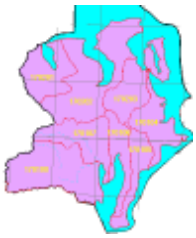


Big Quilcene Basin Pilot Assessment

WRIA 17 - The Big Quilcene Basin

Overview

WRIA 17, located in the northeastern portion of the Olympic peninsula, has 303 identified streams with over 428 linear miles (Williams et al. 1975, Figure XX). All watersheds in WRIA 17 are relatively small and independent, draining directly into bays on Hood Canal or the Strait of San Juan de Fuca. Of the thirteen WRIA 17 watersheds discussed in this report, the Big Quilcene River, Chimacum Creek and the Little Quilcene River are the largest at 68, 34 and 30 square miles respectively.

SASSI identified twelve stocks for WRIA 17 (Table 1). Of the twelve stocks, four are critical, four are depressed, two are healthy and two are unknown. Seventy five percent of the twelve stocks in WRIA 17 are either critical or depressed, compared to 31% of the 434 stocks in Washington state.

Geographic Description

WRIA 17 covers an area of 363 square miles. This section will discuss 13 sub-basins of WRIA 17, which were chosen due to their inclusion in previous works (e.g. Williams et al. 1975) and for their importance as salmonid habitat. The state of Washington has divided WRIA 17 into nine Watershed Administrative Units (Table 2).

Hood Canal streams and their lengths are listed below from south to north, while the Straits' streams are listed from east to west. On Jackson Cove (Hood Canal) is Marple and Spencer creeks with stream lengths of 2.4 and 3.8 miles respectively. Further north on Quilcene Bay, are the Big and Little Quilcene rivers at 18.6 and 12.2 miles in length, and Donovan Creek at 3.0 miles. East from Donovan Creek is Tarboo Creek located on Tarboo Bay with a length of 6.8 miles. North from Tarboo Bay is Thorndyke Creek on Thorndyke Bay with a length of 6.3 miles. Shine Creek on Squamish Harbor and Ludlow Creek on Port Ludlow have lengths of 2.0 and 4.5 miles respectively. Finally Chimacum Creek on Port Townsend has a length of 14.2 miles. Streams draining north to the Strait are Snow Creek and Salmon Creek on Port Discovery with lengths of 10.1 and 8.7 miles, and Jimmycomelately Creek on Sequim Bay with a length of 5.6 miles.

Geology

The Olympic peninsula is young in comparison to the rest of North America with the oldest rocks around 50 million years old (Jamestown S'Klallam 1994). The peninsula can be differentiated into three broad rock types. The "inner core" is composed of sedimentary rocks scraped off the submerging oceanic plate. These sedimentary rocks have folded and faulted to form the core of the Olympic Mountains. The headwaters of watersheds in WRIA 17 are located outside of the inner core.

Surrounding the inner core to the north, south, and east is the "Crescent formation," a basalt-rich section of oceanic plate (Tabor and Cady 1978). Streams that flow through the Crescent formation are found in the southern and northwestern portions of WRIA 17. These watersheds have steeply dissected terrain and limited anadromous habitat. Streams with this geology include the Big Quilcene River and Marple and Spencer creeks to the south on Hood Canal, and Jimmycomelately and Salmon Creeks on the Strait.

Table 1. Stock status for WRIA 17 (WDFW 1993 and others as shown)

Species	Stock	Status	Stock Origin	Production Type
Summer Chum	Hood Canal[1]	Critical	Native	Wild
	Sequim Bay[2]	Depressed	Native	Wild
	Discovery Bay[3]	Critical	Native	Wild
	Chimacum	(Extirpated)[4]	Native	Wild
Fall Chum	Quilcene[5]	Healthy	Mixed	Composite
	Salmon-Snow	(Extirpated)[6]	Native	Wild
Coho	Quilcene-Dabob Bays[7]	Depressed	Mixed	Composite
	Northeast Hood Canal[8]	Depressed	Mixed	Wild
Winter Steelhead	Quilcene-Dabob Bays[7]	Unknown	Unresolved	Unresolved
	Sequim Bay	Depressed	Unresolved	Unresolved
	Discovery Bay	Depressed	Native	Wild

1. In WRIA 17, Hood Canal Summer Chum is primarily found on the Big and Little Quilcene Rivers.
2. Stock originate in Jimmycomelately Creek.
3. Stock originates in Snow and Salmon Creeks.
4. Williams et al. (1975) listed a Summer Chum run that had 60 chum/mile in 1974. In 1983 the density was 3.5 chum/mile and in 1984 only one chum was found. The run appears to have been extirpated during the early 1980's (Lichatowich 1993, McHenry et al. 1996).
5. Stock originates in Big and Little Quilcene Rivers and Tarboo Creek.
6. Williams et al. (1975) listed this run as present, but depressed. Spawners have not been observed at the Snow Creek weir since 1974 (McHenry et al. 1996).
7. Stock originates in the Big and Little Quilcene Rivers, and Spencer, Jackson, Donovan, and Tarboo Creeks.
8. Thorndyke and Shine Creek were included in this stock.

Table 2. Watershed Administrative Units (WAU's) located in WRIA 17.

