of Engineers did extensive channeling and rip-rap work in the lower reach. Prior to the 1994 fire, erosive streambanks contributed less than 0.5% to sediment delivery from all sources. Below is a condensed listing of streambank stability ratings for the 480 km of stream surveyed:

Streambank stability rating	Total length (km)	Percent	Cumulative
excellent	97	20	20
very good	97	20	40
good	116	24	64
very fair	55	12	76
fair	57	12	88
poor	40	8	96
very poor	18	4	100

Of the total sediment originating from the stream system, 68% originates from only 24% (or 115 km) of the stream. These highly erosive areas are along Fox, McCree, Brenegan, Preston, and Mud creeks, Crum canyon, and the mainstem Entiat between Fox and Stormy creeks. Upland erosion is a severe chronic problem in the Entiat Watershed, yet substantial restoration efforts are underway in the WNF to address this problem. The erosive streambanks along private lands contribute very little to the overall problem of sediment delivery to spawning gravels. Besides the efforts to rehabilitate these streambanks, little effort would be required in private lands to mitigate the effects of erosion. Several streambank stabilization projects are proposed for the erosive banks on the mainstem Entiat River. Using properly applied bioengineering methods, these projects can provide instream habitat for adult and juvenile salmonids. However, such remedies are not an adequate substitute for natural stream channel/floodplain conditions. Road closures and obliteration, extensive reforestation, culvert upgrades and other efforts are currently proposed for the forest, and will help the situation substantially.

Agriculture

Irrigated tree-fruit (mostly apples and pears) production is the primary commercial agricultural practice in the Entiat Watershed--orchards comprise more than 75% of irrigated cropland in the valley. Alfalfa and grass hay are also produced to a much lesser degree. The number of small non-commercial farms in the watershed is increasing as a few large commercial orchards are divided. However, small non-commercial farms are increasing as old non-commercial homesteads are being sub-platted for residential development. Most of these are upstream of Mud Creek. Of the basin's roughly 1,000 ha of agricultural lands, 650 ha are irrigated.

Orchard lands are along the lower Entiat River and cover a relatively narrow band, less than 1 km wide on both sides of the stream. All current commercial orchards are in low-lying areas adjacent to the mainstem Entiat River downstream of Mud Creek. Above this point, the winters are generally too severe and late frosts are often too hazardous for the successful production of orchard crops. Most of the bottomland areas upstream of the Mad River confluence are used for irrigated pasture. Production of non-irrigated crops is very limited.

Grazing

There are 3,650 ha of rangeland in the Entiat Watershed. Some of the forested land is also used for grazing. Rangeland areas are mostly steep to very steep. Large tracts of the watershed are not suitable for grazing, because of the steep topography and vegetation types. The rangeland is subject to sheet and rill erosion when vegetation and litter are sparse. The rangelands are best suited to grazing in spring and fall months (USDA 1979). Commercial level grazing is now minor in the Entiat Watershed. There is only one band of sheep in the Tillicum Creek area for about a month, and less than 150 head of seasonal cattle graze in the Mud Creek/Crum Creek drainages. Historically, some areas of the Entiat Watershed were extensively grazed, resulting in loss of ground cover and resultant overland water and mud flows during high intensity storms. However, these problems were addressed after the National Forest System was created; in the 1920's the USFS started to regulate grazing. When compared to the extensive damage from wildlfires in the Entiat Watershed, historical grazing as a vegetative manipulator was not significant.

While smaller in scale, hobby farms can result in significant localized impacts, and contribute to cumulative effects in the watershed. In some locations, concentrated livestock use along streams may be causing loss of riparian vegetation and decreased bank stability. Degradation of water quality may also be occurring (through sediment and pathogens). In some locations, irrigation return flows may be carrying a variety of non-point source pollutants (sediment, nutrients, pathogens, agricultural chemicals) that threaten water quality.

Recreation

Although no attempt has been made to quantify the impacts of recreation, local biologists have observed evidence of poaching and have found campers harvesting LWD in the region. These problems may occur in the upper Entiat River. To protect stream-type chinook salmon, WDFW recently imposed selective resident fishery regulations throughout much of the anadromous fish zone that should significantly reduce juvenile hooking mortality. Portions of the zone however, remain open to bait fishing. The recently abandoned practice of planting catchable hatchery rainbow trout in this portion of the sub-basin probably had some impact on chinook salmon smolt production. Large wood material and higher flows provide protection from poaching, harassment, and predation for mature stream-type anadromous salmonids. Importance of shelter habitat increases as forest road construction provide easier fishing access and vulnerability to legal and illegal harvest.

<u>6.1.2: Water resources and management</u>

Water quantity

The WDOE completed IFIM studies on the upper and lower reaches on Entiat River and lower Mad River (Caldwell and Beecher 1995). The lower site, located at RK 1.6, represents the lower 16 km of the Entiat River (characterized as mostly boulder/cobble riffle due to channelization and rip rap from past flood control activities). The upper site is at RK 27.8, which is less confined with gravel/cobble bars and alternating riffle/pool sequences. The modeling process from this study depict the relationship between instream flow and fish habitat in terms of weighted useable area per 1,000 linear feet of stream. They illustrated how much habitat is available at a given instream flow for a given species and life history stage.

No instream flow recommendations were made in this report. Based on these studies, (Kirk et al. 1995) recommended base flows that are needed to protect fish habitat. These recommendations have not been adopted into rules. The recommended flows are as follows:

Time period	Upper reach	Lower reach
July 1 to March 15	275 cfs	185 cfs
March 16 to April 15	325 cfs	250 cfs
April 16 to May 31	375 cfs	325 cfs
June 1 to June 30	325 cfs	250 cfs

These values may be used to negotiate with interested parties to establish base flows for the Entiat River. Some individuals expressed concerns about the application of the IFIM methodology in setting the recommended instream flows for the Entiat River. Some believed that it yielded unreasonable recommendations for weighted usable areas for rearing fish under some flows. It is recognized as a good tool for setting optimum flows for fish however, and useful for negotiations for instream flows (Cavendish and Duncan 1986).

The Entiat TAC reviewed and found acceptable the IFIM work conducted by WDOE and WDFW. Some TAC members had reservations: the stream channel is highly entrenched in the lower Entiat River, and has a long expansive riffle habitat with a high wetted width:depth ratio. They felt this condition resulted in an IFIM model output that set optimum flows at levels higher than existing flows at certain times of the year. In many reaches, stream flows would have to increase substantially to result in a marginal increase in the weighted usable area. Other members maintained that an IFIM model typically has a higher precision in predicting fluvial processes in an entrenched riffle channel. Some TAC members were concerned about the low number of transects used to depict river conditions, and the lack of a time series approach.

The disparity in mean seasonal flows on Entiat River have the potential to vary more than the other streams in the Mid-Columbia Region. For the period of record 1957-1993, the mean monthly flows (measured at the Ardenvoir gage) range from 80 cfs in September to about 1,500 in June (Kirk et al. 1995). This lack of water retention is partly a result of the natural characteristics of the watershed, irrigation water withdrawals, and human-caused stream channel modifications in lower Entiat River (WNF 1996). These factors, in combination, may limit late summer rearing habitat for juvenile salmonids. Hydrologists involved in the Entiat Watershed Assessment agree that ground and surface water in the valley are hydraulically connected (Kirk et al. 1995). There are no data to demonstrate the speed of ground water movement between the irrigated orchards and the river itself, but most agree that movement is fairly quick.

River flows are below the recommended flows for most of the year--although the recent flow data are not that solid for the lower reach. The Entiat River has been included on state 303(d) list of “water quality limited” waters because of instream flow deficiencies (this list awaits final approval by EPA). This means that it appears that the current flows of the Entiat River are not sufficient to maintain one or more designated uses of those waters, in this case, fishery resources. Agricultural use is not as major a factor in Entiat, however, as it is in other streams in the region. It is not known what percent of the mean monthly flow in the Entiat River is diverted for irrigation. Flow data recorded since 1957 indicates that for the time period from July 1 to March 15, river flows are below the recommended flow levels for 221 days, or 86% of the time (Kirk et al. 1995). At this time, WDOE has 19 applications for water permits for the Entiat River (12 ground water and 7 surface water), all in the lower reach. This would be in addition to the 30 ground water and 75 surface water rights that currently exist. To complicate this, there are a total of 303 unresolved water claims on the river. The WDOE must evaluate the importance of instream flow levels to fish in the Entiat River, and the extent to which these flows are subject to human control. After such an evaluation, WDOE will proceed to either remove the Entiat River from the 303(d) list, because the data do not support it, or initiate a TMDL process and identify actions necessary to maintain instream flows at a desired level.

Water quality

Typically, late summer water temperatures are not a serious problem in the lower Entiat River. However, temperature and pH have exceeded state standards and the Entiat River is listed as an impaired water body on Washington State 303(d) list (Ehinger no date; Kirk et al. 1995). As part of the ongoing watershed assessment, the USFS has six continuous reading thermographs on the river[13]. Maximum temperatures are typically less than 15^{o} C., which is tolerable for rearing juveniles. The 1974-1986 stream temperature record for Entiat NFH has a mean July-September water temperature of 13.6^{o} C. Temperature standards are periodically exceeded in lower Mad River. At times, the pH readings at some sites have reached 8.5[14], which is an exceedence of the WDOE standard, but the causes are not known and are assumed to be partly of natural conditions.   Existing data indicate that summer water temperatures in the lower Entiat (downstream from Burns Creek) and lower Mad Rivers often exceed 16^{o}C. Winter anchor ice is a problem in the Entiat below Ardenvoir and in the Mad River[15].

Sediment levels, especially fine sediments, are impacting beneficial uses, primarily aquatic habitat and irrigation. These sediments are derived from both natural and human-caused (accelerated) sources. Sediment is a natural component of the Entiat River system; however, the natural range of variability of fine sediment loading in Entiat River is unknown. Opportunities exist to reduce existing and future sources of accelerated sediment in the watershed.

In some locations, failing or sub-standard septic systems and/or surface runoff from home sites may be carrying a variety of non-point source pollutants (e.g., pathogens, sediment, nutrients, etc.) that threaten water quality. Orchard management involves use of a number of agricultural chemicals (sprays and fertilizers) that pose a potential risk to water quality.

6.2: Historical and Existing Aquatic Habitat Conditions

6.2.1: Riparian and stream channel condition

Riparian habitat

Prior to the 1995 survey by Entiat TAC, there was limited information available on the condition of the riparian zone in lower Entiat River. An extensive analysis of the status of the riparian system, with recommendations, will be available when NRCS completes its report (preliminary data are in Table 10). The dominant native riparian species in the lower reach (downstream of Ardenvoir) are black cottonwood, coyote willow, and Pacific willow. Orchardists have engaged in efforts to remove cottonwood, which is stoloniferous, and sends extensive root systems into the irrigated orchards. There is also a concern that cottonwoods may be a host for scale, a virus that affects pears, and that cottonwood trees restrict air flow, causing an increased likelihood of frost damage. Second to instream flows, this question of cottonwoods is the most divisive issue in the Entiat River. Fish habitat managers are reluctant to remove cottonwoods, since it is the indigenous climax species which grows quickly and provides important roles in bank

[13] *Archibald, U.S. Forest Service, Entiat, WA.*

[14] *Hall, Washington Department of Ecology, Yakima, WA.*

[15] *Archibald, U.S. Forest Service, Entiat, WA.*

protection, fish cover, and nutrient input. Efforts are now underway to examine the feasibility of using McKenzie willow, water birch, and other species as suitable replacements for revegetation projects. These species grow relatively quickly, provide shade, cover, and food for fish, yet may not be as aggressive a competitor with fruit trees. Some demonstration projects for these species are currently being discussed. Substitutions should be on a site-specific basis, and evaluated periodically. Considerations should include shading effects, LWD recruitment, and allochthonous input.

Based upon the 1995 stream channel inventory and work presented in Mullan et al. (1992), habitat diversity in lower Entiat River is remarkably low (Table 11). The riffle:run:pool ratio, for example, is 0.72:0.25:0.03. The upper reach has 28% pools, which USFS rates as good. Also, there are few woody debris pieces in lower Entiat River; seven large woody debris (>20" d.b.h., >35' long) pieces were found in lower Entiat River (0.4 per km). To provide a comparison, the upper reach, predominantly in WNF, has accumulations of LWD pieces of 24.0 per km or higher. These two factors (lack of pools and woody debris), are the primary limitations to natural production of salmon and steelhead on lower Entiat River. Much of this can be attributed to the flood-control projects undertaken by the U.S. Army Corps of Engineers under the 1946 Federal Flood Control Act. Mudflows resulting from high intensity rainstorms and/or rain on snow events after the significant fires in the Entiat Watershed have made a significant contribution to siltation.

Table 10. Description of the riparian vegetation and stream channel type in the Entiat River from mouth to USFS boundary, determined from 1995 surveys by Natural Resource Conservation Service.

Reach	Length (km)	Reach description	Canopy cover (%)	Dominant age class	Dominant plant community[a]	Dominant stream classes[b]
I	3.7	End of slackwater to firehouse bridge.	5	Small Tree (8.0"- 20.9'd.b.h.)	Cottonwood/ Red osier Dogwood	B3c, C3, F3
2	4.9	Firehouse bridge to old Roaring Creek bridge	5	Small Tree	Cottonwood/Red Osier Cottonwood/Erect Willow	F3, B3c, C3
3	4.4	Old Roaring Creek bridge to bridge near Morical canyon.	5	Large Tree (2 1.0"- 3 1.0" d.b.h.)	Cottonwood/ Erect Willow	B3c, F3, C3
4	4.9	Bridge near Morical canyon to bridge near Mud Creek.	5	Small Tree	Cottonwood/ Alder	F3, B3c
5	3.6	Bridge near Mud Creek to Evan Heaven bridge.	5	Small Tree	Cottonwood/Alder Coffer/Alder	F3, B3c
6	3.6	Evan Heaven bridge to terminal moraine.	5	'Shrub/Seeding and Burned Dead Tree	Mixed Coffer/ Alder	F3, B3c
7	3.6	Terminal moraine to USGS gaging station.	5	Shrub Seedling Grass/Forb	River Birch/ Broadleaf Sedge .	C4
8	4.0	USGS gaging station to section 14 Forest Service boundary.	25	Large Tree Burned Dead Tree	Cottonwood/River Birch/Dogwood	C4, C5
TOTAL	32.7					

[a] - From Hankin and Reeves 1988

[b] - From Rosgen 1994.

The WNF rated aquatic habitat quality in the Transport Zone of Entiat River. That reach is upstream of Entiat Falls (that area inaccessible to anadromous salmonids). Most habitat is rated as fair to excellent (WNF 1996), according to WNF (1990) standards. Fewer than 25% of the surveyed reaches in the upper River do not meet USFS standard for pool habitat. The following is summary of USFS rating for most of that reach in their watershed assessment:

- rearing/holding — fair to excellent
- off-channel winter rearing — fair to good
- in-channel winter rearing — fair to good
- resident adult habitat — good, except in localized areas
- spawning — fair to excellent where suitable habitat exists

The habitat quality in the Transitional Zone (McCrea Creek to Entiat Falls) is rated as fair to excellent (WNF 1996), according to WNF (1990) standards. The following is summary of the USFS rating for most of that reach in their watershed assessment:

- rearing/holding — fair to excellent in fish bearing streams
- off-channel winter rearing — fair to good
- spawning — fair to excellent, where suitable habitat exists
- in-channel winter rearing — fair to good
- resident adult habitat — good, except in localized areas

The habitat quality in the Depositional Zone (Mouth to McCrea Creek) is rated as fair to poor (WNF 1996), according to WNF (1990) standards. The following is summary of the USFS rating for most of that reach in their watershed assessment:

- rearing/holding — fair to poor in fish bearing streams
- off-channel winter rearing — fair to poor
- spawning — fair to poor, where suitable habitat exists
- in-channel winter rearing — fair to poor
- resident adult habitat — seasonally poor, overall rated as poor

In Mad River, which supports salmon and steelhead, the USFS lists spawning and rearing habitat as “poor” up to Tillicum Creek confluence (Table 11). After that, the habitat is upgraded to “fair” up to Young Creek, well beyond the reach of anadromous salmonids.

Table 11. Average dimensions and features of principal streams (order 3 to 5) in the Entiat Watershed (adapted from Mullan et al. 1992).

Steam name (river miles)	Mean area (acres)	Mean low flow (cfs)	Mean flow width (cfs)	Mean gradient (ft)	Mean Pool/riffle (%)	area ratio	Drainage (sq. mile)
Entiat R.							
(0.9-16.0)	146	122	385	80	1.1	6:94	419
(16.0-29.2)	107	68	316	67	1.1	48:52	203
Mad R.							
(0.0-13.9)	50	17	69	30	2.9	19:81	92

Stream channel

The Entiat Valley was impacted by major flood events in the 1940s and 1970s. As a result, virtually all of the lower 35 km of the Entiat River has been channeled--a dike on one side, and the Entiat River road on the other--to protect flood-prone properties. Stream sinuosity is low, with very few point bars for gravel accumulation. The lower 20 km of the mainstem Entiat River is highly channeled (Rosgen stream types B and F), resulting in a trapezoidal stream channel for the bankfull width[16]. Instream habitat diversity is very low, with few pools, glides, or pocket waters to speak of. As a result, there are very few resting areas for both adult and juvenile salmon. Some landowners in the lower Entiat River remove woody debris from the stream, concerned that logjams will accumulate, and increase the potential for streambank damage during flood events.

6.2.2: Wetland resources

As is typical in a landscape with steep slopes and rocky terrain, many wetlands in the Entiat Watershed are closely associated with stream systems. Based on 1983, 1984, and 1990 aerial photographs, roughly 1.4%of the watershed is classified as wetland under the USFWS National Wetland Inventory (Table 12). Virtually all of these wetlands are above Potato Creek Moraine. Wetlands in this reach serve important hydrologic and biological functions in this system. Many of these sites are adjacent to critical spring chinook salmon spawning habitat. These areas are also subject to increased pressure from development.

Table 12. Total area of wetland habitat in the Entiat Watershed, and percent of total. Wetlands were identified in the USFWS National Wetland Inventory.

System and class	Total area (ha)	Percent of watershed
Palustrine emergent	207.0	0.17
Palustrine scrub-shrub	221.9	0.18
Lacustrine open water	947.2	0.77
Lacustrine, littoral, unconsolidated shore	2.3	0.00
Palustrine, open water	28.5	0.02
Riverine, upper perennial, open water	167.7	0.14
Riverine, perennial, unconsolidated shore	37.6	0.03
Palustrine, forested	135.2	0.11
Palustrine, unconsolidated shore	1.5	0.00
Lacustrine, littoral, unconsolidated bottom	9.4	0.01
Total mapped wetland area	1,758.3	1.42
Upland area	121,887.5	98.58
Total area in basin	123,645.8	

[16] *Southerland, Natural Resource Conservation Service, Spokane, WA.*

6.3: The Relationship of Existing Aquatic Habitat Conditions to Biological Productivity

6.3.1: Stream Channel Conditions

Mainstem Entiat downstream from Potato Creek Moraine -Flood control dikes, gravel mining, and channel straightening associated with U.S. Army Corps of Engineers' flood control projects and county roads have dramatically simplified habitat in this section of the river. Channel segments 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 wood recruitment resulting from these and other actions exacerbated conditions. Today, the lower mainstem is almost entirely devoid of large woody debris, and there are some areas with no remaining riparian vegetation. These practices in combination constitute the greatest impact to salmonid habitat in the mainstem Entiat downstream of Mad River. Sedimentation, gravel scour and anchor ice are potential sources of pre-emergence mortality. The early rearing environment is fairly hostile. The combination of natural and artificial channel confinement severely limits the availability of suitable early rearing habitat. Velocity refugia are primarily associated with rip-rap and afford little cover from avian or piscine predators. Habitat enhancement efforts should include creating additional velocity refugia and better cover.

Late rearing habitat quality also lacks in-channel diversity. The lack of cover, particularly as flows drop in the summer and fall, may be limiting the salmonid productivity through both depensatory and compensatory 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[17].

Mainstem Entiat upstream from Potato Creek Moraine - In some reaches, there is stream bank loss due to increased rates of lateral channel migration. This migration is accelerated by bank clearing. In general, this reach has a good pool-riffle ratio, and fish habitat in this reach is in good condition. However, large woody debris is locally lacking. Pool habitat (geomorphic) exists every 5 to 7 bankfull channel widths; off-channel habitat exists in stable locations.