WAU Number	Name	Drainage basin
170104	Ludlow	Ludlow and Shine Creek
170105	Thorndyke	Thorndyke Creek
170106	Dabob	Tarboo Creek
170107	Little Quilcene	Little Quilcene River and Donovan Creek
170108	Big Quilcene	Big Quilcene River, Spencer and Marple Creek
170201	Sequim Bay	Jimmycomelately Creek
170202	Discovery Bay	Snow and Salmon Creek
170203	Chimakum	Chimacum Creek
170204	Protection Island	none

In the lowlands that lie between the Big Quilcene River to the south and Salmon Creek to the north, the remaining watersheds are primarily underlain by unconsolidated to poorly consolidated Quaternary glacial sediment layers, and Holocene alluvium deposited by rivers (Grimstad and Carson 1981). Maximum depth of Quaternary deposits probably exceeds 2000 ft. beneath the tips of Quimper peninsula in the north and Toanados peninsula in the south (Grimstad and Carson 1981). Watersheds underlain by these glacial deposits generally contain significantly more low-gradient anadromous habitat when compared to watersheds

underlain by the Crescent formation. Wetlands are strongly associated with this geology, especially within the Chimacum drift plain (Jamestown S'Klallam 1994).

Climate

Winter storms originate to the southwest of the Olympic peninsula. The Olympic Mountains capture the moisture as rainfall and snow, creating a rain-shadow to the northeast of the mountains. Precipitation decreases in a northeastern direction from the headwaters of the Big Quilcene: approximately 75 in. per year at Mt. Constance (the headwaters of the Big Quilcene), 50 in. per year in Quilcene, 30 in. per year in Chimacum, and 19 in. per year in Port Townsend (Peterson and Breskin 1994).

The majority of precipitation (65-70%) falls between October and March (Peterson and Breskin 1994). It is not known precisely what percentage of WRIA 17 is found within the snow, rain-on-snow and rain zones. A rough estimate would be less than 5% in snow zones, 10-20% in rain on snow zones, and 75-85% in rain zones. For this region, snow zones are above 2900 ft in elevation, rain-on-snow zones are 1600-2900 ft and rain zones are below 1600 ft (USDA 1994).

Hydrology

None of the streams in WRIA 17 are (or were) permanently gauged. Many were periodically gauged over the years by USGS personnel (Table 3). Much of WRIA 17 is located in the rain zone, with high flows occurring between October and March. The rainshadow effect from the Olympic Mountains causes summer flows to be consistently low throughout WRIA 17, when compared to other areas in western Washington (Orsborn 1990).

Land Use

Major population centers are Port Townsend and Quilcene. The 1992 population estimate for eastern Jefferson County (most of WRIA 17) was 20,337 (Jamestown S'Klallam 1994). The highest population growth is projected for Hadlock and Port Ludlow, with water use increasing by 100% and 254% respectively by the year 2020 (Jamestown S'Klallam 1994). Overall, projected water consumption for eastern Jefferson County will increase 78 % by 2020. Constructing new wells will further reduce groundwater supplies in areas where continuity exists between surface water and groundwater. A reduction of groundwater input to streams will decrease already low summer flows, affecting both spawning and rearing life stages of salmonids.

Table 3. Average annual flow for streams in WRIA 17.

Stream	Average annual flow (cfs)	Years of data
Salmon Creek	8.4	unknown[1]
Snow Creek	22	unknown[1]
Little Quilcene River	54.0 [2]	7 [1]
Big Quilcene River	200.0 [3]	2 [1]
Chimacum Creek		
Jimmycomelately Creek	2.0 and 20.0 to 30.0 [1]	unknown[1]
Ludlow Creek	2.87	spot, 8-18-93 [5]
Shine Creek	0.64	spot, 8-18-93 [5]
Thorndyke Creek	4.9	spot, 8-18-93 [5]
Tarboo Creek	2.54	spot, 8-18-93 [5]
Donovan Creek	0.1	spot, 8-18-93 [5]

1 Jamestown S'Klallam (1994)

2 Gauge located at the confluence with Leland Creek. Flow includes the 9.6 cfs Port Townsend water right.

3 Original 220 cfs was adjusted to include 30 cfs water right and to factor out the above average wet years during gauging period (1971-2).

4 Average of several years of spot discharge measurements for summer low flow and winter/ spring flow respectively.

5 Spot surveys by USGS personnel using a staff gauge.

Though WRIA 17 is lightly populated when compared to the eastern Puget Sound, development of this dry region may already be reaching threshold levels where fish habitat is irrevocably degraded.

Descriptions by watershed

The Big Quilcene watershed has a total area of 68 square miles (44,874 acres), and is bounded by the Little Quilcene basin to the north, the Dungeness to the west, the Dosewallips to the south, and Quilcene Bay to the east. Approximately 90% of the watershed lies within the Olympic National Forest and is managed by the U.S. Forest Service (USDA 1994). This is a Tier II Key Watershed, an important source of high quality water, identified under the President's Forest Plan (FEMAT 1993). The Key Watershed concept was developed to provide a network of refugia for maintaining and recovering habitat for at-risk stocks of salmonids and resident non-salmonids (FEMAT 1993).

Geographic description

The Big Quilcene River has an overall length of 18.6 miles and is fed by three major tributaries: Townsend, Tunnel, and Penny Creek. The watershed can be divided into three geomorphic areas: upper, middle and lower.

The upper watershed includes the headwaters of the Big Quilcene, Townsend and Tunnel Creeks, all flowing in an easterly direction. Headwater elevations range to over 7700 feet at Mt. Constance. All three streams form mostly in the Buckhorn Wilderness of the Olympic National Forest, or in a small portion of the Olympic National Park. Roughly one-third of the Big Quilcene watershed area is located within the Buckhorn Wilderness.

The upper Big Quilcene River flows through the Buckhorn Wilderness from river mile (RM) 18.6 to 14.5. Townsend Creek enters the Big Quilcene at RM 11.2 and has a length of 6.7 miles. The upper 0.7 miles of Townsend Creek is located within the Buckhorn Wilderness. Tunnel Creek has two forks, splitting 2.4 miles upstream from the confluence with the Big Quilcene River. The north fork has a total length of 4.7 miles, while the south fork is 6.7 miles long. The upper 3.3 miles of both forks are located within the Buckhorn Wilderness. Channel gradients in the upper watershed are steep with a few moderate gradient areas within the headwater U-shaped valleys (Figure 1). The upper watershed ends at RM 9.4, where Tunnel Creek enters the Big Quilcene.