Based on stream survey information (from USFS, USFWS, and WDFW) and the observations of fish biologists familiar with the basin, most Entiat River stream-type anadromous fish spawn in habitats least modified by land use practices and flood control projects. Early rearing also occurs in these more pristine areas. A portion of the juvenile population may move downstream gradually during summer, fall, and winter rearing (Hillman and Chapman 1989). Here they encounter increasingly altered conditions where recruitment of shelter habitat (primarily large wood) and food supply is reduced because of loss in riparian areas.

Forest practice impacts to this life history type are believed to improve if the riparian buffers required by the NFP remain in effect, and if forest road construction techniques and maintenance standards continue to improve. The Mad River and Mud Creek each experience very low flows during late summer, but it is not known to what extent this phenomenon results from forest management. The current forest hydrology models that have been applied to these watersheds indicate only slight exacerbation of peak and summer low flows. No data regarding spawning gravel condition are available, but the USFS estimates that sediment production from forest practices is minor (<10% of background). The upper mainstem Entiat River still suffers from the scouring effects of minor flood events.

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[17] *Archibald, U.S. Forest Service, Entiat, WA.*

Inland fish

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 bottomland development (bank protection, channelization, water withdrawal). Key habitat conditions for resident fish, in particular rainbow trout, westslope cutthroat trout, and bull trout revolve around minimizing sedimentation and gravel scouring, and providing cover.

SECTION 7: RECOMMENDED STRATEGIES FOR ENTIAT WATERSHED

The following recommendations are based solely upon a biological assessment of the habitat needs and life histories of aquatic species in Entiat Watershed. Most recommendations are made in concert with those being developed under the CRMP Model Watershed Plan. Many of these measures would require participation from private land managers, irrigation districts, and public entities.

7.1: Habitat Protection

The highest priority for maintaining biological productivity will be to allow unrestricted stream channel diversity and flood plain function (Section 1.6.2). The principle means to meet this objective is to secure riparian habitat--anywhere in the watershed--either in conservation agreements, easements or direct purchases. Salmonids which exhibit stream-type life history strategies will benefit most from these efforts. *Category I and II* phenotypes are targeted, and some *Category III* phenotypes may benefit. In addition, protection of these habitats would presumably benefit many non-salmonid species that are identified on the WDFW PHS list. Obviously, some areas have more acute needs, because of their importance for existing life history strategies, and should be given greater emphasis. The following list identifies stream reaches which should receive protection, and is therefore ranked in biological priority:

1) Riparian bottomland and side channels in the Stillwaters Reach (between the terminal moraine and Preston Creek)
2) Riparian bottomland and side channels along the mainstem Entiat between Preston Creek and Fox Creek.
3) Riparian bottomlands in the lower Mad River, Stormy Creek, and Roaring Creek.

7.2: Habitat Restoration

A range of strategies is recommended for habitat restoration in Entiat Watershed. Like the *Habitat Protection* strategy, most strategies center on efforts to maintain or increase complexity of the stream channel and floodplain (Section 1.6.3). Most of these efforts are on the lower reaches and aggradation zones, and would benefit both ocean-type and stream-type salmonids. There is potential to improve instream habitat in the lower Entiat, where the need is acute. Simple structures such as low vortex rock weirs, bankside root and bole placements, and many other actions to encourage thalweg development, decrease the wetted width:depth ratio, and increase the frequency of pools would benefit all species--both hatchery and wild. There is good access to the river for large implements, with many large boulders and boles readily available. These benefits may be short-termed however, and maintenance costs would be substantial.

Woody debris recruitment is needed in the lower Entiat, yet the only realistic means to accomplish this is to have a combined short-term/long-term strategy. Initially, the focus should be to place large wood in the river by cabling snags to the streambank, place boulders in the stream channel to encourage thalweg development and resting cover, and to construct side channel rearing areas.

The long term approach is to secure riparian habitat in the Entiat downstream of the Mad River confluence--where it is needed most. This may be done through conservation agreements, easements, or direct purchases.

Installations of low level vortex rock weirs, root wad revetments, and large boulder barbs would increase the number of pools, and allow deposition of spawning gravels (see subsection on stream channel). In the Mad River, the largest tributary to the Entiat, such measures also would be feasible. In general, these rehabilitation efforts appear to be accepted by most private landowners. A multi disciplinary team of fishery biologists, hydrologists, and fluvial geomorphologists will provide specific recommendations on the types of structures that would work best, based upon channel configuration. These are regarded as short-term approaches to increase productivity, and will likely require maintenance.

The most feasible results for habitat restoration lies primarily in structure placement, as an immediate improvement, and riparian setbacks as the long-term solution. This short term/long term approach is the most pragmatic restoration practice available in situations where there is a potential conflict with agriculture (ACCD 1995). There is potential to purchase or secure easements (on a willing buyer/willing seller concept) for riparian bottomlands on Mud and Potato creeks, Mad River, and the mainstem Entiat River upstream of Brief.

Certainly, the most pressing needs on the Entiat River are the lack of woody debris and riparian cover in the lower reach, yet there are other factors that adversely affect salmonids. Instream flows limit salmonid production in the Entiat River, but not to the chronic and severe extent seen on the Methow River. However, there may be potential to negotiate changes in water use patterns with individual irrigators, as well as the larger irrigation groups that represent many users.

There are defunct side channels near Fox and Brenegan creeks that were used on an intermittent basis for artificial rearing of salmon and steelhead. Similar side channels exist on private properties in the lower Entiat River. There is potential to renovate these artificial side channel rearing areas for potential summer steelhead and spring chinook salmon outplants.

THE METHOW WATERSHED

SECTION 8: ASSESSMENT OF AQUATIC SPECIES IN THE METHOW WATERSHED

8.1: Commercially and Culturally Important Fish Species

The Methow River supports several populations of economically and culturally important fish species. The watershed currently supports anadromous runs of chinook salmon and steelhead. Sockeye salmon are occasionally observed (Chapman et al. 1995b). Important inland species include mountain whitefish, bull trout, rainbow trout, and westslope cutthroat trout. A recreational fishery exists for steelhead, resident rainbow, cutthroat, and brook trout. Currently, no sport fishing for salmon is allowed on the Methow River. Bull trout continue to be legally harvested from the Lost River, a tributary to the upper Methow River. Wild spring and summer chinook salmon and steelhead populations are listed as depressed in SASSI (WDF et al. 1993). Fish passage into the Methow River was significantly impeded from 1912 until the 1930s by a hydroelectric dam built across the river at Pateros.

8.1.1: Ocean-type anadromous salmonids

Ocean-type chinook salmon return to the Methow River primarily in July and August, but may enter the river into early October. No summer chinook salmon spawn in the tributaries of the Methow, and virtually all summer chinook salmon spawn downstream of the Chewuch River confluence. The furthest downstream spawning is near the mouth of French Creek, a total of 61 km of spawning habitat. That section consists of four valley bottom types (Table 15). Spawning begins in late September in the upstream reaches and ends in early November in the lower river (Hillman and Ross 1991). Emergence timing is probably January through April. Juveniles may rear from a few months to a year before migrating downstream. Juveniles generally emigrate to the ocean as subyearling fry, leaving Methow River from one to four months after emerging from the gravel in April. Ocean-type salmonids are most dependent on habitat in the mainstem Methow. From 1967-1991, the average redd deposition of ocean-type chinook salmon to the Methow River was 464 redds (based on adjusted aerial survey estimates), with a range from 93 to 1,055 redds. To minimize redundancy with the stream-type chinook salmon section, only two general life history types are presented here, which express the presumed historical life history strategies for ocean-type anadromous fish: 1) spawn in the mainstem and leave the system in late spring/summer as subyearlings, and 2) spawn in the mainstem and leave the system in fall as subyearlings. Both these phenotypes are classified as *Category I*. Some cohorts presumably rear in the mainstem through winter when conditions are favorable to this strategy (*Categories I and II*).

8.1.2: Stream-type anadromous salmonids

Spring chinook salmon

Stream-type chinook salmon return to Methow River from late May through July. The primary spawning areas are the mainstem Methow River upstream of the Chewuch River confluence, the Twisp River, the Chewuch River, and the Lost River (Hubble and Sexauer 1994). Spawning is observed occasionally in Foghorn Ditch as well, but is likely that the fish that spawn here are of hatchery origin (WDF et al. 1993; Bartlett 1995). A very limited amount of spawning has also been reported in Early Winters, Wolf, and Gold creeks (ONF 1994). Spawning begins in early August in the upstream reaches of the tributaries, and continues downstream through August and September. The average estimated natural escapement to Methow River (which includes wild and hatchery fish, and is based upon redd count expansions) is 3,429 for the period 1960-1969, 2,471 for the period 1970-1979, 1,061 for the period 1980-1989, and 772 for the period 1990-1995[18]. The escapement to Methow River (as measured at Wells Dam) in 1995 was 72.

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[18] *LaVoy, Washington Department of Fish and Wildlife, Wenatchee, WA.*

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 the spring migration begins around the end of April and continues through May, but downstream movement from the tributaries may be continuous, and not always associated with parr/smolt transformation (Hubble and Sexauer 1994).

The Twisp River spring chinook salmon spawning escapement over the past three decades, 1964-1973, 1974-1983, and 1984-1993 is estimated to average 505, 384, and 310, based on spawning ground surveys (USFS 1995a). The highest juvenile rearing densities in Twisp River are found between RK 5 and RK 30--through private lands. Spring chinook salmon spawn in Chewuch River from the mouth of Boulder Creek to Lake Creek, and in a small section around the mouth of Thirtymile Creek. Lake Creek is also used by spawning chinook salmon.

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

a. Spawn, rear, overwinter in upper reach tributaries --above Twisp River *(Categories II and III)*.
b. Spawn, rear, overwinter in lower reach tributaries--below Twisp River (*Category III*).
c. Spawn, rear in tributaries; overwinter in upper mainstem Methow (*Category II*).
d. Spawn, rear, overwinter in mainstem Methow above Twisp River (*Category II).*
e. Spawn, rear, overwinter in mainstem Methow below Twisp River (*Category III).*
f. Spawn in tributaries or mainstem Methow, rear or overwinter in accessible side channels (*Categories II and III)*.
g. Spawn, rear in upper tributaries, overwinter in lower tributaries (*Categories II and III*).
h. Spawn, rear in lower tributaries, overwinter in lower mainstem (*Categories II and III*).
I. Spawn, rear in upper reach tributaries, outmigrate in fall/winter (*Categories II and III*)
j. Spawn, rear in lower reach tributaries, outmigrate in fall/winter (*Category III*).

Sockeye salmon

Sockeye salmon adults are observed nearly every year in Methow River during spawning ground surveys for chinook salmon. The 1990-1994 average number of sockeye salmon seen in Methow River is 52.6 (range: 13 - 90; Chapman et al. 1995b). These fish are either strays from the Wenatchee and Okanogan stocks, or they may be artifacts of the Winthrop NFH releases between 1945 and 1958 (Mullan 1986). Genetically and demographically, these salmon appear to be more similar to the Wenatchee stock than the Okanogan stock (Chapman et al. 1995a).

Little is known about the life history of Methow sockeye salmon; they are assumed to rear primarily in the impounded lower reach of the Methow River and the Columbia River reservoir (Chapman et al. 1995b). Although not generally referred to as such, sockeye salmon are "stream-type" in the sense that they reside in freshwater (nursery lake) for more than a year. Spawning occurs from mid-September to mid-October. It is assumed that juveniles move downstream from the river to the reservoir immediately after they emerge from the gravel (March through May). These fish are classified as *Category III* because of their small population size.

Steelhead

Steelhead use the mainstem Methow River and eleven of its tributaries: Black Canyon Creek, Gold Creek, Libby Creek, Benson Creek, Beaver Creek, Wolf Creek, West Fork Methow, and Early Winters Creek, and the

Chewuch, Twisp, and Lost rivers. In general, steelhead adults migrate into the Methow River in both fall and spring after spending one to three years in the ocean (Wydoski and Whitney 1979). Spawning occurs primarily in late March, but may extend into July. Their eggs incubate from late March through June, and fry emerge in late spring to August. Fry and smolts disperse downstream in late summer and fall. Some fry and parr rear in the mainstem Methow River all year. Their use of tributaries for rearing is variable, depending upon population size, and both weather and flow conditions at any given time. Most smolts leave the Methow River in March to early June, after spending one to seven years in freshwater, but more leave after two to three years (Peven et al. 1994). Some steelhead live their entire lives in fresh water.

Listing all of the possible steelhead life history types will not be attempted here. They probably exhibit all of the types listed for stream-type chinook salmon, compounded by variable fresh water residence, and penetrate deeper into most of the tributaries than stream-type chinook salmon do. Categorization of steelhead robustness can be better done by analysis of their distribution, rather than phenotypic diversity (Table 13). The habitat impacts and threats listed in the stream-type chinook salmon section also apply to steelhead. Those individuals using the upper reaches of tributary habitats have probably been more heavily impacted by forest practices than have stream-type chinook salmon. (8) Again, riparian and shoreline impacts are a major problem.

Table 13. Categorization of steelhead macrodistribution in the Methow Watershed, based upon likelihood of protecting or restoring their habitats. Refer to Section 1.2 for a description of categories.

Category	Locations
I	Chewuch River, Twisp River, lower Gold Creek, upper Methow River (above Chewuch confluence)
II	Black Canyon Creek, South fork Gold Creek, Foggy Dew Creek, north fork Gold Creek, lower Libby Creek, middle Methow River (French Creek to Chewuch River), lower Benson Creek, lower Beaver Creek, Wolf Creek, Lost River, Early Winters Creek
III	Black Canyon Creek, Squaw Creek, French Creek, McFarland Creek, Texas Creek, upper Libby Creek, lower mainstem Methow River (below French Creek confluence)

The average hatchery summer steelhead run size from 1983-1992 was 15,015 with a sport catch of 7,804 and a tribal catch of 388 leaving 6,823 to escape to spawn in the Methow watershed. Natural summer steelhead comprise about 10% of the total steelhead run in the Methow River system[19]. Steelhead spawn naturally in the lower mainstem Methow River from 1 March to 15 May, although hatchery fish have been observed spawning in the lower river as early as January[20]. They spawn in the upper Methow and some tributaries from 15 March to 31 July (Mullan et al. 1992). Most of these steelhead spend two to three years rearing in the mainstem, or three to five years in its tributaries. A given year class undergoes an almost continuous outmigration from the river during this period. Movements are complex and not fully explainable.

[19] *LaVoy, Washington Department of Fish and Wildlife, Wenatchee, WA.*

[20] *Bickford, Douglas County Public Utility District, East Wenatchee, WA.*

After nearly 14 months of rearing in a hatchery (primarily Wells FH, but recently also at Winthrop NFH), the smolts are planted into the mainstem Methow River from 20 April until 20 May. Almost 10% of these hatchery fish spend an additional year in residence prior to emigration. Wild steelhead stock /recruitment relationships from several reports show little or no replacement[21]. Most steelhead smolts leave the system at age 2 or 3, depending upon stream temperatures. Most adults spend two years at sea, so the dominant age in the Methow River system is 2.2 and 3.2. Females tend to stay longer at sea. Currently, and for at least the last twenty years, steelhead spawning in the rivers are, and have been, predominantly hatchery descendants. A more complete discussion of steelhead life history is given in Mullan et al. (1992).

8.1.3: Inland fish

Resident rainbow trout, bull trout, and westslope cutthroat trout use Methow River and tributary habitat most or all their life. Although little is known about their specific population dynamics or demographics, their presumed status and life history patterns for these inland fish are:

a. Spawn and rear in the upper Methow River (above Chewuch confluence) and tributaries (*Category I*).
b. Spawn in lower order tributaries, rear in higher order tributaries (*Category II*).
c. Spawn, rear in tributaries, temporarily rear in upper mainstem Methow River (*Categories I and II*).
d. Spawn in tributaries, rear in middle mainstem Methow River (*Categories I and II*).
e. Spawn in tributaries, rear in lower mainstem Methow River (*Categories I and II*)
f. Spawn in intermittent side channels, rear in mainstem Methow River (*Category II*)
g. Spend some or all the life history in perennial side channels (*Categories II and III*).

Rainbow trout

The status of rainbow trout in Methow River is not known. It is assumed that the Methow system contains a mixture of full time resident rainbow and ocean migrating steelhead. Mullan et al. (1992) detected rainbow trout/steelhead in the mainstem Methow from the mouth to RK 123, and in selected reaches of the following tributaries: Gold Creek, Twisp River, Chewuch River, Lake Creek, Wolf Creek, Early Winters Creek, Lost River, Foggy Dew Creek, Crater Creek, Beaver Creek, Bridge Creek, War Creek, Eightmile Creek, Twentymile Creek, Goat Creek, Trout Creek.

Bull trout

Bull trout have been sampled or observed in selected reaches of the following tributaries: Buttermilk, Goat, Wolf, Early Winters, Lake, Reynolds, South, and Monument creeks, Lost River, Twisp River, and the West Fork and mainstem Methow River (Mullan et al. 1992; Proebstel and Noble 1994). Brook trout have been widely stocked into the Chewuch and Twisp rivers since the 1920s (ONF 1994). These fish are prolific in some tributaries to these rivers and pose a substantial risk to bull trout because these two species hybridize, and produce sterile offspring (Platts et al. 1993).

SECTION 9: ASSESSMENT OF HABITAT CONDITION IN METHOW WATERSHED

9.1: Basin Setting and Demographics

9.2.1 Basin ownership and land use

Methow Watershed has five subwatersheds, and a total drainage area of 464,100 ha. Of the four watersheds in the Mid-Columbia Region, the Methow Watershed has the most land in public ownership-94%, yet it ranks low in annual flows (about 1,600 cfs, measured at Pateros). Methow Watershed has an average run-off (cfs) per square mile of

[21] *Brown, Washington Department of Fish and Wildlife, Wenatchee, WA.*

drainage area of 1.1, compared to 1.9 and 2.6 for the Entiat and Wenatchee watersheds, respectively (Mullan et al. 1992). Most of the riparian bottomlands in the reach accessible to anadromous salmonids are privately owned. The Pasayten Wilderness, Sawtooth Wilderness, and North Cascades National Park comprise a substantial portion of this watershed; the ONF manages the remainder for multiple use--very little of which is irrigated agriculture (The Eight Mile Ranch on the Chewuch River is flood irrigated). Of the remaining 6% of the watershed--the private property--only 5,180 ha are irrigated cropland (orchard, pasture, and hay). Water withdrawal is a major factor in the overall management of Methow Watershed, but is practiced on 1.1% of the drainage. Of the four tributaries, the effect of irrigation on instream flows is most acute in the Methow (MPP 1994; Chapman et al. 1995a). Instream flows limit salmonid production at virtually all stages of the freshwater life cycle (Caldwell and Catterson 1992). Mullan et al. (1992) assert that a strong hydraulic continuity exists between the Methow River and the groundwater aquifer from RK 44 to RK 81, and that dewatering of the stream channel between RK 100 and 119 may be a natural event that is independent of irrigation diversion. They suggest that some irrigation water diverted in summer may return to the river in winter low flow periods through groundwater recharge.

Given the extensive size of the national forest in the basin, “multiple-use” is a dominant factor: timber management, grazing allotments, and recreation. The ONF developed its *Land and Resource Management Plan* in 1989, which in combination with the 1994 *Record of Decision* for the northern spotted owl, will strongly influence the management plans for the upper Methow Basin. The USFS has an extensive list of watershed restoration projects that are proposed, and currently out for public review. In general, habitat conditions are good to excellent in the forest (see subsections below), and sediment delivery to lower reaches is not a major problem (except the lower Chewuch River).

The USFS has completed their analysis for the Twisp and Chewuch watersheds. Chewuch Watershed has over 1,600 km of stream channel, with about 80 km of Class I streams, used by anadromous salmonids (ONF 1995). About 12 km of the Chewuch River flows though private lands. About 30 km of the Twisp River flows through private lands, yet only 7% of the watershed is in private ownership. Both of these watershed were extensively grazed in the 1930s; some effects of these land use practices are still visible today.

Timber culture and harvest

The water quality impacts related to forest practices on private lands are addressed through the Washington Forest Practices Act (RCW 76.09). Forest roads in Twisp watershed are typically located in the narrow floodplains of the mainstems and their tributaries (Poorman, Newby, Coal, Little Bridge, Buttermilk, Canyon, and Lime creeks). An extensive road system was established since the 1930s in Chewuch Watershed, with many roads along the bottomlands of the mainstem, and tributaries (Boulder, Cub, Falls, Twentymile, Thirtymile, and Lake creeks). This road location practice can result in multiple habitat impacts including reduced riparian canopy, increased fine sediment loads, reduced pool habitat, and lost off-channel habitats. Such roads also directly reduce watershed storage capacity by rapidly routing run off into stream channel and by compacting floodplain soils, and also indirectly by discouraging beaver pond construction. Ground-based skidding is still a common practice on the private lands in these watersheds, and can be a significant fine sediment source. Subsequent harvests have left buffers on fish-bearing streams, but the state’s minimum requirements do not always result in adequate shade or large woody debris recruitment.