Below Tunnel Creek, the Big Quilcene flows southeast through a gorge making a sharp northward bend at Elbo Creek (RM 6.1). The middle watershed ends at RM 4.8. The gorge contains several cascades and falls (RM 4.8 to 7.4) believed to be barriers to anadromous fish passage.

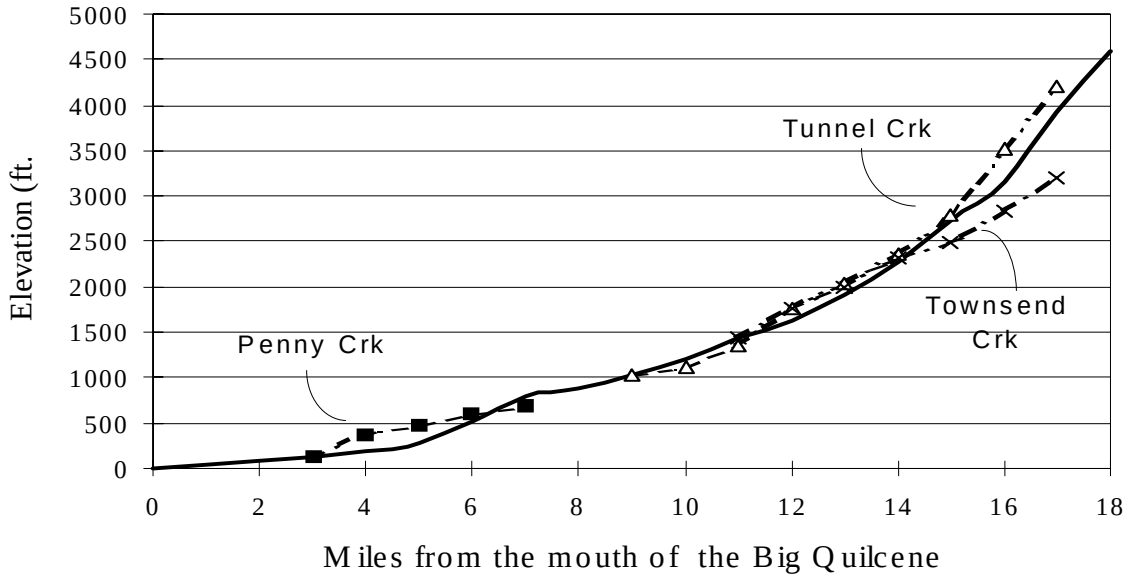
The lower watershed begins at RM 4.8. At around RM 3.5, the channel begins to migrate as sediment transported from upstream reaches is deposited. Reaches containing active meandering are found between RM 1 and 3.5. The Quilcene National Fish Hatchery (QNFH) is located at the
confluence with Penny Creek (RM 2.8). Dikes constraining channel movement are found from RM 2.0 to 2.5 (1990 aerial photos), and again from RM 0.8 to Quilcene Bay (Williams et al. 1995).

Geology

The topography and soil development of the Big Quilcene watershed was markedly altered during the Pleistocene. The Cordillera glacier from the Vashon stade (about 15,000 BP) was the last glacier into the Big Quilcene extending to the confluence of both Townsend and Tunnel Creeks (Long 1974). A glacial lake was formed behind the ice sheet, draining through Rocky Brook Pass south to the Dosewallips watershed. Lake sediments and till extend up to 2300 ft. elevation in Townsend Creek (Long 1974). These deposits have created slope stability problems in Townsend and Tunnel Creek sub-basins (USDA 1994).

A second slope stability issue involves the mechanically weak basalt flows and mudflow breccias of the Crescent formation, which is

Figure 1. Big Quilcene stream elevation by river mile.



exposed in both the upper and middle watershed (Collins 1993). This rock type weathers into small sized particles which are readily transported downstream (Collins and Dunne 1990). As a result of both influences, slope stability problems occur along the steep north-facing tributaries between the South Fork of Tunnel Creek and Elbo Creek (at RM 6.1), and portions of Townsend Creek (USDA 1994).

The lower basin below RM 4.8 contains most of the anadromous zone and is the region of sediment deposition. Penny Creek (RM 2.8) occurs on a north-south uplift zone (Grimstad and Carson 1981, Tabor and Cady 1978). An alluvial fan created by channel migration during the Holocene is found between the mouth of the Big Quilcene River and RM 1.0 (Collins 1995).

Surface water

Forty-four percent of the Big Quilcene watershed is in the rain-on-snow zone, 36% in the snow zone, and 20% in the rain zone (USDA 1994). Outside of wilderness areas, the watershed has been extensively roaded and harvested (USDA 1994). Studies have shown that roaded watersheds within the rain-on-snow zone have earlier peak flows, longer duration peak flows, and higher maximum flows (Jones and Grant 1996).

Mean annual flow for the Big Quilcene River is 200 cfs, with a summer low flow of 20 cfs (Williams et. al 1995). Due to channel aggradation, current channel capacity is a 2 year flow event within the dikes (RM 0-0.8, Williams et al. 1995). Floodplains without dikes naturally flood every 1.5 to 2 years (Leopold et al. 1964).