Conversion of privately owned timber areas into other uses such as residential subdivisions is not regulated by the Washington Forest Practices Rules and Regulations. Okanogan County is involved in regulation of the forest conversion process through local land use planning and zoning authority (RCW 76.09.060 and RCW 76.09.240). Similar to Chelan County, Okanogan County established an ordinance to protect "critical areas", which include riparian bottomlands. The county has established 25 feet buffers to the ordinary high water mark. The following riparian setbacks have been established by the state (WAC 222-16-030) for water bodies:

Water type	Setback (measured on the horizontal from the ordinary high water mark)
Type 1 and 2 waters	200 feet
Type 3 waters	150 feet
Type 4 waters	50 feet
Type 5 waters	Not regulated

The USFS estimates that sediment delivery to Methow River from human activity on public lands is about 10% higher than natural background levels (ONF 1989). Many channel sections of the Methow River are constrained by riprap or channel incision, so that low velocity areas for deposition of fines are limited. Although the effects of surface erosion on salmonid production is not a major concern in Methow Watershed, various actions can be done to mitigate those impacts that do occur. In Twisp Watershed, for example, road obliteration projects are proposed by ONF for about twenty roads and many more spur roads. Similar actions are proposed for Chewuch Watershed.

Boulder Creek watershed, the largest drainage in the Chewuch system, has had several mass wasting events in recent history. Significant bank erosion presently occurs in the lower 40 km of the Chewuch River. Channel down cutting is evident in many parts of this reach, lowering the water table and disconnecting the channel from its flood plain and riparian area.

Agriculture and grazing

The private land in the basin is used for primary and secondary home sites, small farms, irrigated alfalfa and other irrigated crops, non-irrigated grazing land, and some timberland and grasslands. There are some irrigated orchards downstream of Carlton. It is not likely that traditional agriculture will expand significantly in the basin (MPP 1994). Approximately 5,180 ha of the basin is irrigated, and the remaining 672,080 ha are non-irrigated. Irrigation generally occurs from May through September, delivered through a network of unlined canals. Collectively, these canals divert about 260 cfs at peak flows. Up to 90%of the water withdrawn from instream flow is used for agricultural irrigation (MPP 1994).

Most cattle production occurs on the mainstem Methow and tributaries between the Gold Creek confluence and the Wolf Creek confluence. Livestock use of Methow Watershed was heavy in earlier years after settlement of the basin, but has declined considerably. PNRBC (1977) indicates that about 60% of the private bottomlands that livestock use in Methow Watershed have suffered erosion, streambank sloughing, and bank cutting. The OCCD has been actively establishing CRMPs for many cattle producers in Methow Watershed. These agreements are typically endorsed by many agencies as a means to protect fish and wildlife habitat on lands that are actively managed for timber production or grazed. Several CRMPs have been established on riparian bottomlands on French, Texas, Beaver, and Benson creeks, and the mainstem Methow River (similar work is being done on the Okanogan River). If done well, they do have potential to reduce grazing pressure on riparian bottomlands, but these plans provide no assurances of continuance.

Recreation

Although no attempt has been made to quantify the impacts of recreation, there is a likelihood for impacts through poaching, harassment, and removal of LWD in the subwatersheds. Dispersed campgrounds on stream margins cause bank erosion, particularly on the Chewuch River, and should be eliminated where possible. To protect stream-type chinook salmon, WDFW recently imposed selective resident fishery regulations throughout much of the anadromous fish zone that should significantly reduce juvenile hooking mortality. Portions of the zone however, remain open to bait fishing. The recently abandoned practice of planting catchable hatchery rainbow trout in selected areas probably has reduced incidental harvest of chinook salmon smolts.

9.1.2: Regional and local considerations

The basin is experiencing a demographic shift from a natural resource based economy reliant on agriculture, forestry and mining to an economy more dependent on tourism, recreation and general goods and services industries. The population of the Methow Watershed is relatively low, yet smaller parcels in agricultural production are being converted to nonagricultural use including housing, retail businesses, and small manufacturing. As land in the valley bottoms has shifted from agriculture to other uses, somewhat different landscape alterations have emerged. These alterations are commonly clearing vegetation and installing bank protection (rip-rap) for "view" property, and home construction in the jurisdictional shorelines and flood zones.

Although fish habitat protection is of primary concern to fishery managers, they have only limited jurisdiction over land and water use that impact habitat. Land and water use activities are regulated by a patchwork of federal, state, and local laws and ordinances. Even when it appears that fish habitat is adequately protected through written statutes, agreements, guidelines and other documents, on-site observations may show differently. Successful protection of habitat is most likely to occur when both the citizens and the jurisdictions recognize the legitimacy and the worthiness of the policies, standards, and guidelines involved.

9.1.3: Water resources and management

Water quantity

The peak flow typically occurs from late April to early June and is caused by low elevation snow melt. Low flows occur from September and October, but often the winter flows are lower than that of summer. Up to 90% of the water withdrawn from instream flow is used for agricultural irrigation. Thus, there is a greater potential for water conservation in agriculture than in any other area of water use in Methow Basin. With the exception of transpiration and crop use, some of the water diverted to irrigation is eventually returned to points further downstream on the Methow River (where instream flow issues may not be acute). A total of 248.2 cfs is diverted from the Methow River and its tributaries for irrigation, although these values vary considerably, depending upon total stream flow, time of year, and other factors. Below is a rough breakdown of water use by point of diversion (developed by the MPP):

Gold and Libby creeks (two ditches)	5.8 cfs
Twisp River (four ditches)	61.5 cfs
Methow River above Winthrop (six ditches)	93.8 cfs
Chewuch River (two ditches)	87.1 cfs

The tendency for several reaches of mainstem Methow River (about 15 km) and the Twisp River to become dewatered is well documented (NPPC 1990; Caldwell and Catterson 1992; MPP 1994).

Eggs, yearling salmon and all age classes of trout and char are impacted in low flow years. Ironically, these areas are often where the highest densities of spring chinook salmon redds and rearing juveniles are found (Hubble and Sexauer 1994). This dewatering appears to be a natural phenomenon, exacerbated by water use for irrigation. The reaches that go dry during low flow years in Methow Watershed expand in length during extreme drought years. Normally, fall rains cause the river to start rising--typically around mid-October. In 1992 WDOE completed an IFIM study on the Methow River. Based upon the IFIM results, the Pilot Planning Committee recommended that no additional water rights be issued. The IFIM study identified the following areas as most prone to dewatering:

1) between Weeman Bridge and Mazama Bridge, about 2.5 km,
2) between the Early Winters Creek confluence and the Lost River confluence, about 9 km, and
3) from the Lost River confluence to the Robinson Creek confluence, about 1.5 km.

To address these instream flow issues, the Methow Valley Water Pilot Planning Committee completed the *Draft* Methow River Basin Plan in 1994. Using the *Chelan Agreement* as its foundation, the objectives of the plan were to develop strategies that respect existing water rights and to increase instream flow to improve fish and wildlife habitat, allow for growth, and preserve and enhance the unique quality of the Methow Valley. The report provides an analysis of two of the dewatered tributaries (Libby Creek and Gold Creek), water deficient reaches (above Weeman Bridge), irrigation ditches, and recommends strategies to rectify these problems. In addition to several institutional measures, the Pilot Planning Committee proposed the following measures to increase irrigation efficiencies: renovate irrigation diversions on Gold and Libby creeks, and renovate irrigation diversions, in accordance with prescriptions established in the draft Methow River Basin Plan.

Chapter 90.54 RCW requires WDOE to maintain "base flows" for the protection and preservation of instream values, which among other parameters, include fish and wildlife habitats. The WDOE has established instream flow requirements for the Methow Watershed (Chapters 173-548 WAC). These flows are used to condition new water rights, but do not affect water rights acquired prior to adoption.

Water quality

The quality of waters throughout the basin are generally very high. The water quality of the upper Methow and Chewuch rivers is classified as AA (extraordinary), and the lower Methow and Twisp meet the class A (excellent) standards. Water temperatures at times exceed state water quality standards during the summer. Anchor ice development in the winter has been identified as a potential problem for juvenile salmonids in the mainstem Methow River. Four reaches of the mainstem Methow and lower Twisp rivers were rated as water quality limited (on the state 303 (d) list) because of low instream flows[22].

Waste water is discharged into Methow River from municipal waste water treatment systems (Winthrop and Twisp). Commercial or industrial discharge into the river has not historically been a factor affecting water quality. Other activities affecting water quality in the basin are logging, grazing, land clearing, agricultural cropland, resort development and road building on USFS, state owned, and private lands. These activities increase sediment loading of surface waters, but is generally not considered a major problem.

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9.2: Historical and Existing Aquatic Habitat Conditions

9.2.1: Riparian and stream channel condition

Mainstem Methow River

In the subbasin plan, WDW et al. (1989) state that the upper reaches of the Methow River have a riparian zone that is fairly wide and undisturbed. It has isolated damage from natural events, limited agricultural developments, grazing, logging, and road construction. The middle and lower reaches appear to have some damage from livestock grazing and agricultural development (WDW et al. 1989). However, the quality of substrate in the mainstem Methow is in relatively good condition (Chapman et al. 1994a). The USFS (1989) estimated that fine sediments delivered to the Methow River from human activity in the public lands of the watershed has been about 10% greater than that delivered naturally. In the mainstem Methow, gradient, discharge, and substrate combine to keep accumulations from occurring in the open channel (Chapman et al. 1994a). From the confluence of the Chewuch River downstream, Methow River is moderately confined alluvial valley with an average gradient of 0.37% (Tables 15, 16). Agriculture is extensive in the unconfined and moderately confined reaches.

Table 15. Inventory of valley bottom types and miles of stream state types (Lotspeich and Platts 1982) in the mainstem Methow River and shoreline conditions from the Twisp River confluence to the Columbia River confluence (adapted from Hillman and Ross, 1992).

Valley bottom type	Kilometers of stream state type	
U-shaped moderately confined alluvial valley RK 0.0 - 6.5	Eroded banks	2.63
	Laid-back banks	0.52
	Impounded or multiple channel	3.31
U-shaped confined alluvial valley RK 6.5 - 36.0	Eroded banks	20.94
	Laid-back banks	1.20
	Channelized banks	5.98
	Entrenched channel	1.45
U-shaped moderately confined alluvial valley RK 36.0 - 52.4	Eroded banks	10.18
	Laid-back banks	2.59
	Channelized banks	1.45
	Entrenched channel	2.10
U-shaped unconfined alluvial valley RK 52.4 - 83.4	Eroded banks	17.97
	Laid-back banks	5.90
	Channelized banks	4.20
	Straight channel	2.96

Chewuch River

While there are some areas in the Chewuch where habitat is in poor condition, a large portion of the drainage is in very good condition. Stream width to depth ratios are relatively high in reaches one and two of Chewuch River (Table 17), but USFS recommends more analysis to determine if this is a natural phenomenon (USFS 1996). Roughly half the drainage, covering the portions of the watershed north and east of Lake Creek is relatively undisturbed and functionally intact. Stream habitat inventories using the Forest Service Region 6 Hankin-Reeves protocol have been conducted on the mainstem Chewuch from the ONF boundary to just above Chewuch Falls, and on Eightmile Creek, Falls Creek, Boulder Creek and tributaries, and Twentymile Creek. Stream survey data show that the Chewuch River is deficient in large woody material in the lower 30 km of surveyed channel from the ONF boundary to Sheep Creek. The USFS hydrologists believe this low level of woody debris is a result of stream cleanouts for flood control, salvage of instream wood, and extensive stream-channel harvest of potential recruitment trees. Portions of the lower Chewuch River have been channelized as a result of bank protection efforts after the 1948 flood.

Table 16. Average dimensions and features of principal streams (order 3 to 5) in the Methow Watershed (from Mullan et al. 1992).

Steam name (River miles)	Mean area low flow (acres)	Mean flow (cfs)	Mean width (cfs)	Mean gradient (ft)	Mean Pool/riffle (%)	area ratio	Drainage (sq. mile)
Methow R.							
(1.8-27.1)	478	491	1592	155	0.4	41:59	1792
(27.1-50.1)	432	310	1352	156	0.3	55:45	
(50.1-73.0)	176		820	63		43:57	480
W. Fk. Methow R.							
(0.0-10.5)	28	30	149	29	2.6	22:78	83
Lost R.							
(0.0-7.1)	49	58	146	57	1.6	19:81	146
Early Winters Cr.							
(0.0-7.5)	28	24	119	32	2.9	17:83	79
Chewuch R.							
(0.0-32.3)	249	57	375	64	1.7	52:48	525
Lake Cr.							
(0.0-6.5)	19	3 1	8 1	25	4.4	41:59	54
Twisp R.							
(0.0-28.2)	169	66	226	49	1.7	29:71	247
Gold Cr.							
(0.0-2.2)	7	7	33	26	3.7	35:65	87

Table 17. Comparison of various stream fish habitat features, categorized by reach, on the Chewuch Watershed. The reach numbers go upstream (from USFS 1996).

Stream Reach	Eroded banks (feet per mile)	Woody debris per mile	Stream pools per mile	Percent pool	Bankfull width (ft)	Width:depth ratio
1	575	9	5	26	114	37
2	275	12	4	13	96	35
3	60	28	8	11	63	16
4	50	22	7	12	66	20
5	180	54	17	85	58	19
6	30	66	8	27	84	38
7	0	50	13	8	42	13
8	90	126	18	53	41	14
9	100	68	23	22	58	15
10	40	30	11	23	50	20
11	0	46	24	22	35	12

Twisp River

Twisp River surveys conducted in ONF by USFS indicate that large woody debris standards are about two-thirds what is specified by ONF Guidelines. The reach below War Creek is about half of what is specified (Talayco et al. 1994). There is considerable evidence that the LWD level listed in the guidelines are far lower than those that were present historically in the mainstem Twisp River that flows through the national forest (ONF 1995a). The highest densities of salmonid production for all species combined in the Twisp River has been observed in relatively undisturbed tributary reaches with the slowest moving water (Hubble 1994). These areas contain abundant cover in the form of LWD and boulders, and other associated habitat features (Mullan et al. 1992). Pool to riffle ratios in the Twisp River indicate a lack of instream cover (Table 18). The ONF has identified the following degraded riparian areas in public lands of the Twisp River drainage: Canyon Creek, Poorman Creek, Little Bridge Creek, Slate Creek adjacent to the mainstem Twisp, and West Fork Buttermilk Creek. Some measures to rehabilitate these areas are proposed, but have not been implemented.

Table 18. Comparison of various stream fish habitat features, categorized by reach, on the Twisp Watershed (adapted from ONF 1995a).

Stream Reach	River mile	Woody debris per mile	Gradient	Pool:riffle ratio	Residual depth (ft)	Width:depth ratio
1	0.0-2.7	- -	0.76	18:82	- -	- -
2	2.7-4.2	- -	1.44	43:57	- -	- -
3	4.2-7.0	9	2.00	34:66	2.7	22
4	7.0-9.2	9	1.26	27:73	2.7	22
5	9.2-10.2	7	0.39	41:59	3.2	30
6	10.2-12.5	7	0.81	31:69	3.2	30
7	12.5-14.5	7	0.68	63:37	3.2	30
8	14.5-16.8	14	0.86	20:80	2.5	38
9	16.8-18.2	14	1.72	20:80	2.4	36
10	18.2-20.9	18	1.76	03:97	2.3	26
11	20.9-21.9	18	1.86	30:70	2.3	26
12	21.9-23.7	- -	- -	- -	- -	- -
13	23.7-26.2	7	2.86	27:73	2.5	30
14	26.2-28.2	19	5.89	51:49	2.3	17

9.3: The Relationship of Existing Aquatic Habitat Conditions to Biological Productivity

Ocean-type chinook salmon

It is unclear why the summer chinook salmon population in the Methow River is not as robust as those in the Wenatchee and Okanogan Rivers. In general, the condition of spawning gravels in the lower Methow are good, as is water quality during the majority of their residence. Mullan et al. (1992) maintain that historically the Methow River had lower runs of chinook salmon than other mid-Columbia tributaries. There is evidence that some subyearlings remain in the Methow River through summer, and emigrate in fall (Chapman et al. 1994). If a large component of the population remains through summer, they may be impacted somewhat by irrigation water withdrawals. Irrigation water withdrawals may also reduce adult migration, holding, and spawning habitat (Chapman et al. 1994), and effectively increase summer water temperatures[23].

Stream-type salmonids

Clearly, the mainstem Methow River and tributaries can be a hostile environment for salmonids during the late summer low flows and in winter. Stream channel confinement provides adequate depth and cover for salmonids, yet temperature and flow extremes during both summer and winter may cause significant mortality. Based upon analyses of

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aerial photographs, Chapman et al. (1994a) identified that 6.4%of the mainstem Methow River from the Chewuch River confluence downstream to the mouth has extensive placements of rip-rap, and 4.1%has no riparian vegetation. This lack of riparian coverage would allow significant loss of thermal insulation to the river.

Much of the spawning and early rearing habitat for spring chinook salmon lies upstream from irrigation diversions and return flows, and is in a permeable glacial deposit. Not directly influenced by irrigation, some reaches of the upper Methow and Twisp rivers are alternately watered and dewatered. Irrigation is known to dewater portions of Gold Creek, Benson Creek, and Beaver Creek. Flow is much reduced by irrigation in the lower Twisp River, Wolf Creek, Goat Creek, and Early Winters Creek (Chapman et al. 1994a). Irrigation water diversions would be especially severe in effect in drought years. Prespawning mortality may be a significant factor for spring chinook salmon in the Methow (Scribner et al. 1993; Chapman et al. 1995a). Among a myriad of potential causes could be the lack of appropriate holding cover associated with large woody debris.

Loss of woody debris in the lower Chewuch and Twisp rivers may exacerbate the movement of juvenile chinook salmon out of those tributaries in the fall, and into areas that may be less suitable for overwinter holding. Hubble (1993) states that a major reason for downstream movement of chinook salmon from the Chewuch River is the lack of woody debris. Several authors (Mullan et al. 1992b, McIntosh et al. 1994; Chapman et al. 1995a) cite evidence that quality and quantity of juvenile rearing and adult holding habitat has either remained the same, or increased slightly since the 1930s. However, Chapman et al. (1994a) believe that fry habitat in Methow River may be limited, because it has large segments with unvegetated banks (both eroded and laid-back banks; Table 15) that would not provide suitable habitat for fry at high flows. Griffith and Hillman (1986) observed that juvenile chinook salmon in Methow River used deep pools and selected stations close to woody debris and boulder rip rap. Juvenile stream-type salmonids have been documented in lower reaches of smaller tributaries that often go dry in late summer (examples are Gold Creek, Libby Creek, Beaver Creek, Wolf Creek)[24].

Inland fish

Many of the key habitat factors that apply to anadromous salmonids in the Methow Watershed also apply to resident 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 bottomland development (bank protection, channelization, water withdrawal). Key habitat conditions for resident fish, in particular rainbow trout, westslope cutthroat trout, and bull trout revolve around minimizing sedimentation and gravel scouring.

SECTION 10: RECOMMENDED STRATEGIES FOR THE METHOW WATERSHED

In general, the headwater habitat in the Methow Basin where stream-type anadromous salmonids and inland salmonids spawn (and potentially rear) is in reasonably good condition. Most of these streams are in publicly owned lands and are afforded some state of protection. Further downstream (where late summer rearing and overwinter holding occur), the impacts of habitat alterations become more apparent. Low flows in these reaches, in three out of four seasons, limit salmonid production and survival in the Methow. The mechanism to address this need is there, via the Pilot Project Implementation Plan.

[24] *Bambrick, Yakama Indian Nation, Toppenish, WA*

Also, the purchase of riparian bottomlands in the Methow River is a feasible approach to habitat protection, and would be fairly cost-effective. This would benefit many species, they would serve as flood desynchronization and protection areas, and have numerous other benefits to fish and wildlife.