Water rights for both the Big Quilcene River and Penny Creek overallocate the flow during the low flow months of August to October. Major water rights on the Big Quilcene River include 30 cfs for the Port Townsend diversion dam (RM 9.4), and a 25 cfs water right and a 15 cfs certificate for the Quilcene National Fish Hatchery at RM 3.1 (Peterson and Breskin 1994). On Penny Creek, the QNFH has another water right for 25 cfs (RM 2.8). The hatchery requires 34 cfs of flow for single-pass (one trip through the hatchery) operation of its 38 ponds (Hosey and Assoc. 1985). During low flows, it recycles water with double and triple-passes through the hatchery (Larry Telles, personal communication). During some low-flow years, the Big Quilcene River is dewatered for the 0.3 miles between the intake and outlet pipes (Mike Parton, personal communication).

In 1994, Port Townsend informally agreed to reduce or halt its water withdrawal during the

low flow period (August to October) to maintain a minimum of 25 cfs in the channel for fish (Jamestown S'Klallam 1994). For 10 consecutive years prior to that agreement, the entire flow (at RM 9.4) was diverted for weeks to several months (USDA 1994). While this agreement may represent a movement towards recognizing water requirements for spawning and rearing, increased future water demand from population growth will place even more stress on wild fish populations (Jamestown S'Klallam 1994).

Water quality from the upper watershed (above the diversion dam) is excellent. Raw water quality exceeds Safe Drinking Water Act minimum requirements for water filtration by a full order of magnitude (Peterson and Breskin 1994). During high flows, water turbidity causes the City of Port Townsend to shift its water supply to Lords Lake in the Little Quilcene Watershed.

High concentrations of fecal coliform caused a closure of shellfish harvesting in Quilcene Bay during the mid to late 1980's (USDA 1994). The source was traced to residential septic tanks located in the alluvial fan of the Big Quilcene River (RM 0-1.0, USDA 1994). The sewage effluent was mobilized by high groundwater levels at or near the surface. Despite flood protection afforded by dikes, groundwater from the alluvial fan is hydraulically connected to both the Big Quilcene River and Quilcene Bay.

Groundwater can move easily through the porous gravel substrate found beneath the river channel and adjacent residences (e.g. Grimstad and Carson 1981, Collins 1995). In addition, groundwater can also move through relic channels left by the Big Quilcene River (e.g. Collins 1995, Williams et al. 1995) to Quilcene Bay. These relic channels would leave a "pipeline" from the Big Quilcene River to Quilcene Bay where resistance to groundwater flow is less than in the surrounding sediment. While no shellfish closure has occurred since the 1980's, frequent flooding of this landform opens the possibility for future septic systems failures (USDA 1994).

Groundwater

The upper and middle portions of the Big Quilcene watershed are exposed Crescent Formation rocks or bedrock thinly covered by glacial deposits and colluvium. In these areas, groundwater storage is limited to the fractures in bedrock and temporary storage in the soil. The lowlands are underlain by Vashon recessional drift (Grimstad and Carson 1981). This sediment type is generally lacking in clay and silt particles and is relatively porous and permeable (Grimstad and Carson 1981). Groundwater in the lowlands (below RM 2.8) is well-connected to the Big and Little Quilcene Rivers. Thus, new wells constructed in the lowlands will further reduce already low summer flows. Projected future water use surrounding Quilcene (including the Big and Little Quilcene watersheds) is expected to increase 40% by 2020 (Jamestown S'Klallam 1994).

Land cover and land use

Approximately 14,000 acres (33%) of the upper Big Quilcene Watershed is located within the Buckhorn Wilderness, with another 677 acres in the Olympic National Park (Peterson and Breskin 1994). Below the Buckhorn Wilderness, the Forest Service and private landowners manage their lands primarily for timber production (roughly 65% of the watershed). Less than 5% of the watershed is occupied by the town of Quilcene and residential areas.

Previous studies have correlated increased sediment yield with increasing density of forest roads (e.g. Reid and Dunne 1984). Road densities are high at 3.0 to 4.8 miles/square mile in the lower and middle watershed, along with the harvested portions of Townsend Creek and the main fork of Tunnel Creek (USDA 1994). Besides increased sediment yield, roads and ditches increase the rate of water delivery to tributaries resulting in flashier systems with higher peak flows (Jones and Grant 1996).

Riparian vegetation

A distinct difference exists between the riparian

forests managed by the Forest Service (above RM 4.6) and riparian forests in non-federal ownership (below RM 4.6). Large woody debris (LWD) recruitment potential for the total river miles of middle and upper Big Quilcene watershed was rated as 80% good on Forest Service land, and 68% poor on non-federal land (USDA 1994). Sixty-seven percent of federal riparian forests are composed of conifers greater than 120 years, whereas non-federal lands are dominated by deciduous species less than 80 years (USDA 1994). The reason for this disparity is complex and involves physical channel processes and land use patterns.

Non-federal lands are located below RM 4.6 where the channel gradient decreases and the valley becomes unconfined. This allows sediment transported from upstream areas to deposit and form gravel bars. Examination of 1947 aerial photos show a meandering channel with well vegetated banks above and below the fish hatchery (Findorff et al. 1993). By 1962, gravel deposition above the hatchery (RM 3.8) had caused the channel to widen 200-300% (Findorff et al. 1993).

Construction of many Forest Service roads in the upper and middle watershed began in the 1940's and continued to the 1960's. This road construction (and subsequent road failure) increased the volume of sediment downstream (USDA 1994). As the channel aggrades, riparian trees fall into the channel, where most were subsequently removed (see watershed hydromodification section, Mike Parton personal communication). One reason for a lower assessment is the loss of older riparian trees, which are replaced by colonies of red alder and black cottonwood on the newly formed gravel bars.