10.1: Habitat Protection

The highest priority for maintaining biological productivity will be to allow unrestricted stream channel diversity and flood plain function (Section 1.6.2). The principle means to meet this objective is to secure riparian habitat--anywhere in the watershed--either in conservation agreements, easements or direct purchases. Obviously, some areas have more immediate needs, because of their importance for existing life history strategies, and should be given greater emphasis. The following list identifies stream reaches which should receive protection, and is therefore ranked in biological priority:

1) Riparian areas along point bars on the mainstem Methow River from Beaver Creek to French Creek.
2) The wetland complexes along the mainstem Methow from Lost River to Chewuch River.
3) The lower Twisp River (Buttermilk Creek downstream).
4) The lower Chewuch River (Boulder Creek downstream).
5) The lower Benson Creek.
6) The upper Methow and lower Lost rivers.
7) Beaver, Hancock, and Wolf creeks.

10.3: Habitat Restoration

A range of strategies is recommended for habitat restoration in the Methow Watershed. Like the *Habitat Protection* strategy, most strategies center on efforts to maintain or increase the complexity of the stream channel and floodplain (Section 1.6.3). These recommendations are listed in order of biological priority.

1) If not already done, implement the Methow Valley Irrigation District renovation.
2) The two operating irrigation diversions on Gold Creek should be either enclosed with pipe, maintaining the current diversion points, or replaced with wells in continuity with Methow River.
3) Williams Ditch and Richardson Ditch on Libby Creek should be enclosed with pipe, and maintain their current diversion points.
4) Restore side channel function in all reaches of the watershed.
5) Support water conservation measures in tributary diversions.
6) Restore riparian habitat on the lower Gold Creek.
7) Provide passage at the SR 153 culvert on Beaver Creek.

THE OKANOGAN WATERSHED

This chapter provides a summary of existing information on aquatic species and their habitats in the Okanogan Watershed of Washington State. Virtually all of this assessment is on those reaches that lie within the United States, yet some information on the Canadian reaches is provided, where appropriate.

SECTION 11: ASSESSMENT OF AQUATIC SPECIES IN THE OKANOGAN WATERSHED

11.1: Commercially and Culturally Important Fish Species

The Okanogan River currently supports anadromous runs of chinook salmon, sockeye salmon, and smaller runs of steelhead. Important inland species include mountain whitefish, bull trout, rainbow trout (a resident form of steelhead), and westslope cutthroat trout. A discussion is provided of three major evolutionary life history strategies (ocean-type, stream-type, and inland) of Okanogan River populations.

11.1.1: Ocean-type anadromous salmonids

In general, the run strength of ocean-type chinook salmon has declined slightly in the Okanogan River over the last 20 years, and has increased slightly in the Similkameen River, its largest tributary, during this period (Chapman et al. 1994a). Adults enter the Okanogan River from July through late September, with the duration of spawning from late September through early November, peaking in mid-October. The spatial distribution of spawners in the watershed is fairly discontinuous. Summer chinook spawn in limited areas between Zosel Dam and the town of Malott, about 103 km. On the Similkameen River, summer chinook spawn from Enloe Dam to Driscoll Island--14 km (Hillman and Ross 1992).

Emergence timing is probably January through April. Juveniles may rear from a few months to a year before migrating downstream. Juveniles generally emigrate to the ocean as subyearling fry, leaving Okanogan River from one to four months after emerging from the gravel in April, although there is evidence that some fish undergo an extended residence period, with protracted downstream movement. Many subyearlings rear in the mid-Columbia impoundments. Only one general life history type is presented here, which express the presumed historical life history strategies for ocean-type anadromous fish: spawn in the mainstem and leave the system in late spring/summer as subyearlings. This phenotype would be classified as *Category I*. We presume some cohorts rear in the mainstem Okanogan through the fall or winter when conditions are favorable to this strategy (*Categories I and II*).

11.1.2: Stream-type anadromous salmonids

Spring chinook salmon

There are no indications that spring chinook salmon currently use the Okanogan drainage, but historical records indicate use of three systems: 1) Salmon Creek, prior to construction of the irrigation diversion dam (Craig and Suomela 1941), 2) tributaries upstream of Lake Osoyoos (Chapman et al. 1995a) and 3) possibly Omak Creek (Fulton 1968). Historically, all or more of the following stream-type anadromous fish life history types may have been present in the basin:

1) Spawn, rear, overwinter in Salmon Creek *(Category III)*.
2) Spawn and rear in Salmon Creek, overwinter in mainstem Okanogan River (*Category III*).
3) Spawn, rear in tributaries above Lake Osoyoos; overwinter in the lake (*Category III*).
4) Spawn, rear, overwinter in mainstem Okanogan above lake Osoyoos (*Category III).*
5) Spawn, rear, overwinter in Omak Creek (*Category III*).

There were probably several life history strategies that historically existed in the Similkameen Watershed, prior to construction of Enloe Dam in 1920, although there is no clear evidence that chinook salmon passed the natural falls on the lower Similkameen River. These life history strategies are classified as *Category IV*.

Sockeye salmon

The run strength of sockeye salmon to Okanogan River is highly variable; escapement has ranged from a low of 1,662 in 1994 to a high of 127,857 in 1966 (as measured at Wells Dam). The 1986-1995 average run size is 28,460. Lake Osoyoos is the primary rearing area for sockeye salmon in the Okanogan Watershed. The lake is eutrophic (Section 12.4.3), and has an abundant food supply (Rensel 1996), thereby producing relatively large sockeye smolts. Sockeye salmon spawn in the mainstem Okanogan River upstream of Lake Osoyoos, between Lyons Park and McIntyre Dam, a distance of 8 km, although some may spawn in the reach downstream of Lyons Park, and in Vaseux Creek (Hagen and Grette 1994). Spawning occurs from early October through early November, with the peak in mid-October (Hansen 1993). Adult passage through lower Okanogan River (downstream of Lake Osoyoos) may be blocked, in certain years, by a thermal barrier during late July and early August (Pratt et al. 1991). Reconstruction of Zosel Dam in 1987 improved passage conditions into the lake. Sockeye salmon probably exhibited four historical life history strategies:

1) Spawn in Okanogan River downstream of McIntyre Dam, rear to a subyearling stage in Lake Osoyoos, outmigrate in spring (*Category I*).
2) Spawn in Okanogan River upstream of McIntyre Dam, rear to a subyearling stage in Lake Osoyoos, outmigrate in spring (*Category III*).
3) Spawn in Okanogan River below McIntyre Dam, rear to a subyearling stage in Okanogan River downstream of Lake Osoyoos, outmigrate in spring (*Category II*).
4) Spawn in lower Similkameen River, rear to a subyearling stage in Okanogan River downstream of Lake Osoyoos, outmigrate in spring (*Category II*).

Steelhead

Very few wild steelhead currently use Okanogan River. The historical record for steelhead in the Okanogan Watershed is not complete, yet Mullan et al. (1992) assert that very few steelhead historically used Okanogan River. Salmon Creek and Omak Creek had small runs of steelhead, but are not used now because of passage barriers on each stream (Section 12.3). Steelhead may have historically used some tributaries upstream of Lake Osoyoos (Chapman et al. 1994b). Current habitat conditions in the migration corridor are poor for most if not all life history types. Five life history types are identified:

1) Spawn, rear, and overwinter in Salmon Creek; outmigrate in spring (*Category III*).
2) Spawn and rear in Salmon Creek, overwinter in Okanogan River; outmigrate in spring (*Category III*).
3) Spawn and rear in Okanogan River and tributaries upstream of Lake Osoyoos, overwinter in the lake, and outmigrate in spring (*Category III*).
4) Spawn, rear, and overwinter in Omak Creek; outmigrate in spring (*Category III*).
5) Spawn and rear in Omak Creek, overwinter in Okanogan River; outmigrate in spring (*Category III*).

11.1.3: Inland fish

Rainbow trout

Rainbow trout appears to have one life history pattern: to spawn and rear in upper tributaries: Salmon Creek, Omak Creek, upper Toats Coulee, Sinlahekin Creek, Bonaparte Creek, and Tonasket Creek. The population size and distribution of rainbow trout in these streams are not known.

Bull trout

The status of bull trout in the Okanogan Watershed is unknown, but they are believed to be extinct downstream of Enloe and Zosel dams. The Toats Coulee subwatershed was surveyed by USFS personnel in 1994, and no bull trout were seen (ONF 1995b). Salmon and Loup Loup creeks supported bull trout populations, yet hybridization with introduced brook trout may have caused a functional extinction of these populations.

Cutthroat trout

The status of cutthroat trout in the Okanogan Watershed is unknown. The Toats Coulee subwatershed was surveyed by USFS personnel in 1994, and no cutthroat trout were seen. However, historical records indicate the presence of cutthroat in the Middle Fork Toats Coulee (ONF 1995b). It is speculated that cutthroat trout are not native to the Okanogan Watershed; those currently present in Toats Coulee (and possibly Salmon Creek) may have been planted.

SECTION 12: ASSESSMENT OF HABITAT CONDITION IN THE OKANOGAN WATERSHED

12.1: Basin Setting and Demographics

Okanogan River originates in British Columbia and flows through several large lake systems before reaching the United States. Most of this discussion are on that portion within the United States. That reach is comprised of five subwatersheds and 32 WAUs. Migration barriers are an important issue in Okanogan Watershed. Included in the assessment for the Okanogan therefore, is a separate section that discusses fish passage conditions in this watershed.

12.1.1 Basin ownership and land use

The biggest and most complex ecosystem, the Okanogan/Similkameen Watershed has the largest portion of the four tributaries in private ownership (Table 17). Land use is about equally dominated by forest and rangelands (Table 18). Despite the extensive private lands, the largest landowners in the U.S. portion of the basin are USFS and CCT. This diverse ownership is a significant factor complicating the management of the resource base in the watershed. The lower Okanogan River, that portion which lies in the United States, is characterized as low gradient, with very porous glacial soils (PNRBC 1977). Soils along the main river channel lack cohesion and high spring runoff causes serious erosion of streambanks, large deposits of sediment and low dissolved oxygen in the river. Many of these characteristics were historically present. These conditions (warm water and low velocities) therefore favor non-salmonid fishes. Only ocean-type chinook salmon, which hatch early and emigrate early, and mountain whitefish have successful (but limited) life histories in the mainstem Okanogan and Similkameen rivers (Mullan et al. 1992).

Table 17. Land ownership in the Okanogan Watershed (from PNRBC 1977).

Land Manager	Area (ha)
U.S. Forest Service	59,692
Bureau of Land Management	19,183
U.S. Fish and Wildlife Service	1,133
Bureau of Reclamation	324
Department of Defense	41
Federal subtotal	80,373
State	86,645
County	121
Municipal	1,174
Total public	168,313
Colville Indian Reservation	166,815
Private	263,537
Total land area	598,665
Large water areas	8,094
Total area	606,759

Table 18. Cover crop and land use in the Okanogan Watershed (from PNRBC 1977).

Category	Area (ha)
Cropland	36,018
Rangeland	278,834
Forest land	262,242
Other land	21,934
Total land area	599,028
Large water area	8,094
Total basin area	607,222

The average annual flow for Okanogan River, measured at Ellisforde, is about 3,200 cfs, which is highest of the four watersheds considered in this assessment. About 75% of that flow comes from its largest tributary, the Similkameen River, which lies mostly in Canada. Upstream of the Similkameen confluence, the Okanogan River flows through six large lakes--five of which are entirely in Canada and inaccessible to anadromous salmonids. Lake Osoyoos lies both in Canada and United States, and is used by sockeye salmon. The lower 27 km of shorelines of Okanogan River have been inundated by the pool of Wells Hydroelectric Project.

The ONF developed its *Land and Resource Management Plan* in 1989, which in combination with the 1994 *Record of Decision* for the northern spotted owl, has set the management plans for the Toats Coulee and upper Salmon Creek watersheds. The ONF has an extensive list of watershed restoration projects that are proposed, and currently out for public review. In general, stream habitat conditions are fair to good in the forest (see subsections below), and sediment delivery from ONF to lower reaches is not a significant problem.

The lack of overhead cover, woody debris recruitment, invertebrate drift, undercut banks, and streambank stability are common in lower Okanogan River because of limited riparian bottomlands. Similar to Chelan County, Okanogan County's ordinance to protect "critical areas", which include riparian bottomlands, is conservative relative to that of the state (WAC 222-16-030). The county has established 25 foot buffers, measured on the horizontal from the ordinary high water mark.

Timber culture and harvest

Forest land management varies between the differing agencies and locations. Of the areas of commercial forests in public ownership, 58% is managed by USFS, 24% by the Bureau of Indian Affairs, and 16% by WDNR. Commercial forest land that are privately owned are for the most part in small ownerships. The forests of Okanogan County are relatively low in productivity because of low precipitation, steep, rocky terrain, and the short growing season in mountainous areas. The water quality impacts related to forest practices on private lands are regulated through the Washington Forest Practices Act (RCW76.09). Conversion of privately owned timber areas into other uses such as residential subdivisions is not regulated by the Washington Forest Practices Rules and Regulations. This is not yet as large a problem in the Okanogan Watershed as it is in the Wenatchee, Entiat, or Methow watersheds. Okanogan County is involved in regulation of the forest conversion process through local land use planning and zoning authority (RCW 76.09.060 and RCW 76.09.240).

The principle timber producing public lands are in Toats Coulee, managed by ONF, and the Loomis Forest, managed by WDNR. Roughly one fifth of the Toats Coulee lies within the Pasayten Wilderness, with the rest of the national forest system lands managed for lynx habitat, scenic values, timber harvest, and recreational opportunities. Forest roads in the Toats Coulee watershed are of concern. Within that watershed, 40% of the roads sampled had stream sediment loads ranging from 22.1 tons/mile of road up to 30.5 tons/mile of road (ONF 1995b). Stream sedimentation from roads was highest where steep road grades and steep cut slopes and fill slopes exist within 150 m of streams. Roads are typically located in the narrow floodplains of the mainstems and their tributaries. This road location practice can result in multiple habitat impacts including reduced riparian canopy, increased fine sediment loads, reduced pool habitat, and lost off-channel habitats. Such roads also directly reduce watershed storage capacity by rapidly routing run off into stream channel and by compacting floodplain soils, and also indirectly by discouraging beaver pond construction. Subsequent harvests have left buffers on fish-bearing streams, but the state's minimum requirements do not always result in adequate shade or large woody debris recruitment. Soil compaction and erosion from ground-based skidding can still be a significant fine sediment source in some reaches. Based upon available records dating back to 1970, approximately 400 ha of USFS lands in Toats Coulee have been tractor logged. Of these compacted areas, about 290 ha have been treated to reduce compaction. There are currently no plans to treat the remaining areas because of the risks of increased sedimentation from the process.

The Loomis State Forest is the largest contiguous block (54,230 ha) of land managed by the WDNR. It is located west of Tonasket. It was managed primarily for cattle grazing until the 1970s, when a spruce budworm epidemic motivated heavy cutting in some Douglas fir stands. The WDNR considers the Loomis Forest to be in generally poor health, as indicated by recent mountain pine beetle epidemics in the lodgepole pine stands and mortalities to numerous species from dwarf mistletoe and defoliating insects (WDNR 1996). Many of these conditions are presumed to be a result of fire suppression strategies in this century.

Due to limited timber harvest and current fire suppression practices, most of the Loomis is composed of mid and late successional forest stands. Water quality is generally good throughout the forest, yet grazing impacts to streamside vegetation has occurred in localized areas (WDNR 1996).

Agriculture

The economy of the Okanogan Watershed is centered around agriculture, most of which is apple and livestock production. The trend over the last thirty years has been away from dryland farming to irrigated crops. Irrigable land that has not been developed into orchards is generally used for livestock production. Much of the flood plain on the Okanogan is used for forage crops and livestock wintering grounds (PNRBC 1977). During the summer months, livestock graze lands in the more mountainous areas surrounding the river valley. Some of the major tributary valleys support year-round ranching operations. There are close to 16,700 ha of irrigated croplands in the U.S. portion of the Okanogan Watershed (about 3% of the area), which uses a corresponding amount of the total water supply (about 2%). Most of this demand is during summer low flows. The upper Okanogan Valley in Canada also has extensive orchards in the river valley.

Several large irrigation districts have been established in the Okanogan Watershed. North of Tonasket, irrigators rely on water from two sources: 1) water diverted from the Similkameen River--about 180 cfs during the peak season, and 2) water pumped from the Okanogan by the Oroville-Tonasket Irrigation District--about 33,500 acre feet of water annually for application to about 9,500 acres. The terraces in Pogue Flat receive irrigation water pumped from Conconully Reservoir and diverted from Salmon Creek by the Okanogan Irrigation District. The district supplies about 17,000 acre-feet annually to irrigate about 4,000 acres. The Aeneas Lake Irrigation District provides about 12 cfs of water for irrigation of about 900 acres near the Aeneas Lake region. South of Riverside, about half the irrigation on the valley floor relies on water pumped from the Okanogan River by individual growers. Small amounts of water are diverted for irrigation from Little Loup Creek, Loup Loup Creek, and Leader Lake. About 10,000 acre feet of water per year is diverted from Toats Coulee for storage in Spectacle and Whitestone Lakes and for subsequent irrigation in the area between Spectacle Lake and Tonasket.

Okanogan Basin rangelands were evaluated in the 1970s in the level B study, and indicated that 25% of the rangeland was in good condition, 34% in fair condition, and 41% in poor condition (PNRBC 1977).

Mining

The Similkameen River is considered one of the better gold producing streams in the state (Barth and DeMayer 1982). The beds and shore lands of the Similkameen River are currently under leases from WDNR to private individuals for mineral prospecting and mining. The leases have a checkerboard pattern, and can be issued for two years.

12.2: Sedimentation

Surface erosion on agricultural bottomlands and mass wasting on adjacent hill slopes were serious problems in the 1970s, when clean cultivation and rill irrigation were extensively used in the U.S. part of the Okanogan Basin. Although not completely rectified, this soil loss was substantially reduced when many of the crops were changed to alfalfa and certified seed plantings for carrots and potatoes. Another important factor was the adoption of BMPs by USDA. A BMP is defined as "a practice or combination of practices that is determined by a state (or designated area-wide planning agency) after problem assessment, examination of alternative practices, and appropriate participation, to be the most effective, practicable (including technological, economic, or institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals.

These USDA sponsored measures, and the joint agency sponsored CRMPs have benefited the resources, and the economy, of Okanogan Watershed. Okanogan County and OCCD have received grant funds to identify water quality problems in Okanogan Watershed. They will develop a water quality plan (point source and non point source) which will assist in this process.

Sedimentation within the forested lands can be a severe and chronic concern as well. In Toats Coulee watershed, for example, 36% of the national forest lands have a low potential for soil erosion, 31% have a moderate potential, and 32% have a high potential for soil erosion (ONF 1995). A mass wasting assessment was performed by USFS in 1994 in Toats Coulee; 21 debris torrents, one large persistent deep seated failure, and one small sporadic deep seeded failure were observed (ONF 1995).

The predominant soils suffering the most severe erosion along the Okanogan River are the Colville silt loams and the Bosel fine sandy loams. A 1994 survey by NRCS of erosive streambanks on the Okanogan River between Oroville and Tonasket (35 km) indicated that about 93,000 tons of soil are lost each year . The OCCD and NRCS estimated that about 14,600 m of riverbank in this reach requires woody vegetative treatment to help stabilize the most erosive streambanks. Of this, 23 sites were identified as highly erosive, with a cumulative total of about 5,900 m requiring placement of a rock toe and/or root wads and sloping of the bank. Sixty two sites required vegetation plantings to stabilize the streambanks and enhance water quality; this represents about 20% of the streambank where these erosive soils occur. The OCCD and NRCS recently started collaborative work to stabilize stream banks on Okanogan River from Oroville Bridge to Ellisforde Bridge using bioengineering concepts. In 1995, a demonstration project was done to stabilize 506 m of highly erosive stream bank near Ellisforde. This project included bank sloping, willow and cottonwood plantings, apple tree root wad placements, rock toe placements, and stock watering access points.

12.3 Fish Passage

There are several major barriers to upstream passage of salmonids in Okanogan Watershed. Most of them are a result of a given structure such as in Omak Creek or Salmon Creek, but the use of water from upstream structures also affects passage of sockeye in lower Okanogan River. Although the issues surrounding them are quite complicated and potentially divisive, these passage barriers may be addressed in a tributary plan.

Omak Creek

The CCT collaborated with NRCS to develop a watershed plan and environmental assessment for Omak Creek (watershed size is 36,700 ha). This stream is significant to CCT, as it is the only watershed that lies solely within the reservation. The goals of the plan are to restore over 60 km of steelhead habitat by improving water quality, reducing soil erosion, reducing water temperatures, and eliminating man-made barriers. This last task, removal of a “velocity barrier” through a large culvert under the Omak Wood Products mill at the mouth of the creek, is the single most important means to restore natural production in Omak Creek. After an extensive public review process in which several alternatives were considered, an implementation plan has been established, which will be funded jointly by the two entities (total cost is $3,031,000). Several individuals have questioned whether Omak Creek, with documented flows at the mouth of less than 1 cfs, can support the number of steelhead which is claimed--1,536 spawners, yet flows could be increased substantially if some of the water diversions are addressed. Likewise, there will be other benefits to sensitive species, and potential for increased flows when some of the upland rehabilitation practices are implemented.

Salmon Creek

In 1916, a diversion dam was built on Salmon Creek for irrigation of about 1,200 ha of orchard and crop land. The dam, located at RK 5, diverts all water into a 12 km long ditch, which provides gravity fed irrigation water to about 300 users. The lower 5 km of Salmon Creek is dewatered, except during spring freshets, when excess water overpasses the diversion dam. At other times, some groundwater surfaces into reaches of the dewatered channel, but not enough to support most aquatic biota.

The Okanogan Irrigation District (OID) can manage the water supply to the irrigation ditch through controlled releases from two reservoirs--Conconully Lake and Conconully Reservoir. The former feeds the latter, and both systems regulate the flows into upper Salmon Creek. From lower Conconully Reservoir, Salmon Creek flows through about 20 km of public and private lands before it is diverted into the irrigation channel. In 1998, the earthen dams for both water bodies will be improved to meet flood safety requirements. There is no upstream passage structure on either water body. Kokanee and resident rainbow trout naturally reproduce in these two systems, and support a local sports fishery. These fish spawn in the north and west forks of Salmon Creek, which feed the reservoirs, or along the reservoir shorelines. Omak FH (managed by WDFW) plants catchable-size rainbow trout in these lakes. Historical records indicate bull trout were present in the North Fork Salmon Creek.

In years of poor water supply from the reservoirs, the OID pumps up to 30 cfs of water from Okanogan River near Omak to supplement the irrigation channel. This water is pumped directly to the channel, whereby it then can be gravity fed to growers on the lower reach of the ditch. This measure is done only on extreme situations, because the electrical power costs are high--pumping costs for an irrigation season is about $90,000/year. Likewise, maintenance costs for the impellers are high, because of the high silt load in Okanogan River. The life span of impellers under normal load is one year. The intake system could be modified however, to decrease the silt intake from the river, which would significantly decrease impeller wear.

Upstream of the irrigation diversion dam, the average flow in Salmon Creek is 49 cfs, which could provide substantial habitat for salmon and steelhead. Habitat and water conditions upstream of the dam are in fair to very good condition, depending upon the reach. The West Fork has a relatively high sediment load, the North Fork was good water quality. Water temperatures are suitable for all stages of salmonid life history. There are numerous affidavits from early settlers of salmon and steelhead in this stream prior to dam construction. Currently, adult steelhead and spring chinook salmon have been observed in the lower reach of Salmon Creek when water flows to the Okanogan River confluence[25]. Some entities have proposed to renovate the diversion dam to provide water to lower Salmon Creek. This would require installation of a passage structure at the diversion dam, and the addition of water to the ditch from the pump station on the Okanogan River. Additionally, if sockeye salmon were to be introduced to the system, a passage structure at the landfill dam on Conconully Reservoir would be required. There currently is little incentive for OID to make these modifications, as the current system has a high irrigation conversion, and requires little maintenance.

Okanogan River

In the mainstem Okanogan River in British Columbia, there are 13 vertical drop structures (VDS) between Lake Osoyoos and Lake Vaseaux. These structures regulate water flow for flood control and irrigation purposes, and are spaced at roughly 1 km intervals. McIntyre Dam is 7.8 km upstream up the furthest upstream structure (VDS 13), and is a barrier to sockeye migration, although some salmon have been known to pass the dam in high water years (Hansen 1993). These structures limit the spawning distribution of sockeye salmon, and are suspected of contributing to the dewatering of sockeye redds in winter. The reach between VDS 13 and McIntyre Dam is where the majority of sockeye

[25] *B. Steele, Washington Department of Fish and Wildlife, Wenatchee*.

salmon spawn. Some sockeye also spawn in Vaseaux Creek (1.5 km below McIntyre Dam) and in the mainstem Okanogan River between VDS 13 and VDS 4 (10.2 km). In low water years, passage into Vaseaux Creek may be blocked (Hansen 1993).

Zosel Dam (RK 125) controls the level of Lake Osoyoos, and is jointly operated by the Oroville-Tonasket Irrigation District, WDOE, and BCME. Releases of water from Zosel Dam and others in the British Columbia reaches of Okanogan River affect passage of salmonids and water quality conditions in the lower Okanogan River.

Enloe Dam, located at RK 15 on the Similkameen River, blocks anadromous fish passage. However, there is evidence from historical records (Teit and Boas 1898) and affidavits by the Upper Similkameen Indian Band that anadromous salmonids were blocked from upstream passage by a falls on the lower Similkameen River, which is now inundated by Enloe Dam. These records suggest that anadromous salmonids were not native to the upper Similkameen Watershed.

12.4: Water Resources and Management

Water quantity

Flows in lower Okanogan River are regulated by the series of dams in British Columbia and Zosel Dam. Water releases to meet fishery needs are negotiated yearly by a consortium of fisheries and irrigation managers from both Canada and United States. During sockeye salmon spawning, water flow from the upper Okanogan River into Lake Osoyoos is generally between 250 cfs and 380 cfs. However, extreme flow fluctuations have occurred in the river after completion of spawning, resulting in both redd scouring and dewatering. In 1976 WDOE established base flows for Okanogan River (WAC 173-549; Table 19), and ruled that no further appropriation of surface water shall be made from Okanogan River and tributaries which would conflict with these base flows. Likewise, no further appropriations of water from lakes will be granted, except for livestock watering and domestic uses (Kauffman 1976).

The coarse soils in the basin create hydraulic continuity between the ground and surface waters. Virtually all municipal water in the valley is supplied from wells, which penetrate the ground water aquifers. Supplies appear to be adequate given the current demand, but ground water tables are dropping in some areas. This has minimal effect on instream flows, however. Availability of ground water in the area varies. Chapter 90.54 RCW requires WDOE to maintain “base flows” for the protection and preservation of instream values, which among other parameters, include fish and wildlife habitats. The WDOE has established instream flow requirements for the Okanogan Watershed (Chapters 173-549 WAC). These flows are used to condition new water rights, but do not affect water rights acquired prior to adoption.

The valley aquifers of alluvial and glaciofluvial deposits of Quaternary Age yield moderate to large supplies, from 100 to 2,000 gallons per minute. The dissolved solids in this water are less than 400 mg/L, and there are no excessive constituents (Lenfesty 1980).

Table 19. Base flows for selected reaches of Okanogan River, established by WDOE in 1976. Data are in cubic feet per second, and based on measurements made at the USGS Tonasket gaging station and snow survey data collected by Natural Resource Conservation Service. The top value is for the first half of the month, the bottom value is for the latter half of the month. To make this table readable, this is a simplified version of the flow standards set in the Washington Administrative Code.

Reach	April	May	June	July	August	September	October
Lower Okanogan	1,120	1,400	4,000	2,400	1,050	800	940
(RK 28 to 82)	1,250	4,000	4,000	1,400	800	800	1,100
Middle Okanogan	910	1,200	3,800	2,150	840	600	730
(RK 82 to 113)	1,070	3,800	3,800	1,200	600	600	900
Upper Okanogan	330	350	500	420	320	300	330
(RK 113 to 125)	340	500	500	350	300	300	370
Similkameen	510	800	3,000	1,650	590	400	450
(RK 0 to 44, Canadian border)	640	3,000	3,000	900	400	400	500

Water quality

Water temperatures often exceed lethal tolerance levels for salmonids in lower Okanogan River. This exceedence is partly a result of natural phenomena (low gradient and solar radiation on the upstream lakes), but is exacerbated by sedimentation and summer low flows caused by dam operations and irrigation. High water temperatures in late summer and fall effectively exclude juvenile salmon from rearing in most of the basin, except the first few weeks after emergence. However, some limited summer rearing may occur in Similkameen River where ground water enters the stream. At times, high water temperatures in lower Okanogan River have blocked adult anadromous salmonid passage.

Okanogan River, Similkameen River, Omak Creek, and Lake Osoyoos have all been listed on WDOE's 303 (d) list of impaired water bodies (Class B). Okanogan River water quality is measured at Malott and Oroville. Both Okanogan County and OCCD have secured funds from WDOE through the Centennial Clean Water Program to identify and plan for means to mitigate point and nonpoint pollution sources, respectively. The level B Okanogan River Basin study (PNRBC 1977) attributed this problem to various agricultural problems such as return flows of irrigation water, livestock impacts on bank vegetation and stability, erosion from non-irrigated cropland, and forest harvest practices such as road construction. The CCT noted that of the 26 primary streams in the reservation, that Omak Creek and the Ninemile Creek watersheds are in the poorest condition. Fecal coliform bacteria, total bacteria, pH, temperature, and dissolved oxygen levels all exceeded state and federal water quality criteria. Seasonal patterns of water quality in Okanogan River are blurred by the effects of Lake Osoyoos, but some effects of non-point pollution in the lower river can be seen. Total suspended sediments seem to be elevated at the Malott station, above what would be expected from Similkameen River and Lake Osoyoos combined. Fecal coliform, nitrate/nitrite, and total phosphorous levels also appear to be higher than at the upstream sites (PNRBC 1977). When assessed in 1975, 30 industrial dischargers were identified in the basin (WDOE 1975).

The state of water quality in Similkameen River in Canada is considered to be good, according to levels established by BCME. Coliform in the river, molybdenum in a tributary, and phosphorus in some area lakes may periodically exceed acceptable levels (Table 20). During a survey from 1987 to 1993, the objectives for fecal coliform, an indicator of human and animal waste, was not met at times in the mainstem Similkameen River and in Allison Creek (BCME 1994). The phosphorus objective was exceeded in Missezula and Osprey lakes. The molybdenum objective in Wolf Creek, a tributary to the Similkameen, was exceeded at times during the survey period downstream from a copper mine. The objectives for aluminum, iron, and zinc were exceeded occasionally at the mouth of Hedley Creek or just downstream in the Similkameen River. Other sources of potential contaminated water from Canada in the Similkameen Watershed include treated municipal sewage at Princeton and Keremeos, diffuse discharges from agriculture and mining operations near Wolfe, Cahill and Hedley creeks (Swain 1990; BCME 1994)

Table 20. Percentages of time when water quality objectives were met for certain parameters in the Canadian reach of the Similkameen Basin from 1987 to 1993 (adapted from BCME 1994).

Parameter	Percent of time objective was met.
Fecal coliform	54
Suspended solids	96
Turbidity	100
Cyanide	100
Phosphorus	44
Dissolved oxygen	100
pH	100
Aluminum	97
Iron	96
Molybdenum	77
Zinc	95
Other heavy metals	100

12.5: Historical and Existing Aquatic Habitat Conditions

12.5.1: Mainstem Okanogan River

The riparian habitat in the Okanogan is the most degraded of the four watersheds (Chapman et al. 1994a). This lack of riparian vegetation contributes to the two major limiting factors, high water temperatures, and sedimentation. Likewise, the instream habitat has the most limitations to salmonid production. Establishment of riparian and instream habitat would have limited benefits after mid-summer, because of high water temperatures. Spawning gravels are severely limited in the mainstem Okanogan River because of sedimentation. Heavy silt loads from mass failures have caused fines to infiltrate redds and smothers habitat for invertebrates in the Similkameen and lower Okanogan. High turbidity in these reaches reduces the feeding efficiency of juveniles.

From the mouth to McAllister Rapids (RK 68), the river flows through a U-shaped, unconfined alluvial valley, has a gradient of 0.03%, and consists of mostly eroded banks, straight and impounded stream state types. Between RK 68 and Aeneas Creek (RK 84), the river flows through a moderately confined alluvial valley with a gradient of 0.05%. Eroded banks and multiple channels dominate this reach. From RK 84 to Mosquito Creek (RK 104) the river valley is again unconfined, lessens in gradient (0.04%), and consists of eroded bank, channelized, multiple channels with eroded banks, and straight eroded-bank stream states. Above RK 104 to Zosel Dam (RK 125) the unconfined valley is filled with lacustrine sediments, with a lower gradient (0.03%), and multiple channels with extensive bank erosion (Hillman and Ross 1992; Table 21).

Table 21. Inventory of valley bottom types and miles of stream state types (Lotspeich and Platts 1982) in the mainstem Okanogan River and shoreline conditions from Zosel Dam to the Columbia River confluence (from Hillman and Ross, 1992).

Valley bottom type	Kilometers of stream state type	
U-shaped unconfined alluvial valley RK 0.0 - 67.9	Eroded banks	25.53
	Channelized	3.23
	Impounded	9.70
	Multiple channel	1.78
	Multiple channel with eroded bank	8.16
	Straight channel with eroded bank	19.47
U-shaped moderately confined alluvial valley RK 67.9 - 83.9	Eroded banks	8.63
	Multiple channel	0.99
	Multiple channel with eroded banks	6.38
U-shaped unconfined alluvial valley RK 83.9 - 104.2	Eroded banks	9.58
	Channelized banks	1.73
	Multiple channel with eroded bank	7.14
	Straight channel with eroded bank	1.91
U-shaped unconfined lacustrine valley RK 104.2 - 124.4	Eroded banks	0.31
	Multiple channel with eroded banks	18.18
	Straight channel with eroded banks	1.73

12.5.2: Similkameen River

Historically, the Similkameen River was estimated to contain about 5.3 million square meters of spawning substrate, 80% of the total for the Okanogan Watershed (Chapman et al. 1994a). Half was estimated to lie between Palmer Creek and Keremeos B.C. (USFWS 1985). Only the lowest 14 km of the Similkameen River is available to salmonids, because of the now defunct Enloe Dam. Some of the highest densities of summer chinook salmon redds in the Mid-Columbia Region have been documented in that reach of the Similkameen River (Hillman and Ross 1992), which is a combination of deep canyon channel and unconfined lacustrine valley (Table 22). Over 38% of this reach has no riparian habitat.

Table 22. Inventory of valley bottom types and miles of stream state types (Lotspeich and Platts 1982) in the mainstem Similkameen River and shoreline conditions from Enloe Dam to the Okanogan River confluence (from Hillman and Ross, 1992).

Valley bottom type	Kilometers of stream state type	
U-shaped unconfined lacustrine valley RK 0.0 - 9.2	Straight channel	1.78
	Multiple channel with eroded banks	2.42
	Entrench channel	2.59
	Multiple channel with entrenched bank	2.42
V-shaped confined valley RK 9.2 - 13.8	Deep canyon	4.61

The Similkameen River provides 75% of the average flows to the Okanogan Basin. Like the upper Okanogan River, the Similkameen has high summer temperatures, often up to 22ºC (Chapman et al. 1994a). As such, the lower Similkameen cannot support summer rearing by juvenile salmonids. Soils in the Similkameen Watershed have a high potential for accelerated mass or surface erosion (PNRBC 1977; NHC 1986; NPPC 1990), and has degraded spawning habitat in the accessible reach of the lower river.

12.5.3: Lake Osoyoos

Lake Osoyoos is the final catchment of a large drainage area, receiving nutrients from population centers, industries, and agriculture along its course (Booth 1969, Mullan 1986). The 13-km long lake is relatively shallow, very warm in the summer months, highly polluted, and appears to be in the transitory state leading to complete eutrophication (Booth 1969, Allen and Meekin 1980). Lake Osoyoos is a series of three connected basins with the largest basin in the north end. The maximum depth is 21 m. The three basins are relatively independent with upstream basins sufficiently large to influence nutrient content in downstream basins. Rensel (1995) states that the condition of the lake has deteriorated only slightly since the early 1970s, when it was then, as now, rated as moderately enriched. Unlike Lake Wenatchee (the other principle sockeye salmon rearing area in the Mid-Columbia Region), Lake Osoyoos is characteristic of eutrophic lakes (Mullan 1986) with shallow, warm water enriched by agricultural influences (Allen and Meekin 1980). Artificial enrichment of the lake affects water quality in late summer after algal blooms that result in high water temperatures and an anoxic hypolimion (Pratt et al. 1991).

Lake Osoyoos is the primary rearing area for juvenile sockeye salmon in the Okanogan River system. Lake Osoyoos has a relatively abundant food source, consequently producing relatively large sockeye smolts (Mullan 1986). Predators, warm water temperatures, and anoxic hypolimnentic areas may limit sockeye salmon production in Lake Osoyoos (Pratt et al. 1991). Eighteen species of fish inhabit the lake, and many are potential sockeye predators (Chapman et al. 1995b). Water temperatures rise early in the year, reaching 18ºC at the surface of the lake as early as May. In August, surface temperatures reach 25ºC (Allen and Meekin 1980). Recent dissolve oxygen and temperature profiles of Lake Osoyoos (Rector 1993) indicate the formation of a strong thermocline in summer months that persists until fall turnover. Thermoclines of this magnitude shut off large portions of the lake for early rearing of sockeye fry and cause Lake Osoyoos to be “rearing limited” (Pratt et al. 1991). Rensel (1995) states that it is possible that sockeye fry do not rear in the south basin during mid to late summer in certain years, depending upon water and dissolve oxygen conditions.

12.5.4: Other Lakes

There are several lakes (over 10 ha in size) in the Okanogan Watershed that are currently, or were historically, blocked to anadromous fish passage. Omak Lake is a large, oligotrophic, deep alkaline lake with a high concentration of dissolved substances typical of the hard-water lakes of eastern Washington. Conductivity is generally high and has a high clarity, and high dissolved oxygen levels. Conconully, Palmer, and Spectacle lakes generally have good water quality, although algae blooms have occasionally been observed (WDOE 1975).

12.5.5: Wetland Resources

Based on 1983, 1984, and 1990 aerial photographs, roughly 2.4% of the Okanogan Watershed is classified as wetland under the USFWS National Wetland Inventory (Table 23). As to be expected, the majority of wetlands are associated with Lake Osoyoos, and the confluence of the Similkameen and Okanogan rivers, although there are some extensive riverine wetlands near Cassimer Bar.

Table 23. Area and types of wetland habitat in the Okanogan Watershed, and percent of total. Wetlands were identified in the USFWS National Wetland Inventory.

System and class	Total area (ha)	Percent of watershed
Palustrine emergent	9,791.2	0.71
Palustrine scrub-shrub	3,632.5	0.26
Lacustrine littoral, open water	19.5	0.01
Lacustrine, limnetic, open water	11,571.1	0.83
Lacustrine, littoral, unconsolidated shore	354.0	0.03
Palustrine, open water	1,495.6	0.11
Riverine, upper perennial, open water	1,797.8	0.13
Riverine, lower perennial, unconsolidated shore	10.5	0.00
Riverine, upper perennial, unconsolidated shore	570.6	0.04
Palustrine, forested	3,249.0	0.23
Palustrine, unconsolidated shore	236.6	0.02
Palustrine, aquatic bed	104.2	0.01
Lacustrine, littoral, aquatic bed	88.0	0.01
Riverine, lower perennial, open water	2.5	0.00
Riverine, upper perennial, rock bottom	0.2	0.00
Palustrine, unconsolidated bottom	5.5	0.00
Riverine, intermittent, streambed	4.6	0.00
Lacustrine, littoral, unconsolidated bottom	197.6	0.01
Lacustrine, littoral, rock bottom	0.4	0.00
Total mapped wetland area	33,125.9	2.40
Upland area	1,352,758.9	97.60
Total mapped area	1,386,092.6	

12.6: The Relationship of Existing Aquatic Habitat Conditions to Biological Productivity

Ocean-type chinook salmon

Water temperatures pose the most difficult problem for increasing survival of most both ocean-type and stream type salmonids. Chapman et al. (1994a) plotted water temperature in the Okanogan River at Oroville and Tonasket, showing that mean daily temperatures were frequently well over 21ºC in 1986 and 1987 in mid-summer when sockeye could be expected to migrate upstream. Hansen (1993) plotted mean daily temperatures near Zosel Dam at 21ºC or higher for at least 50 days in 1992, and higher than 25ºC for periods of up to 10 days. He also documented that temperatures upstream from Lake Osoyoos remained higher than 21ºC for many days in July and August. Hansen (1993) speculated that the alteration of flow regimes by upstream structures have possibly changed retention times in Lake Osoyoos that exacerbate the problem. The high temperatures in the lower Okanogan River could force ocean-type chinook salmon subyearlings to remain well upstream in cooler areas or leave the Okanogan Watershed for the Columbia Rive before the high temperatures begin to develop.