Additionally, the riparian forests on non-federal land have been logged several times beginning in the mid 1800's. More recently, conversion of riverside land to residences and farms has also reduced the number of streamside trees. The rapidly aggrading channel has spurred the construction of dikes and riprap, necessitating removal of riparian vegetation and precluding future re-establishment of a riparian forest.

Habitat Assessment

Results: Watershed level

The Big Quilcene watershed is managed to produce clean water for Port Townsend and the QNFH hatchery, hatchery salmon, and timber. The following results will quantify how this focus and other impacts limit the amount and quality of habitat necessary to maintain healthy wild anadromous stocks.

Lost anadromous habitat

The anadromous zone of the Big Quilcene River (to RM 7.4) contains 7.4 miles of large tributary, 5.1 miles of small tributary (Figure 2), 15.1 acres of perennial wetland, and 41.8 acres of seasonal wetland (Figure 3). The anadromous zone has no side channel or distributary slough habitat. Habitat permanently lost to anadromous salmonids include 1.7 miles of small tributary, 1.2 miles of side channel slough, at least 0.8 miles of lost distributary slough (Figure 2), and 22.2 acres of isolated wetlands (Figure 3).

A General Land Survey map of 1859 showed a large wetland near the town of Quilcene. While most of this wetland is still there today, the small stream that connected it to the Big Quilcene River (through the town of Quilcene) no longer remains. This lost stream accounts for the 1.7 miles of lost small tributary habitat, which in turn isolated the 17.9 acre wetland from the Big Quilcene River.

A War Department 1936 topographic map indicated a significant side channel (0.5 miles long) at approximately RM 1.5. While this side channel no longer exists, it could still be seen on 1957 aerial photos. In addition, the 1936 topographic map had a 0.8 mile long distributary slough exiting the Big Quilcene River just east of the town of Quilcene and flowing northeast to Quilcene Bay. Evidence of this channel was confirmed through field visits and 1990 aerial photo analysis. Finally, 1957 aerial photos show multiple side channels totaling 0.5 miles in length, near RM 1.0.

The lower mile of the Big Quilcene River flows through a wide alluvial fan created by channel

migration during the Holocene. This fan defines the 100 year floodplain for the Big Quilcene (Collins 1995, Williams et al. 1995). General land survey maps (1859 and 1877) and U.S. geodetic survey maps (1883) placed the channel approximately 700 ft. north of its current location (Collins 1995). By 1936 (and maybe as early as 1910) the channel was in its current location (Collins 1995). In a natural setting without dikes, the channel would continue to switch location in response to sediment accumulation and LWD jams. Channel switching creates side channels and distributary sloughs. While a series of distributary sloughs are faintly observable on 1990 aerial photos, dikes, grazing and farming apparently erased almost all signs of their existence.

Hydromodification and culverts

All modifications to the channel must have an approved hydraulic permit (HPA) from Washing ton Department of Fish and Wildlife (WDFW). The HPA's are divided into three classes: bank protection (which includes riprap and dike installation and repair), LWD removal, and dredging (gravel bar scalping, gravel traps, and channel dredging). Large woody debris removal is probably underestimated since pieces of LWD are sometimes illegally removed by riverside landowners or salvage loggers without an HPA (Mike Parton, personal communication). A total of 24 permitted hydromodifications have occurred from 1989-1995 to the lower four miles of the Big Quilcene River (Figure 4). Eleven permits were authorized for channel dredging or gravel removal, 3 for LWD removal, and 10 for bank protection.

Between RM 0 and 2, eight permits were issued to reinforce or protect the dikes (RM 0-0.8), remove LWD, or increase flood conveyance between the dikes. Between RM 2 and 4, most of the remaining 16 permits occurred directly above and below the QNFH hatchery. Some may have been issued for bank protection in the Hiddendale development (approximately RM 3.8), which is located on the Big Quilcene floodplain.

Hydromodifications were also identified directly from aerial photo analysis and from an 1992 Ambient Monitoring survey. This information was utilized to determine the length of diked channel or banks reinforced with riprap. In the lower two miles of the Big Quilcene River, 1.1

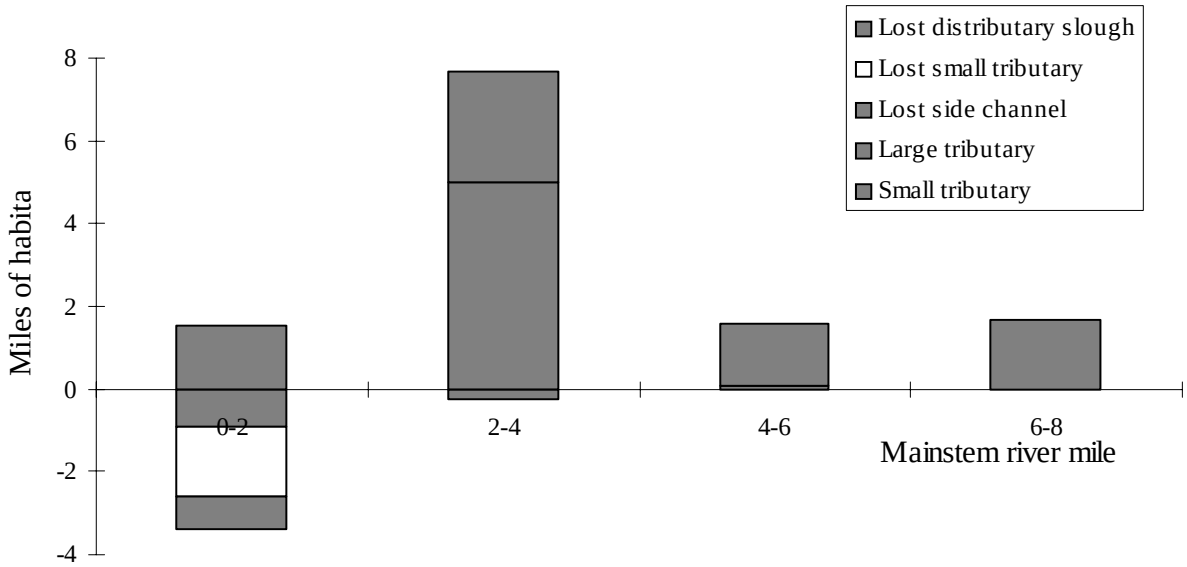


Figure 2. Big Quilcene current (+) and lost (-) anadromous habitat. Lost habitat only includes habitat that is permanantly lost.