Other than providing passage through Enloe Dam, little can be done to improve productivity of ocean-type chinook salmon in the Similkameen River. Spawning habitat for ocean-type chinook salmon is highly degraded, but still supports a viable population. As in the Okanogan, water temperatures can be a significant problem. Progeny of chinook salmon spawners in Similkameen River must emigrate as subyearlings to maintain viability.

Stream-type salmonids

Sockeye salmon production is spawning habitat limited (Allen and Meekin 1980; Mullan 1986; Chapman et al. 1995b), although flow conditions in lower Okanogan River (downstream of Lake Osoyoos), and related elevated temperatures in the lake have been shown to adversely affect adult survival. Pratt et al. (1991) suggest that sockeye salmon rarely reach compensatory stages of mortality in Lake Osoyoos. They estimate the carrying capacity to be 4 million smolts, substantially higher than the current production (from 0.5 million to 2.0 million). Incubation survival in the reach of the Okanogan River controlled by the 13 vertical drop structures is lower than that in the unregulated reaches of the river (Allen and Meekin 1980; Hansen 1993), although it is speculated that incubation survival is within reasonable limits. However, other factors, such as the high density of spawners in a limited area, may be an important factor in the stability of the sockeye run. Flow reductions in this reach may have serious impacts upon incubation survival (Major and Mighell 1966). Mullan (1986) stated that 15,000 more sockeye salmon could spawn in the river if the flows were increased from 325 cfs to 470 cfs during spawning. These sustained flows would obviously be required during incubation as well.

Shepherd and Inkster (1995) discussed the inadequacy of irrigation diversion screening in the Okanogan River between McIntyre Dam and Lake Osoyoos. Screen opening requirements in Canada are 2.5 mm, which would not prevent uptake of sockeye salmon fry. It is possible that some intakes in the lower Okanogan River are not properly screened as well.

Predators, warm water temperatures, and anoxic hypolimnentic areas may limit sockeye production in Lake Osoyoos (Pratt et al. 1991). Recent dissolved oxygen and temperature profiles of Lake Osoyoos (Rector 1993) indicate the formation of a strong thermocline in summer months that persists until fall turnover. Thermoclines of this magnitude shut off large portions of the lake for rearing of sockeye fry and limit its rearing capacity (Pratt 1991).

SECTION 13: RECOMMENDED STRATEGIES FOR THE OKANOGAN WATERSHED

13.1: General Strategy

Most of the actions to improve salmonid production on the Okanogan drainage are institutional in nature. Facilitation and funding of BMPs and CRMPs for growers would provide indirect benefits to water quality and quantity. Several benefits to aquatic organisms would result from these practices, including a reduction in nonpoint sources of organic pollutants and sediments, and lowered late-summer water temperatures. The riparian and floodplain standards in the BMPs should be strengthened however. We believe that sediment delivery to Okanogan Watershed has serious repercussions on many aspects of the salmonid life-cycle. A sediment budget analysis should be conducted to determine the causal mechanisms and to identify a means to rectify this problem.

Passage improvements on Omak Creek and Salmon Creek would benefit steelhead, and possibly bull trout and spring chinook salmon, if they were introduced to the latter stream. Both these actions are institutionally and logistically feasible, and should be strongly considered. There is potential to provide funds to Oroville/Tonasket Irrigation District to increase flows from Zosel Dam during periods of sockeye salmon outmigration from Osoyoos Lake. There may be potential for similar negotiations with British Columbia water managers to better manage flows for passage, spawning, and incubation.

Several of the important spawning areas should be revegetated to help maintain their current production potentials. The areas below McIntyre Dam, Zosel Dam, and Enloe Dam could benefit from streambank improvements. Some riparian bottomlands, primarily the areas above Riverside, could be protected or established on the lower Okanogan, but this may have limited effect on the overall water quality, given the temperature or magnitude of the sediment load coming from the upper Similkameen and Okanogan. These riparian areas have some benefits though. They would increase woody debris recruitment to the stream, which would provide instream holding areas (when the water is cool enough) and stabilize some erosive banks. Also, there would obviously be benefits to species other than salmonids from these purchases. Many landowners would be willing to do cooperative ventures to stabilize streambanks using bioengineered methods. These efforts would improve holding areas for adult summer chinook salmon. One would suspect that juvenile chinook and sockeye salmon gradually drift downstream in winter; these stabilized areas would potentially provide resting cover as they move from the Okanogan system.

Discussions with Canadian authorities on means to improve passage and spawning conditions for sockeye salmon would be the single most important step in addressing the Okanogan salmon problem. The authors feel that this is an easier task than is commonly believed. The nascent Cooperative River Basin Project, facilitated by the OCCD, is an appropriate avenue to accomplish this task. PUD support of this process would benefit sockeye salmon.

13.2: Habitat Protection

The highest priority for increasing biological productivity will be to maintain existing stream channel function and diversity and flood plain function (Section 1.6.2). The principle means to meet this objective is to secure riparian habitat--anywhere in the watershed--either in conservation agreements, easements or direct purchases. Obviously, some areas have more immediate needs, because of their importance for existing life history strategies, and should be given greater emphasis. The following list identifies stream reaches which should receive protection, and is therefore ranked in biological priority:

1) The upper mainstem Okanogan River, from McIntyre Dam downstream to VDS 13.
2) The lower Similkameen River, from Enloe Dam to the confluence.
3) Any riparian area on the Okanogan River from Zosel Dam to the confluence.

13.3: Habitat Restoration

A range of strategies is recommended for habitat restoration in the Okanogan Watershed. Like the *Habitat Protection* strategy, most strategies center on efforts to maintain or increase the complexity of the stream channel and floodplain (Section 1.6.3). These recommendations are listed in order of biological priority.

1) The upper mainstem Okanogan River, from McIntyre Dam downstream to VDS 13.

2) Passage should be restored for anadromous salmonids on Salmon Creek and Omak Creek.
3) The erosive banks on the Okanogan between the Similkameen River and Bonaparte Creek should be revegetated, and stabilized with bioengineering, where appropriate.
4) The denuded reaches of the lower Similkameen River should be revegetated, and stabilized with bioengineering, where appropriate.
5) If fish passage is restored, the denuded reaches of the middle Similkameen should be revegetated.
6) The erosive banks on the Okanogan between Bonaparte Creek and Omak Creek should be revegetated, and stabilized with bioengineering, where appropriate.
7) Rock structures should be placed at selected locations to create scour pockets in an effort to develop suitable spawning habitat.

MONITORING AND EVALUATION

<u>14.1: Program Specific Studies</u>

Programs undertaken to protect and restore aquatic/riparian/wetland habitat should be monitored and evaluated. Program monitoring and evaluation should have two components: (1) studies to determine the efficacy of specific projects, and (2) continuous monitoring of selected parameters in the streams. Both components should be based on short and long term analyses using Proper Functioning Condition (PFC; Prichard et al. 1993; 1994) and Future Desired Condition (DFC; Reeves et al. 1995), respectively (Figure 1).

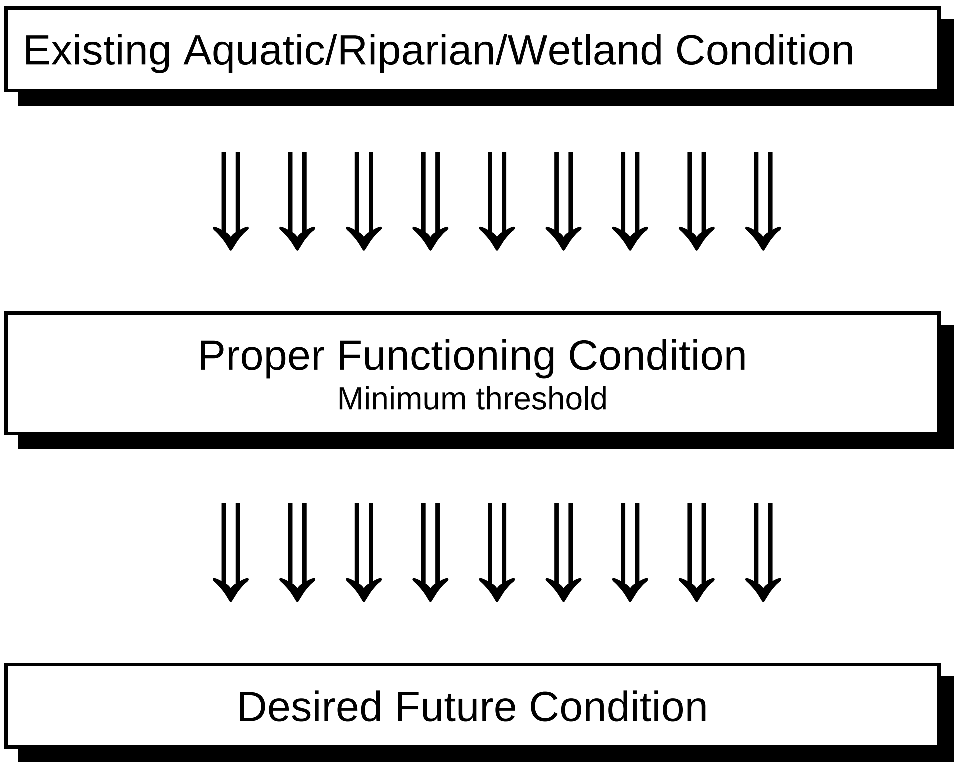

Figure 1. Conceptual monitoring and evaluation format for watershed protection and restoration.

A realistic monitoring schedule should be set and reviewed annually, to avoid inappropriate and excessive expenditures of effort and money. Enough time should be allowed for pre- and post project monitoring so that the estimates of baseline and reference conditions used are representative and reliable. Monitoring should be maintained long enough to confirm that the restoration can withstand unusual environmental events, such as floods and droughts (NRC 1992; Wissmar 1993). As the project's database management process becomes well established, and restoration technology improves in reliability, selective monitoring using cost-effective indicators should become possible.

The parameters typically used for assessing quality of salmon habitat (temperature, substrate embeddedness, pool-riffle ratios, LWD frequency) may be useful for only a limited set of conditions. These parameters are easily and inexpensively measured, but they do not take into account the dynamic nature of fluvial systems. These parameters should still be measured, as they will provide important information leading to decision on reach-specific management objectives. Standardized criteria will not be appropriate for all stream systems (Haskins 1993; Dawson 1996). Long term analyses of the dynamic nature of streams should include factors unique to the separate reaches, including: (1)

predominant rock type, substrate characteristics, stream gradient, and channel confinement; (2) local climate and flow regimes; (3) natural disturbance history, and (4) anthropogenic disturbance history (Bisson et al. *in prep*). Within each of these reaches, stream channel classification systems (for example, Rosgen 1985) will provide a baseline indication of what potential stream conditions may exist, given the geomorphic constraints to that reach. The established monitoring criteria for a given stream should be established as the program is established.

Highly intensive surveys of habitat and stream geomorphic conditions should be done on a short-term (2-3 years), on each stream (or stream reach) followed by low-intensity surveys done over a relatively long period (10-12 years). These two survey methods may form the basis for a long-term monitoring program. The principle survey types may be Hankin/Reeves (USFS 1995) for fish habitat, Myers (1989), Haskins et al. (1993), and Schuett-Hames et al. (1993) for riparian and in-stream function, and Rosgen (1994) for stream geomorphology. Three indicators of stream health should be analyzed: fish habitat, stream channel function, and riparian function (Table 24). These methods should be modified by interdisciplinary teams to fit the information or management needs for each stream, and to meet the goals of DFC.

Table 24. General parameters to be measured during pulsed inventories of streams.

<u>Fish habitat parameters</u>	
1)	Migration barriers
2)	Adult holding
3)	Spawning gravel quantity, quality, and stability
4)	In-stream and overhead cover
<u>Stream channel parameters</u>	
1)	Channel bed morphometry and pattern
2)	Bank and gravel bar characteristics
3)	Pool frequency and quality
4)	Flood plain attributes
<u>Riparian function parameters</u>	
1)	Current LWD status
2)	LWD recruitment potential
3)	Canopy closure
4)	Stream temperature

Virtually all evaluation of restoration projects will be done through habitat analysis, since fish production indicators are often confounded by factors outside the control of restoration projects (Platts and Rinne 1985). In some situations however, information on fish production may provide important information to determine the effectiveness of watershed restoration. Indices of fish productivity should be done in conjunction with hatchery evaluations for various fish settlement agreements. Some projects should be designed to protect against the scouring action of high flows, to desynchronize flood events, and to provide a refuge for aquatic organisms during both extreme high and low points on the hydro graph. A protocol for "event-triggered" (NRC 1992) monitoring should be planned as part of restoration projects designed to convey, resist, or use floods or other extreme hydrologic or meteorologic events. Surveys should be done during the event, or immediately after, to determine whether the restoration is meeting the design criteria.

An effective means to establish restoration goals and to evaluate the success of stream restoration is to develop reference streams. Researchers should compare the biological communities in a disturbed reach to communities in a set of relatively undisturbed reference streams of the same order in the same region. The suite of reference streams should include more than one representative of each stream order so that variability among streams of the same order can be quantified. Replication makes it possible to decide whether a restored stream is close enough to the reference standard to be judged a success. Several index reaches, preferably in drainages of 4th order or higher should be established, and intensively inventoried, to provide a reference for restoration projects. These reaches should be free from major anthropogenic disturbances, or have recovered from such perturbations to the point that they approximate conditions in pristine watersheds. Table 25 provides some suggested streams in the Mid-Columbia Region that will probably be required for reference. For some combinations of stream order and geomorphic type, no suitable reference streams exists within the region; streams in Idaho are proposed for use as reference for these stream types.

Table 25. Suggested reference streams and reaches for inventory in Mid-Columbia watershed protection and restoration projects.

Stream order	Geomorphic type	Reference streams (or reach)
2	Confined high gradient	Lost River, Panther Creek
3	Unconfined alluvial	Chewuch River (Twentymile Creek to Cub Creek)
	Confined alluvial	Icicle Creek (Trout Creek to Snow Creek)
	Unconfined lacustrine	Salmon River, Idaho (from lake outlet to East Fork).
4	Unconfined alluvial	Chiwawa River
	Confined alluvial	Middle Fork, Salmon River, Idaho.
	Unconfined lacustrine	Wenatchee River (from lake outlet to Chiwawa River)
5	Unconfined alluvial	Methow River (Twisp River to Gold Creek)
	Confined alluvial	Methow River (Gold Creek to mouth)
6	Unconfined alluvial	Salmon River, Idaho (selected reaches)
	Confined alluvial	Salmon River, Idaho (selected reaches)

14.2: Project Specific Studies

The primary objectives of project-specific studies are to determine the efficacy of a given restoration action in approximating DFC, and to provide an indication of the expected effects of similar projects under consideration. In most situations, restoration projects can be undertaken in a straightforward manner. For those opportunities, a well-defined habitat restoration plan can be developed and implemented using general guidelines (Table 26). In other situations however, the deleterious alterations are not fully understood, and a well-defined plan cannot be developed without additional information. In such situations, some studies may be required to decide if the deleterious alterations can be rectified or improved though restoration. These would be clearly defined studies that would identify how an alteration is deleterious to watershed function, and how it can be rectified.

Table 26. Project Monitoring and Evaluation: General Considerations

1.	To what extent were the project goals and objectives achieved? What were the ecological, economic, and social benefits realized by the project?
2.	How similar in structure and function is the restored habitat to the targeted habitat condition (Desired Future Condition)? If not all natural components of the habitat are restored, have critical components been restored?
3.	How long did the project take?
4.	What was the final cost, in standardized value terms, of the restoration project? How cost effective was the project?
5.	Would another approach to restoration have produced the desired results at lower cost?

Specific performance indicators should be linked to each objective of the restoration projects. These performance indicators are specific measurable quantities that reveal to what extent the objectives are achieved. Additionally, the assessment should be appropriate in scale (areal and temporal extent), and in sampling frequency and intensity. This allows one to measure the performance indicators accurately and reliably, and thereby assess progress toward the project objectives, goals, and mission. Periodic, recurring inventories are an integral part of the evaluation process, and form the foundation for the selection criteria for future projects. They should produce reliable information, both between watersheds and across time. Specifically, these inventories should identify existing aquatic and riparian conditions, identify the factors limiting the productive capabilities of habitats, measure attainment of habitat restoration projects, and help to assess cumulative effects of restoration projects.

14.3: Continuous Monitoring

Stations should be established at selected sites on each stream (or stream reach) to collect water quality and quantity data on a continuous (or near continuous) manner. These monitoring stations should be closely linked with those stations already maintained by USGS, USFS, and WDOE. Data to be collected may include those factors identified as having deleterious effects upon natural fish production, and are being addressed in the implementation plan for that stream (or stream reach).

14.4: Public Participation

The public in the Mid-Columbia Region has become increasingly aware of the need for aquatic restoration. Several groups have undertaken stream restoration projects, and are likely to interact directly or indirectly other watershed processes underway. These organizations, if properly guided and supported, can be a valuable impetus for effective aquatic ecosystem restoration, and occasionally a valuable source of volunteer labor to collect data frequently. In a collaborative effort with local conservation districts and state agencies, ambient monitoring stations (Michaud 1991) should be encouraged for each watershed. Short term benefits to citizen monitoring are tangible: convenience and expense. From a long range perspective, the advantage of citizen monitoring is that it promotes a citizenry committed to the goals of watershed restoration.

14.5: Database Management

The authors recognize the importance of a well-designed database management system for all its activities. Decisions on project selection and implementation may depend upon information derived from ongoing monitoring and evaluations, and through other sources, such as USFS, WDNR, WDOE, and county governments. A Geographic Information System (GIS) database may be developed and maintained for information retrieval by watershed managers. In the event a GIS database is developed, it should be able to link with cooperating entities.

REFERENCES

ACCD (Asotin County Conservation District). 1995. Asotin Creek Model Watershed Plan. Clarkston, WA.

Allen, R. L. and T. K. Meekin. 1980. Columbia River sockeye salmon study 1971-1974. Washington Department of Fisheries, Olympia, WA.

Andrusak, H., and T. G. Northcote. 1971. Segregation between adult cutthroat trout (*Salmo clarki*) and Dolly Varden (*Salvelinus malma*) in small coastal British Columbia lakes. Journal of the Fisheries Research Board of Canada. 28:1259-1268.

Averett, R. C., and C. MacPhee. 1971. Distribution and growth of indigenous fluvial and adfluvial cutthroat trout (*Salmo clarki*), St. Joe River, Idaho. Northwest Science 45(1):38-47.

Bailey, P.B. 1991. The flood pulse advantage and the restoration of River floodplain systems. Regulated Rivers: Research and Management 6:75-86.

Barth, D., and J. DeMeyer. 1982. Aquatic land management plan for the Okanogan-Similkameen rivers. Washington Department of Natural Resources, Olympia, WA.

Bartlett, H. 1995. Summary report for Methow Basin spring chinook salmon hatchery program: 1993 brood year annual report from Washington Department of Fish and Wildlife to Douglas County Public Utility District, East Wenatchee, WA.

BCME (British Columbia Ministry of the Environment) 1994. Water quality status report, Similkameen River. Available from British Columbia Ministry of the Environment, Penticton, B.C.

Beamish, R. J., and D. R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Canadian Journal of Fisheries and Aquatic Science. 50:1002-1016.

Bellrose, F. C., F. L. Paveglia, Jr, and D. W. Steffeck. 1979. Waterfowl populations and the changing environment of the Illinois River Valley. Illinois Natural History Survey Bulletin, Volume 32, Article 1.

Behnke, R. L. 1992. Native trout of western North America. American Fisheries Society Monograph 6. Bethesda, MD.

Beschta, R. L. and W. S. Platts. 1986. Morphological features of small streams: significance and function. American Water Resources Association, Water Resources Bulletin. 22(3):369-379.

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry implications. Pages 191-232 *in* E. O. Salo and T. W. Cundy, editors. Streamside Management: Forestry and Fisheries Interactions. Contribution Number 57, Institute of Forest Resources, University of Washington, Seattle, WA.

Beschta, R. L., W. S. Platts, and J. B. Kauffman. 1992. Field review of fish habitat improvement projects in the Grande Ronde and John Day River Basins of eastern Oregon. Bonneville Power Administration DOE/BP-21493-1, Portland, OR.

Bilby, R. E., and P. A. Bisson. 1987. Emigration and production of hatchery coho salmon *(Oncorhynchus kisutch)* stocked in streams draining an old-growth and a clear-cut watershed. Canadian Journal of Fisheries and Aquatic Sciences 44:1397-1407.

Binns, N. A. 1986. Stabilizing eroding stream banks in Wyoming. Wyoming Fish and Game Department, Laramie, WY.

Bisson, P. A., and J. R. Sedell. 1984. Salmonid populations in streams with clear-cut versus old-growth forests of western Washington. Pages 121-129 *in* W. R. Meehan, T. R. Merrell, Jr., and T. A. Hanley, editors. Fish and Wildlife Relationships in old-growth forests. American Institute of Fisheries Research Biologists, Juneau, AK.

Bisson, P. A, G. H. Reeves, and R. E. Bilby. In preparation. Desired Future Conditions.

Bjornn, T. C, and J. Mallet. 1964. Movements of planted and wild trout in an Idaho river system. Transactions of the American Fisheries Society 93:70-76.

Bjornn, T. C., and six co-authors. 1977. Transport of granitic sediment in streams and its effects on insects and fish. Bulletin 17, College of Forestry, Wildlife, and Range Sciences, University of Idaho, Moscow ID.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

Booth, D. M. 1969. Water quality studies in Osoyoos Lake. M.S. Thesis. University of British Columbia, Vancouver, B.C.

Bovee, K. D., and T. Cochnauer. 1977. Development and evaluation of weighted criteria probability-of-use curves for instream flow assessments: fisheries. Instream flow information paper number 3. Cooperative Instream Flow Service Group, Fort Collins, CO.

Bovee, K. D., and R. Milhous. 1978. Hydraulic simulation in instream flow studies: theories and techniques. Instream flow information paper number 5. Cooperative Instream Flow Service Group. Fort Collins, CO.

Bovee, K. D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream flow information paper number 12. Cooperative Instream Flow Service Group. Fort Collins, CO.

Brinsom, M. M., B. L. Swift, R. C. Plantico, and J. S. Barclay. 1981. Riparian ecosystems: their ecology and status. U.S. Fish and Wildlife Service. Biological Services Program. FWS/OBS-81/17, Washington, D. C.

Brown, T. G., and G. F. Hartman. 1988. Contribution of seasonally flooded lands and minor tributaries to the production of coho salmon in Carnation Creek, British Columbia. Transactions of the American Fisheries Society 117:546-551.

Brown, L. G. 1992. Draft management guide for the bull trout *Salvelinus confluentus* (Suckley) on the Wenatchee National Forest. Washington Department of Wildlife, Olympia, WA.

Brown, L. G. 1994. On the zoogeography and life history of Washington's native char. Report 94-04. Washington Department of Fish and Wildlife, Olympia, WA.

Bryant, M. D. 1995. Pulsed monitoring for watershed and stream restoration. Fisheries 20(11):6-13.

BRT (Biological Review Team). 1996. Preliminary conclusions of the review of the status of sockeye salmon (*Oncorhynchus nerka*) from Washington and Oregon under the Endangered Species Act. Available from National Marine Fisheries Service, Seattle, WA.

Budhabhatti, J., and O. E. Maughan. 1994. Cage designs for fish culture in irrigation waters. The Progressive Fish Culturist 56-147-148.

Bugert, R. M., T. C. Bjornn, and W. R. Meehan. 1991. Summer habitat use by young salmonids and their responses to cover and predators in a small southeast Alaska stream. Transactions of the American Fisheries Society 120:474-485.

Bugert, R. M., and T. C. Bjornn. 1991. Habitat use by steelhead and coho salmon and their responses to predators and cover in laboratory streams. Transactions of the American Fisheries Society 120:486-293.

Bugert, R., K. Petersen, G. Mendel, L. Ross, D. Milks, J. Dedloff, and M. Alexandersdottir. 1992. Lower Snake River Compensation Plan, Tucannon River Spring Chinook Salmon Hatchery Evaluation Program. 1991 Annual Report to U.S. Fish and Wildlife Service, Cooperative Agreement 14-16-0001-91534. Washington Department of Fisheries, Olympia, WA.

Bugert, R. M. 1996. Potential to increase anadromous salmonid productivity in the mid-Columbia region using artificial propagation. Mid-Columbia Mainstem Conservation Plan. Available from Chelan County PUD, Wenatchee.

Burgner, R. L. 1991. Life history of sockeye salmon *(Oncorhynchus nerka*). Pages 1-117 in C. Groot and L. Margolis, editors. Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, B.C.

Busack, C. A., and K. P. Currens. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. American Fisheries Society Symposium 15. Bethesda MD.

Bustard, D. R., and D. W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 32:667-681.

Cairns, J. Jr. 1988. Increasing diversity by restoring damaged ecosystems. Pages 333-343 *in* E. O. Wilson and F. M. Peter. Editors, Biodiversity. National Academy Press, Washington, D.C.

Caldwell, B., and D. Catterson. 1992. Methow River Basin fish habitat analysis using the instream flow incremental analysis. Publication Number 92-82. Washington Department of Ecology, Olympia, WA.

Caldwell, B, and H. Beecher, H. 1995. Entiat River Basin fish habitat analysis using the instream flow incremental methodology. Open file technical report 95-166. Washington Department of Ecology. Olympia, WA.

Carie, D. G. 1996. Spring and summer chinook salmon and sockeye salmon spawning ground surveys on the Entiat River, 1995. U. S. Fish and Wildlife Service, Leavenworth, WA.

Cavendish, M. G., and M. I. Duncan. 1986. Use of the instream flow incremental methodology: a tool for negotiation. Environmental Impact Assessment Review 6:347-363.

Chapman, D. W. 1961. Effects of logging upon fish resources of the west coast. Journal of Forestry 60(8):533-537.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. McMillan Lectures in Fisheries. University of British Columbia, Vancouver.

Chapman, D. W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Transactions of the American Fisheries Society 109:357-363.

Chapman, D., and eight co-authors. 1994a. Status of summer/fall chinook salmon in the mid-Columbia Region. Don Chapman Consultants, Inc. Boise, ID.

Chapman, D., and four co-authors. 1994b. Status of summer steelhead in the mid-Columbia Region. Don Chapman Consultants, Inc. Boise, ID.

Chapman, D., and four co-authors. 1995a. Status of spring chinook salmon in the mid-Columbia Region. Don Chapman Consultants, Inc. Boise ID.

Chapman, D., and seven co-authors. 1995b. Status of sockeye salmon in the mid-Columbia Region. Don Chapman Consultants, Inc., Boise ID.

Chapman Consultants, Inc. 1988. Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Available from Chelan County Public Utility District, Wenatchee, WA.

Chelan County Regional Planning Council. 1973. West Central Chelan County Comprehensive Plan. Wenatchee, WA.

CCPD (Chelan County Planning Department). 1988. Upper Wenatchee River Valley Comprehensive Plan. Wenatchee, WA.

CCCP. 1994. Critical Areas Ordinance, Chelan County. Available from Chelan County Planning Department, Wenatchee, WA.

CCT (Colville Confederated Tribes) and Natural Resource Conservation Service. 1995. Draft Omak Creek Restoration Plan. Available from Natural Resource Conservation Service, Spokane, WA.

Ciolek, C. C. 1975. Mission Creek watershed land use study: alternatives for land management. Leavenworth Ranger District, Wenatchee National Forest, Leavenworth, WA.

Craig, J. A., and A. J. Suomela. 1941. Time of appearance of the runs of salmon and steelhead trout native to the Wenatchee, Entiat, Methow, and Okanogan rivers. U.S. Fish and Wildlife Service, Olympia, WA.

Cuenco, M. L., T. W. H. Bachman, and P. R. Mundy. 1993. The use of supplementation to aid in natural stock restoration. Pages 269-293 *in* J. G. Cloud and G. H. Thorgaard, editors. Genetic Conservation of Salmonid Fishes, Plenum Press, New York, NY.

Dambacher, J., and M. Eason. 1992. Lower White River 1992 stream survey report, to Wenatchee National Forest. Tioga Trading Company, Roseburg, OR.

Dawson, P., and six co-authors. 1996. Integrated survey assessment of habitat condition and response to flooding: three case studies in two eastern Cascades geomorphic land units (subsections). Wenatchee National Forest, Wenatchee, WA.

Ehinger, B. 1993. Water quality data summary and linear trend analysis of the Wenatchee River basin. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA.

Ehinger, W. No date. A review of the data from the Entiat River Basin collected for the ambient monitoring database. Washington Department of Ecology, Olympia, WA.

Ellner, S., and N. G. Hairston, Jr. 1994. Role of overlapping generations in maintaining genetic variation in a fluctuating environment. The American Naturalist 143:403-417.

Eltrich, R., K. Petersen, A. Mikklesen, and M. Tonseth. 1995. Summary report on the 1992 brood sockeye and chinook salmon stocks reared at Rock Island Fish Hatchery Complex facilities. Report to Chelan County PUD from Washington Department of Fish and Wildlife, Olympia, WA.

ERCC (Entiat River Valley Citizens Committee), and USDA SCS. 1979. Entiat Cooperative River Basin Study. Available from Entiat Ranger District, Wenatchee National Forest, Entiat, WA.

Everest, F. H., and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29(1):91-100.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: an ecological, economic, and social assessment. U.S. Forest Service, Portland, OR.

Fish, F. F., and M. G. Hanavan. 1948. A report upon the Grand Coulee Fish Maintenance Project 1939-47. Special Scientific Report No. 55. U. S. Fish and Wildlife Service, Leavenworth, WA.

Free, D. L. 1995. Analysis of fish populations in Icicle Creek, Trout Creek, an Jack Creek, Washington, 1994. U. S. Fish and Wildlife Service, Leavenworth, WA.

Fulton, L. A. 1968. Spawning areas and abundance of chinook salmon (*Oncorhynchus tshawystcha*) in the Columbia Basin--past and present. U.S. Fish and Wildlife Service Special Scientific Report--Fish. No. 571. Washington D.C.

Gharrett, A. J., and W. W. Smoker. 1993. Genetic components in life history traits contribute to population structure. Pages 197-202 *in* J. G. Cloud and G. H. Thorgaard, editors. Genetic conservation of salmonid fishes. Plenum Press, NY.

Goetz, F. 1989. Biology of the bull trout, *Salvelinus confluentus*, a literature review. Willamete National Forest, Eugene, OR.

Griffith, J. S., and T. W. Hillman. 1986. Analysis of fish populations in the Methow River. Idaho State University report to U. S. Fish and Wildlife Service, Leavenworth, WA.

Haas, G. R., and J. D. McPhail. 1991. Systematics and distributions of Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in North America. Canadian Journal of Fisheries and Aquatic Sciences 48:2191-2211.

Hagen, J. E., and G. B. Grette. 1994. 1993 Okanogan River sockeye salmon spawning ground population study. Parametrix report to Douglas County Public Utility District. East Wenatchee, WA.

Hall, J. D., and N. J. Knight. 1981. Natural variation in abundance of salmonid populations in streams and its implication for design of impact studies. EPA-600/53-81-021. U.S. Environmental Protection Agency, Corvallis, OR.

Hansen, J. 1993. Upper Okanogan River sockeye salmon spawning ground survey - 1992. Colville Confederated Tribe Report to Douglas County Public Utility District. East Wenatchee, WA.

Haskins, J., P. Dawson, K. MacDonald, and T. Robison. 1993. Stream health parameter/desired future condition analysis. Wenatchee National Forest, Wenatchee, WA.

Hawkins, C. P., and ten co-authors. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18(6):3-12.

Healey, M. C. 1983. Coastwide contribution and ocean migration patterns of stream- and ocean-type chinook salmon *Oncorhynchus tshawystcha*. Canadian Field Naturalist 97-427-433

Healey, M. C. 1991. Life history of chinook salmon (Oncorhynchus tshawystcha). Pages 311-394 in C. Groot and L. Margolis, editors. Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, B.C.

Heifetz, J., M. L. Murphy, and K. V. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaska streams. North American Journal of Fisheries Management 6:52-58.

Hillman, T. W., and D. W. Chapman. 1989. Abundance, growth, and movement of juvenile chinook salmon and steelhead. Pages 1-41 in Don Chapman Consultants, Inc. Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Final report to Chelan County Public Utility District, Wenatchee, WA.

Hillman, T. W., and M. D. Miller. 1994. Estimated abundance and total numbers of chinook salmon and trout in the Chiwawa River, Washington, 1993. Report to Chelan County Public Utility District, Wenatchee, WA. Don Chapman Consultants, Inc., Boise, ID.

Hillman, T. W., and K. E. Ross. Summer/fall chinook salmon spawning ground surveys in the Methow and Okanogan River Basins, 1991. Don Chapman Consultants, Boise, ID.

Hindes, R. 1994. Wenatchee River Watershed Ranking Project. Chelan County Conservation District, Wenatchee, WA.

Holton, G. D. 1990. A field guide to Montana fishes. Montana Department of Fish, Wildlife, and Parks, Helena, MT.

Hoover, M. D. 1952. Water and timber management. Journal of Soil and Water Conservation 7:75-78.

House, R. A., and P. L. Boehne. 1986. Effects of instream structures on salmonid habitat and populations in Tobe Creek, Oregon. North American Journal of Fisheries Management. 6:38-46.

Hubble, J. 1993. Methow valley spring chinook supplementation project. Annual report to Douglas County Public Utility District, East Wenatchee, WA.

Icicle Irrigation District. 1993 Comprehensive Water Conservation Plan. Klohn Leonoff, Inc. Kirkland, WA.

Inglis., C. C., 1947. Meanders and their bearing on river training. The Institute of Civil Engineers. 1-23.

Johnson, W. C. 1992. Dams and riparian forests: case study from the Upper Missouri River. Rivers 3(4):229-241.

Junk, W. J., P. B. Bailey, and R. E. Sparks. 1989. The flood pulse concept in river floodplain systems. Page 110-127 *in* D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences, Number 106.

Kapuscinski, A. R., and L. M. Miller. 1993. Genetic hatchery guidelines for the Yakima/Klickitat Fisheries Project. Co-Aqua. St. Paul, MN.

Kauffman, J. B., R. L. Beschta, and W. S. Platts. 1993. Fish habitat improvement projects in the Fifteenmile Creel and Trout Creek basins of central Oregon: field review and management recommendations. Bonneville Power Administration, DOE/BP-18955-1. Portland, OR.

Kauffman, K. G. 1978. Water resources management program, Okanogan River Basin. Basin Program Series No. 3. Washington Department of Ecology, Olympia, WA.

Kaumheimer, D. 1988. Similkameen River instream flow study. Part 2: Fish Preference Curves. Okanogan County Washington. U. S. Fish and Wildlife Service, Olympia, WA.

Kelly, B. 1995. Spring and summer chinook salmon and sockeye salmon spawning ground surveys on the Entiat River, 1994. U. S. Fish and Wildlife Service, Leavenworth, WA..

Kirk, T., P. Kerr, and H. Riddle. 1995. Initial watershed assessment, water resources inventory area : Entiat River Watershed. Open file report 95-02. Washington Department of Ecology, Olympia, WA.

Leary, R. F., and F. W. Allendorf. 1991. Population genetic structure of bull trout in the Columbia and upper Klamath River drainages. Lewis and Clark Conservation Laboratory report 91/2. University of Montana, Missoula, MT.

Lenfesty, C. D. 1980. Soil survey of Okanogan County Area, Washington. USDA Soil Conservation Service. Okanogan, WA.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. Fluvial processes in geomorphology. Freeman, San Francisco, CA.

Leopold, L. B., and W. B. Langbein. 1966. River meanders. Scientific American 214:66-70.

Leopold, L. B. 1994. A view of the river. Harvard University Press, Cambridge, MA.

Lewis County Conservation District. 1992. Chehalis River Basin Action Plan, for the control of nonpoint pollution. Available from Lewis County Conservation District, Chehalis, WA.

Lichatowich, J. A. 1989. Habitat alteration and changes in abundance of coho (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawystcha*) in Oregon's coastal streams. Pages 92-99 *in* C. D. Levings, L. B. Holtby, and M. A. Anderson, editors. Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Canadian Special Publication in Fisheries and Aquatic Sciences 195.

Lichatowich, J., L. Mobrand, L. Lestelle, and T. Vogel. 1995. An approach to the diagnosis and treatment of depleted Pacific salmon populations in Pacific Northwest watersheds. Fisheries 20(1):10-18.

Lisle, T. E. 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska. North American Journal of Fisheries Management. 6:538-550.

Lotspeich, F. B., and W. S. Platts. 1982. An integrated land aquatic classification system. North American Journal of Fisheries Management 2:138-149.

Major, R. L., and J. L. Mighell. 1966. Influence of Rocky Reach Dam and the temperature of the Okanogan River on the upstream migration of sockeye salmon. Bulletin 66(1):131-147. Bureau of Commercial Fisheries Biological Laboratory, Seattle, WA.

Marshall, A. R., C. Smith, R. Brix, W. Dammers, J. Hymer, and L. LaVoy. 1995. Genetic Diversity Units and Major Ancestral Linkages for chinook salmon in Washington in C. Busack and J. B. Shaklee, editors. Genetic Diversity Units and Major Ancestral Lineages of salmonid fishes in Washington. Technical Report RAD 95-02, Washington Department of Fish and Wildlife, Olympia, WA.

Mason, J. C., and D. W. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. Journal of the Fisheries Research Board of Canada. 22:173-190.

MCHWG (Mid-Columbia Hatchery Work Group) 1998. Biological assessment and management plan: Mid-Columbia River Hatchery Program. Available from Chelan County Public Utility District, Wenatchee, WA.

Meehan, W. R., and W. S. Platts. 1978. Livestock grazing and the aquatic environment. Journal of Soil and Water Conservation 33(6):274-278.

Mendel, G., J. Bumgarner, K. Petersen, R. Bugert, L. Ross, D. Milks, J. Dedloff, J. B. Shaklee, and C. Knutson. 1993. Tucannon River spring chinook salmon hatchery evaluation program 1992 Report to U.S. Fish and Wildlife Service, Cooperative Agreement 14-16-0001-92542. Washington Department of Fisheries, Olympia, WA.

Michaud, J. P. 1991. A citizen's guide to understanding and monitoring lakes and streams. Publication 94-149. Washington Department of Ecology, Olympia, WA.

Milton, J. 1995. Watershed approach to water quality management: needs assessment for the Okanogan Water Quality Management Area. Washington State Department of Ecology, Water Quality Management Program, Yakima, WA.

Mobrand Biometrics. 1995. Recommendations for application of the ecosystem diagnosis and treatment method to the Grande Ronde Model Watershed. Report to Bonneville Power Administration, Portland, OR.

Montgomery Water Group, Inc. 1995. Initial watershed assessment, water resources inventory area 45--Wenatchee River Watershed. Open file report 95-12. Washington Department of Ecology, Olympia, WA.

Moyle, P. B., and R. M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: a five-tiered approach. Fisheries 19(2):6-18.

MPP (Methow Valley Water Pilot Planning Project Planning Committee). 1994. Draft Methow River Basin Plan. Available from Okanogan County Planning Department, Okanogan, WA.

Mullan, J. W. 1984. Overview of artificial and natural propagation of coho salmon (*Oncorhynchus kisutch*) on the mid-Columbia River. Report No. FRI/FAO-84-4. Fisheries Assistance Office, U.S. Fish and Wildlife Service, Leavenworth, WA.

Mullan, J. W. 1986. Determinants of sockeye salmon abundance in the Columbia River, 1880s -1982: a review and synthesis. Report Number FRI/FAO-84-4, U.S. Fish and Wildlife Service, Leavenworth, WA.

Mullan, J. W. 1987. Status and propagation of chinook salmon in the mid-Columbia River through 1985. U.S. Fish and Wildlife Service Biological Report 89(3). Leavenworth, WA.

Mullan, J. W., K. R. Williams, G. Rhodus, T. W. Hillman, J. D. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. Monograph 1. U.S. Fish and Wildlife Service, Leavenworth, WA.

Myers, L. H. 1989. Riparian area management: inventory and monitoring of riparian areas. Technical Report 1737-3. Bureau of Land Management Service Center, Denver, CO.

NHC (Northwest Hydraulic Consultants, Inc.) 1986. Appraisal of potential changes in river regime due to Similkameen Multipurpose Project. Report No. 2096/4223A to U.S. Army Corps of Engineers, Seattle, WA.

NPPC (Northwest Power Planning Council). 1987. Columbia River Basin fish and wildlife program. Northwest Power Planning Council, Portland, OR.

NRC (National Research Council) 1992. Restoration of aquatic ecosystems. National Academy Press, Washington D.C.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific Salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4-21.