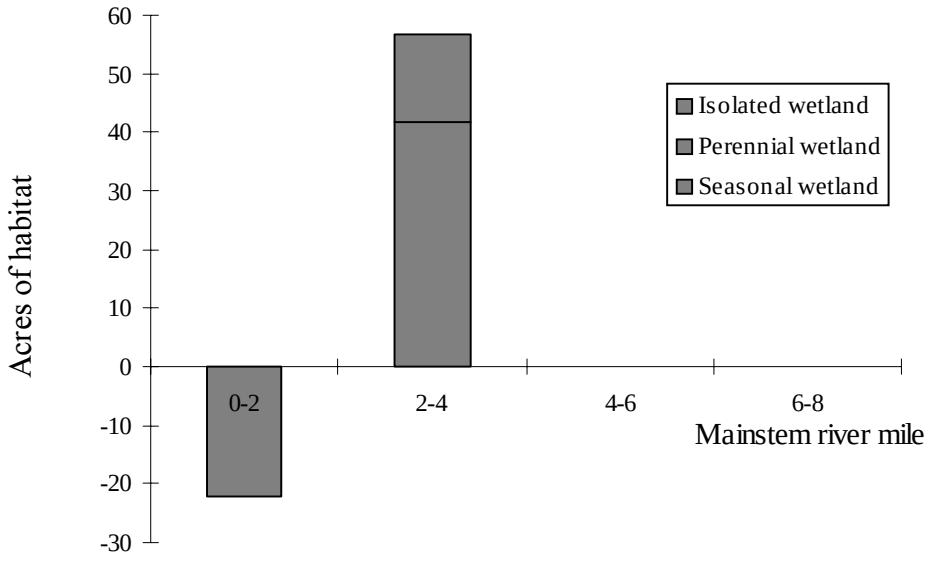


Figure 3. Big Quilcene current (+) and lost (-) wetland habitat accessible to anadromous species.

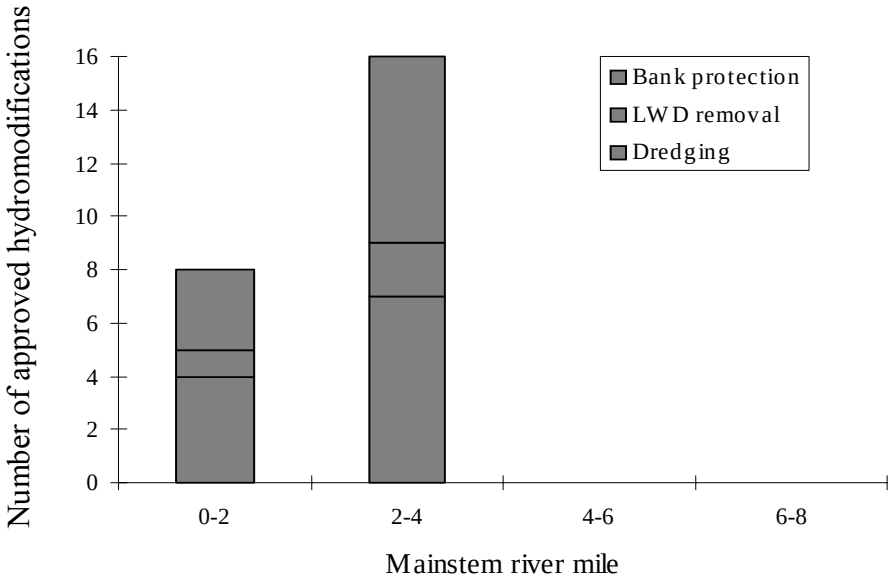


Figure 4. Big Quilcene approved HPA's by river mile. All changes to stream channels and their

miles of bank have been diked or protected through riprap (Figure 5). Between RM 2 and 4, 0.6 miles have been modified (Figure 5). Thus 41% of the lower four miles have been modified through dikes and riprap.

Culvert location was divided into sediment source, transport, and response stream segments (based on Montgomery and Buffington 1993). In the Big Quilcene, a total of 87 culverts were located from USGS maps (Figure 6). Sixty seven percent of culverts were placed in sediment source areas, 25% in sediment transport reaches, and 8% in sediment response reaches. Note the concentration of sediment source culverts in the unstable canyon reach between RM 6-10 (Figure 6). There is only one known blocking culvert in the anadromous zone, at RM 1.0 on Penny Creek.

Obstructed habitat

Most anadromous habitat is fully or partially obstructed (Figure 7). Only the lower 2.8 miles of the mainstem Big Quilcene is unobstructed. This is just 23% of the 12.4 miles of anadromous habitat.

Several man-made barriers occur on the Big Quilcene River. First are the two barriers constructed by the QNFH: Penny Creek and the fish weir on the Big Quilcene River. The lower 250 ft. of Penny Creek is routed through a culvert, which then empties through a steel grate into a QNFH fish ladder (USDA 1994). This design blocks all upstream and downstream fish passage and accounts for 5.0 of the 5.1 miles of obstructed small tributary (Figure 7).

The second QNFH barrier is the fish weir on the Big Quilcene River in operation from June to January. The weir blocks up to 4.6 miles of large tributary (Figure 7), however this varies by stock. The weir is considered to be only a partial blockage, during high flows fish can pass around it (USDA 1994). The weir is not operating during most of the winter steelhead migration. While coho escapement is not allowed upstream, about 25,000 coho fry are released above the weir to rear (L. Telles, personal communication).

The final man-made barrier is the diversion dam at RM 9.4. Since this is located above the anadromous zone, it was not considered a blockage in this report.

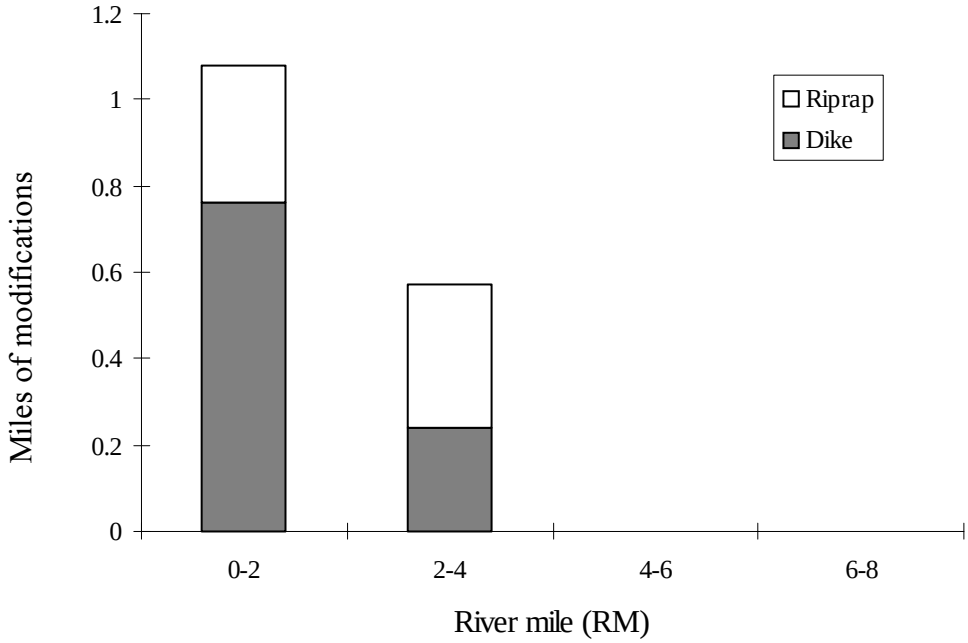


Figure 5. Big Quilcene River hydromodifications within the anadromous zone.

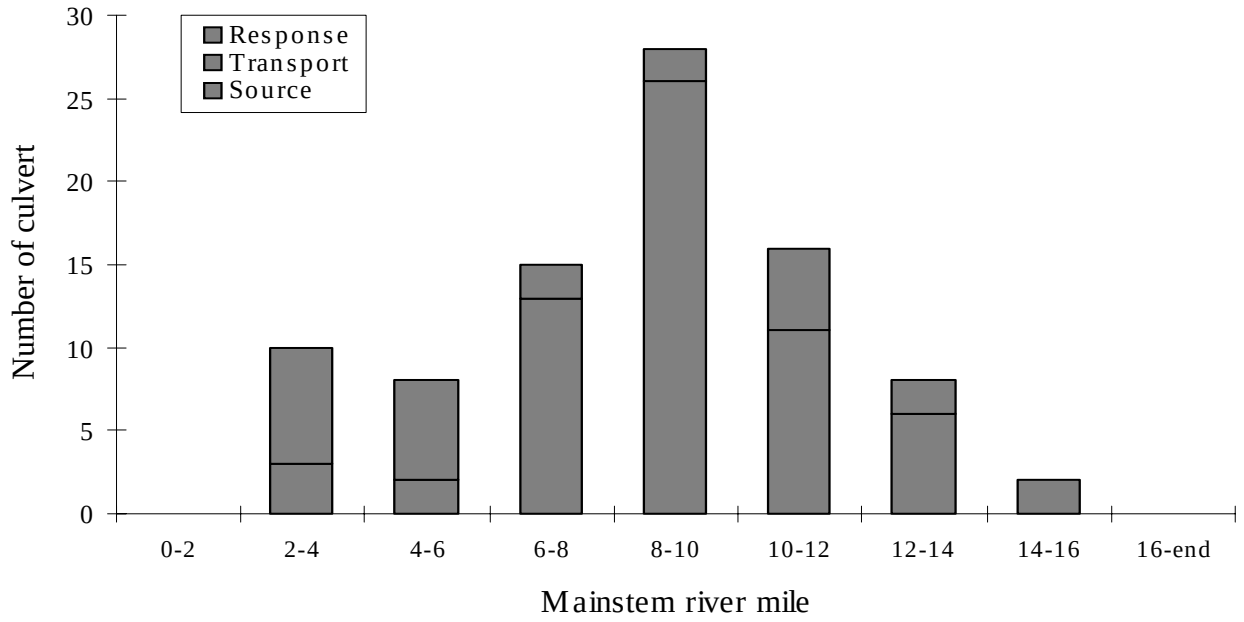


Figure 6. Distribution of Big Quilcene culverts by sediment transport characteristics. Note most of the "source" culverts are located within the steep, unstable tributaries between RM 6-10.