OCCD (Okanogan County Conservation District). 1980. Long range resource program for the 1980s. Available from Okanogan County Conservation District, Okanogan, WA.

OCCD. 1994. Stream bank stability survey. Available from Okanogan County Conservation District, Okanogan, WA.

ODFW (Oregon Department of Fish and Wildlife) and WDFW (Washington Department of Fish and Wildlife). 1995. Status Report: Columbia River fish runs and fisheries, 1938-1994. Olympia, WA.

Peshastin Irrigation District. 1993 Comprehensive Water Conservation Plan. Klohn Leonoff, Inc. Kirkland, WA.

Petersen, K., R. Eltrich, A. Mikkelsen, and M. Tonseth. 1995. Downstream movement and emigration of chinook salmon from the Chiwawa River in 1994. Report H95-09. Washington Department of Fish and Wildlife, Wenatchee, WA.

Peterson, N. P. 1982. Immigration of juvenile coho salmon (*Oncorhynchus kisutch*) into riverine ponds. Canadian Journal of Fisheries and Aquatic Sciences 39:1308-1310.

Peven, C., and K. Truscott. 1995. Spring and summer chinook spawning ground surveys on the Wenatchee River Basin, 1994. Chelan County PUD, Wenatchee, WA.

Peven. C. 1992. Population status of selected stocks of salmonids from the mid-Columbia River Basin. Chelan County Public Utility District, Wenatchee, WA.

Peven, C. M., R. R. Whitney, and K. R. Williams. 1994. Age and length of steelhead smolts from the mid-Columbia River Basin. North American Journal of Fisheries Management. 14:77-86.

Platts, W. S., and J. N. Rinne. 1985. Riparian and stream enhancement management and research in the Rocky Mountains. North American Journal of Fisheries Management. 5:115-125.

Platts, W. S., and R. L. Nelson. 1985. Stream habitat and fisheries response to livestock grazing and instream improvement structures, Big Creek, Utah. Journal of Soil and Water Conservation. 40(4):374-379.

Platts, W. S., M. Hill, T. W. Hillman, and M. D. Miller. 1993. Preliminary status report on bull trout in California, Idaho, Montana, Nevada, Oregon, and Washington. Don Chapman Consultants, Boise ID.

Platts, W. S. 1976. Validity of methodologies to document stream environments for evaluating fishery conditions. Pages 267-284 in Proceeds of the symposium on instream flow needs. Western Division, American Fisheries Society, Boise, ID.

Platts, W. S., and J. N. Rinne. 1985. Riparian and stream enhancement management and research in the Rocky Mountains. North American Journal of Fisheries Management. 5:115-125.

PNRBC (Pacific Northwest River Basins Commission). 1977. The Okanogan River Basin Level B Study of the water and land related resources. Available from the Okanogan Conservation District, Okanogan WA.

Pratt, K. L. 1992. A review of bull trout life history. Pages 5-9. In Proceedings of the Gearhart Mountain Bull Trout Symposium. Oregon Chapter, American Fisheries Society.

Pratt, K. L., D. W. Chapman, and M. T. Hill. 1991. Potential to enhance sockeye salmon upstream from Wells Dam. Report of Don Chapman Consultants to Douglas County Public Utility District, East Wenatchee, WA.

Pritchard, D, and eight co-authors. 1993. Process for assessing proper functioning condition. Technical Reference 1737-9. Bureau of Land Management Service Center, Denver, CO.

Prtichard, D., C. Bridges, S. Leonard, R. Krapf, and W. Hagenbuck. Process for assessing proper functioning condition for lentic riparian-wetland areas. Technical Reference 1737-11. Bureau of Land Management Service Center, Denver, CO.

Proebstel, D. S., and S. M. Noble. 1994. Are “pure” native trout in the Mid-Columbia Basin? Pages 177-184 *in* R. Barnhart, B. Shake, and R. H. Hamre, editors. Proceedings of the Wild Trout V Symposium, Yellowstone National Park, WY.

Randall, R. G., M. C. Healey, and J. B. Dempson. 1987. Variability in length of freshwater residence of salmon, trout, and char. American Fisheries Society Symposium 1:27-41.

Rasmussen, J. L. 1996. AFS position statement: floodplain management. Fisheries 21(4):6-10.

RASP (Regional Assessment of Supplementation Project). 1992. Supplementation in the Columbia Basin, Part 3: RASP summary report series, planning guidelines. Project 85-62. Bonneville Power Administration, Portland, OR.

Reckhow, K. H. 1994. Importance of scientific uncertainty in decision making. Environmental Management. 18(2):161-166.

Rector, J. 1993. Washington citizen lake monitoring program. 1993 data summary: Lake Osoyoos, Okanogan County. Washington Department of Ecology, Olympia, WA.

Reeves, G. H., L. E. Benda, K. M. Burnett, P. A. Bisson, and J. R. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17:334-349.

Reice, S. R., R. C. Wissmar, and R. J. Naiman. 1990. Disturbance regimes, resilience, and recovery of animal communities and habitats in lotic ecosystems. Environmental Management 14:747-659.

RICC (Rock Island Coordinating Committee) 1992. Evaluation Plan for the Rock Island Fish Hatchery Complex. Chelan County Public Utility District, Wenatchee, WA.

Rensel, J. 1995. Water quality and sockeye salmon rearing in Lake Osoyoos during 1994. Report to Douglas County Public Utility District, East Wenatchee, WA.

Rieman, B. E., and J. D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. General Technical Report INT-302. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. Ogden, UT.

Rhodes, J. J., D. A. McCullough, F. A. Espinosa, Jr. 1994. A course screening process for evaluation of the effects of land management activities on salmon spawning and rearing habitat in ESA consultations. Technical Report 94-4. Columbia River Intertribal Fish Commission, Portland, OR.

Rosgen, D. L. 1994. A classification of natural rivers. Catena 22: 169-199.

Rottiers, D. V., and L. A. Redell. 1993. Volitional migration of Atlantic salmon from seasonal holding ponds. North American Journal of Fisheries Management 13:238-252.

Schuett-Hames, D., B. Conrad, M. McHenry, P. Peterson, and A. Pleus. 1993. Salmonid Spawning Gravel Composition Module. Timber Fish and Wildlife Ambient Monitoring Program. Available from Northwest Indian Fisheries Commission, Olympia, WA.

Scribner, T., T. K. Meekin, J. Hubble, and W. Fiander. 1993. Spring chinook spawning ground surveys of the Methow River Basin 1993. Yakama Indian Nation, Toppenish, WA.

Scudder, G. G. E. 1989. The adaptive significance of marginal populations: a general perspective. Canadian Special Publication, Fisheries and Aquatic Sciences. 105:180-185.

Shaklee, J. B., J. Ames, and L. LaVoy. 1996. Genetic Diversity Units and major Ancestral Linkages for sockeye salmon in Washington. Draft report. Washington Department of Fish and Wildlife, Olympia, WA.

Sharp, W. R. 1993. Snorkel observations of hatchery spring and summer chinook at the discharges of four mid-Columbia River rearing and acclimation ponds. A report from the Yakama Indian Nation to Chelan County Public Utility District, Wenatchee, WA.

Shepard, B., K. Pratt, and J. Graham. 1984. Life histories of Westslope cutthroat trout and bull trout in the upper Flathead River Basin, Montana. Montana Department of Fish, Wildlife, and Parks. Kalispell, MT.

Shepherd, B. G., and B. A. Inkster. 1995. Sockeye and kokanee fry migration study, Okanogan River above Osoyoos Lake, 1994. Project Report 18, British Columbia Ministry of Environment, Penticton, B.C.

Sheppard, J. D., and J. H. Johnson. 1985. Probability-of-use for depth, velocity, and substrate by subyearling coho salmon and steelhead in Lake Ontario tributary streams. North American Journal of Fisheries Management 5:277-282.

Simpson, J. C., and R. L. Wallace. 1982. Fishes of Idaho. The University Press of Idaho. Moscow, ID.

SRG (Scientific Review Group). 1993. Critical uncertainties in the Fish and Wildlife Program. Bonneville Power Administration, Portland, OR.

Stearns, S. C. 1989. The evolutionary significance of phenotypic plasticity. Bioscience 39:436-446.

Swain, L. G. 1990. Okanagan Area Similkameen River Subbasin water quality assessment and objectives. British Columbia Ministry of the Environment, Penticton, B.C.

Thomas, J. W., M. G. Raphael, R. G. Anthony, E. D. Forsman, A. G. Gunderson, R. S. Holthausen, B. G. Marcot, G. H. Reeves, J. R. Sedell, and D. M. Solis. 1993. Variability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. Research Report, USDA Forest Service, Portland, OR.

Thorpe, J. E. 1987. Smolting versus residency: developmental conflict in salmonids. American Fisheries Society Symposium 1:244-252.

TFW (Timber/Fish/Wildlife) 1987. Timber/Fish/Wildlife Agreement: A better future in our woods and streams. Available from Washington Department of Natural Resources, Olympia, WA.

Triska, F. J., V. C. Kennedy, R. J. Avazino, G. W. Zellweger, and K. E. Bencala. 1989. Retention and transport of nutrients in a third order stream: hyporheic processes. Ecology: 70:1893-1905.

USFS (United States Forest Service) 1989. Final environmental impact statement; land and resource management plan. Okanogan National Forest, Okanogan, WA.

USFS. 1990. Final environmental impact statement; land and resource management plan. Wenatchee National Forest, Wenatchee, WA.

USFS and Bureau of Land Management. 1994. Record of Decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Available from U. S. Forest Service, Wenatchee, WA.

USFS, 1994. Chewuch River Watershed Analysis. Okanogan National Forest. Twisp Ranger District, Twisp, WA.

USFS, 1995. Stream inventory handbook, level 1 and 2. Pacific Northwest Region, version 9.5.

USFS, 1995a. Twisp River Watershed Analysis. Okanogan National Forest. Twisp Ranger District, Twisp WA.

USFS. 1995b. Toats Coulee Watershed Analysis. Okanogan National Forest. Okanogan, WA.

Utter, F. M., D. W. Chapman, and A. R. Marshall. 1995. Genetic population structure and history of chinook salmon of the upper Columbia River. American Fisheries Society Symposium 17:149-165.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Waknitz, F. W., G. M. Matthews, T. Wainwright, and G. A. Winans. 1995. Status review for mid-Columbia River summer chinook salmon. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-22.

Walters, K. W. 1974. Water in the Okanogan River Basin, Washington. Water Supply Bulletin 34. Washington Department of Ecology. Olympia, WA.

Waples, R. S. 1991. Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. Marine Fisheries Review. 53(3):11-22.

Waters, T. F. 1995. Sediment in streams: sources, biological effects, and controls. American Fisheries Society Monograph No. 7. Bethesda, MD.

WCC (Wells Coordinating Committee). 1995. Methow Basin Spring Chinook Salmon Supplementation Plan. Available from Douglas County Public Utility District, East Wenatchee, WA.

WDF (Washington Department of Fisheries), Washington Department of Wildlife, and Western Washington Treaty Tribes, 1993. Washington State Salmon and Steelhead Stock Inventory. Washington Department of Fisheries, Olympia, WA

WDF. 1990. Wenatchee River subbasin plan; Columbia Basin system planning and production plan for salmon and steelhead. Washington Department of Fisheries, lead agency; funding provided by Northwest Power Planning Council, Portland, OR.

WDFW (Washington Department of Fish and Wildlife). 1995. Priority habitats and species list. Washington Department of Fish and Wildlife, Olympia, WA.

WDNR (Washington Department of Natural Resources) 1996. Loomis State Forest Draft Landscape Plan, with Environmental Impact Statement. Washington Department of Natural Resources, Colville, WA.

WDOE (Washington Department of Ecology) 1975. 303(e) Water Quality Management Plan, Okanogan, Methow, Nespelem Basins. Technical Report 75-3. Washington Department of Ecology, Olympia, WA.

WDOE. 1992. Designing wetland preservation programs for local governments. Publication 92-18. Washington Department of Ecology, Olympia, WA.

WFPB (Washington Forest Practices Board). 1991. Standard Guidelines for Watershed Assessment. Version 2.0. Washington Forest Practices Board, Olympia, WA.

Wilson, M. F., and K. C. Halupka. 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9(3):489-497.

Winans, G. A., P. B. Abersold, and R. S. Waples. 1995. Allozyme variability of *Oncorhynchus nerka* in the Pacific Northwest with special consideration to populations of Redfish Lake, Idaho. Transactions of the American Fisheries Society.

Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific Coast of North America. Journal of the Fisheries Research Board of Canada. 23:365-393.

WNF (Wenatchee National Forest) 1992. Chiwawa Stream Survey Report. Lake Wenatchee Ranger District, Wenatchee National Forest, Leavenworth, WA.

WNF 1994. Mission Creek Watershed Assessment. Leavenworth Ranger District, Wenatchee National Forest, Leavenworth, WA.

WNF 1995. Temperature monitoring, Wenatchee National Forest, Lake Wenatchee and Leavenworth Ranger Districts. Available from Supervisors Office, Wenatchee National Forest, Wenatchee, WA.

WNF 1996. Watershed Assessment: Entiat Analysis Area, version 2.0. Wenatchee National Forest, Entiat, WA.

Wydoski, R. S., and R. R. Whitney. 1979. Inland Fishes of Washington. University of Washington Press, Seattle, WA..

Yang, C. T. 1971. On river meanders. Journal of Hydrology 13:231-253.

Young, M. K., and R. N. Small. 1994. Mobile trout: consequences of a new paradigm. Pages 185-188 *in* R. Barnhart, B. Shake, and R. H. Hamre, editors. Proceedings of the Wild Trout V Symposium, Yellowstone National Park, WY.

APPENDIX A

A.1: Definitions

To allow full understanding of the assumptions made in this document, several terms must be fully defined. These terms have been defined to meet the functional needs of users of this document, and watershed managers the Mid-Columbia Region. They are not necessarily appropriate for use elsewhere.

Deepwater habitat	The permanently flooded lands that are sufficiently deep so that water, rather than air, is the principal medium within which the dominant organisms live. These habitats include partially submerged structures (example: woody debris).
Deleterious alterations	Those changes in any riparian, wetland, or deepwater habitat caused by human activities that have reduced the natural productivity of aquatic biota at one or more stages in their life history.
Habitat protection	To enter into an agreement with a given landowner or manager to retain certain riparian, wetland, or deepwater habitat features which are known or presumed to benefit aquatic biota. Protection may be done through purchase, lease, or easement of the given habitat or through a form of conservation agreement with the land manager or owner. Protection is used for category I life histories in the triage concept (Section 1.6).
Habitat restoration	Any action taken to rectify or ameliorate those deleterious alterations, used primarily for categories I and II in the triage concept (Section 1.6).
Hatchery salmonid	A given fish that has been spawned, incubated, and has emerged in a hatchery.
Native	A stock of fish that historically reproduced naturally in a given watershed.
Natural salmonid	A given fish that has spent the early stages of its life history (at least through emergent stage) in a riverine or lacustrine environment, and can be the progeny of hatchery, natural, or unknown parentage.
Non-native	A stock of fish that whose ancestral lineage is outside a given watershed, and has either genetic or phenotypic differences with the native population.
Population	A group of interbeeding animals of hatchery, natural, or unknown parentage which exhibit substantial reproductive isolation from other groups. This term is synonymous with stock.
Resident salmonid	A fish population that spends its entire life history within one of the four major drainages to the mid-Columbia River.
Riparian habitat	The area adjacent to aquatic systems that contains elements of both aquatic and terrestrial ecosystems that mutually influence each other. Riparian habitat encompasses the area beginning at the ordinary high water mark and extends to that portion of the terrestrial landscape that is influenced by, or that directly influences, the aquatic ecosystem.

Suitable opportunity — Any habitat restoration or protection effort that is technically, financially, and socially feasible to undertake, with reasonable assumptions that it would increase natural productivity of the aquatic biota.

Supplementation — The use of hatchery facilities to increase or reestablish the natural production of fish, while maintaining their long-term fitness, and keeping the ecological impacts on non-target species, both within and outside the basin, within specified limits.

Viability — The capacity of a population or species to live, grow, and reproduce through time and to restore its numbers following a disturbance.

Wetland habitat — The transitional land between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered with shallow water.

A.2: Assumptions on Habitat and Productivity

The habitat problems identified in this document are based on a combination of available empirical information and the best professional judgment of the fish managers. In many situations, there is not sufficient information available to make unequivocal statements about the effect of a given habitat alteration on fish production, so some inferences were made by the fish managers. The guiding assumptions behind this document are that:

1) Reduced habitat quality in the tributaries is one of several factors responsible for the poor returns of mid-Columbia anadromous salmonids, relative to historical returns.

2) Despite a lack of information on the influence of landscape changes on species distribution, abundance, and life history expression, we have a reasonable understanding of how habitat quality has diminished over time, and how those changes have reduced the productivity of mid-Columbia aquatic biota.

3) Significant improvement to overall habitat conditions in the tributaries is possible.

4) These improved overall habitat conditions will increase natural production of aquatic species, especially anadromous fish. This will produce corresponding increases in average adult returns (to fisheries, the spawning grounds or both).

5) Improvements in tributary habitat conditions will result in increased productivity of resident fish, as measured by population size at selected life stages.

6) Some habitat improvement projects will not necessarily result in a sustainable increase in fish productivity and stock diversity. Therefore, continuous monitoring and maintenance of these restoration projects will be required.

7) Some of the losses in habitat features that have reduced fish productivity may be difficult, if not impossible, to mitigate. These obstacles may be a result of technical, legal, societal, or cost constraints. As a result, some restoration projects may have a high value in terms of increasing fish productivity, yet may not be attempted because of these obstacles.

8) Similar habitat restoration measures at similar sites may not produce similar results. However, it will not be logistically feasible to assess the effectiveness of each action. Representative “index” projects will be required to determine the success of a series of like actions. There is the likelihood though, that benefits of several similar actions may diminish with increased frequency.

9) Critical shoreline and in-stream habitats should remain undisturbed and should be considered for cooperative agreements such as conservation easements. These agreements would be considered a habitat conservation measure even though no habitat manipulation/restoration activities occur.

A.3: Critical Uncertainties Pertaining to Habitat and Fish Populations

Habitat restoration efforts began at least thirty-five years ago, but the science of restoration has progressed little in that time. A major reason for this stunted development is the failure to apply fundamental scientific methods to restoration efforts. Many projects have been implemented without regard to the specific biological and physical watershed context. Few projects or project techniques have been evaluated for effectiveness. Some of this is changing. The WDFW has documented extensive coho and chum salmon use of the artificial percolation channels they built in the Skagit basin. Other investigators have shown that juvenile chinook, coho, steelhead, and adult resident trout will readily use contrived structure and cover features, but the authors are unaware of any documentation that such use resulted in increased smolt production in the case of anadromous fish, or recruitment of adults in the case of resident fish. Treatments proposed in this document are based upon limited understanding of factors restricting the production potential of salmonids in the mid-Columbia Region. It is, therefore, important that restoration efforts be accompanied by a reasonable monitoring and evaluation program. An M & E program will not only help guide and redirect habitat restoration efforts, but will be essential for determining the viability of various restoration techniques.

The poor status of mid-Columbia anadromous fish runs is the result of multiple in and out-of- basin factors. Implicit in Assumption 4 above is the notion that out of basin mortality results from density independent phenomena. If the assumption is correct then as more smolts are produced the number of fish that die before returning to their natal streams will also increase, but the rate of mortality through subsequent life stages will not. Therefore, as smolt production increases so too will the stock’s ability to accommodate out of basin mortality sources.

In order to develop an understanding of how habitat condition affects fish production, it is necessary to have some understanding of the condition of the habitat as well as the areas and times that the fish are attempting to use it. There is a reasonable quantity of available information regarding the physical and chemical habitat characteristics of Mid-Columbia subbasins, but a surprising scarcity of information regarding the life history characteristics and life stage-specific mortality rates of these stocks. This document attempts to overlay what is believed about the latter onto what is known about the former. The more that is learned about lost and extant life history types the better equipped fish managers will be to design effective restoration projects. This habitat condition/life history juxtaposition provides insight into which opportunities for habitat restoration are suitable, and which are not. Several assumptions can be made about what suitable opportunities can be addressed to increase the natural productivity of anadromous fish. For those opportunities, a well-defined habitat protection or restoration plan can be developed and implemented. In other situations however, the deleterious alterations are not fully understood, and a well-defined plan cannot be developed without additional information. In such situations, some studies may be required to determine if the deleterious alterations can be rectified or ameliorated though restoration.