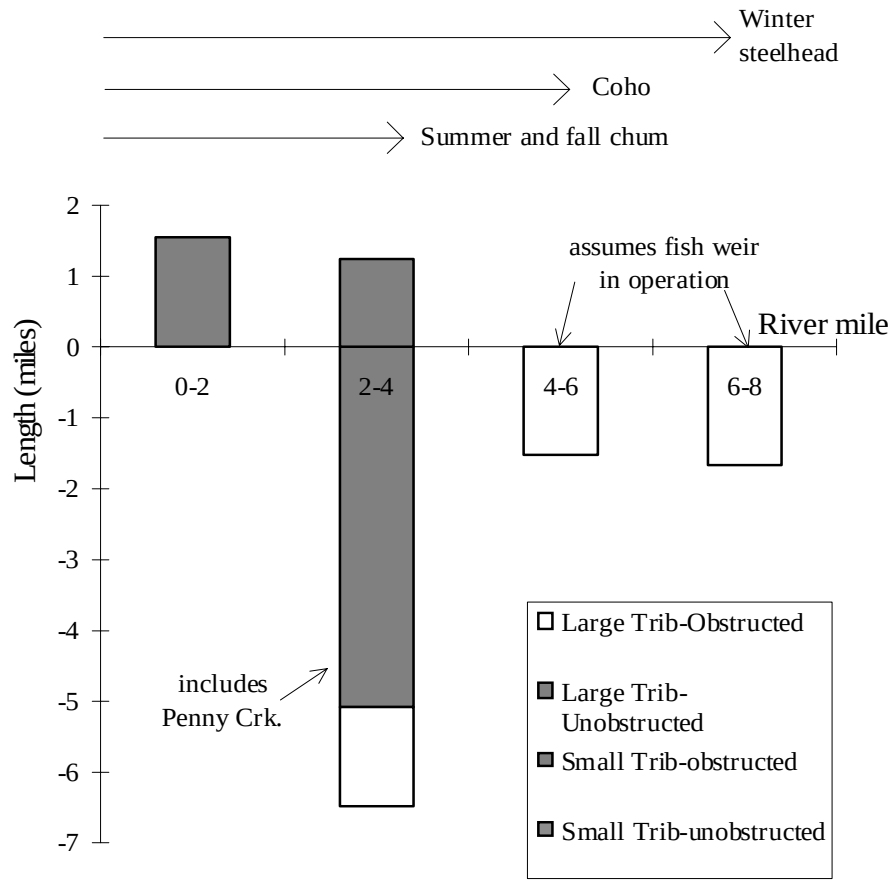


Figure 7. Big Quilcene available (+) and obstructed (-) habitat. Obstructed habitat can be restored if the obstruction is removed.

Results by stock

Hood Canal summer chum

Status: *Depressed*

Origin: Hood Canal summer chum is a native stock, genetically distinct from the later fall chum runs elsewhere (WDFW 1994). In the Big Quilcene, it was recently discovered that the summer chum was a hatchery stock from the 1920's to 1940's (Larry Telles, personal communication).

Trend: Petitioned for ESA listing in 1994 (USFWS 1994). Hood Canal summer chum began to decline precipitously throughout the Hood Canal region beginning in the mid-1970's. In the Big Quilcene, escapement was less than 200 from 1981-1994, with a low of 10 in 1989 (USFWS 1994). The QNFH initiated a (NMFS supported) 12 year brood stocking program in 1992. This was implemented to restart the run from chronically low levels with the hope that during the 12 year period, chum habitat would also be enhanced. Early returns have been excellent, with total escapement of 1179 in 1994 and 4555 in 1995 (Tom Kane, personal communication).

Table 4. Number of consecutive days and date when no water was flowing over the diversion dam (RM 9.4).

Year	Number of consecutive days	Date
1981	30	Aug 26 to Sep 24
1982	12	Oct 11 to Oct 21
1983	34	Sep 29 to Nov 1
1984	21	Sep 17 to Oct 7
1985	58	Aug 23 to Oct 19
1986	64	Aug 23 to Oct 25
1987	92	Aug 31 to Nov 30
1988	13, 14, 13	Sep 14 to Sep 26 Oct 4 to Oct 17 Oct 21 to Nov 2
1989	68	Aug 15 to Oct 21
1990	46	Sep 10 to Oct 25

Timing: Big Quilcene summer chum return late August and spawn September through October.

Historical Distribution: Summer chum spawn up to RM 2.8, the location of the QNFH fish weir. Their primary spawning grounds are the first mile of the Big Quilcene.

Lost Habitat: Roughly 1.7 miles of small tributary used to flow through what is now the town of Quilcene (Figure 2). Between the town of Quilcene and the Highway 101 bridge, 1.2 miles of side channel slough was lost. Finally, 0.8 miles of distributary slough were lost and 22.2 acres of wetlands were isolated (Figure 3).

Obstructed Habitat: None to up to two miles of large tributary habitat. The QNFH fish weir blocks upstream passage, however the amount of chum spawning habitat upstream of the hatchery is considered to be limited (M. Parton, personal communication).

Hydromodification: Of the lower 2 miles, 1.1 miles have been diked or armored with rip-rap (Figure 5). Chum favor spawning between the dikes (RM 0-0.8) since the gravel is loose and easily dug out (L. Telles, personal communication). Dikes and bank armoring increase the frequency and period that the channel bed is mobilized, resulting in greater scouring of redds (Williams et al. 1995).

Other impacts: *Water quantity*. For ten years starting in 1981, the Big Quilcene at the diversion dam contained no downstream flow between 12 and 92 days per year (Figure 8). More telling is the number of consecutive days with no water and the date it occurred (Table 4). Summer Chum spawn in the Big Quilcene during September and October, coinciding with a channel de-watered by withdrawal (Table 4). From 1982-1983, spawning was possible early in the run however eggs may have desiccated as the flow declined in October. From 1985-1989, the channel was dry during most of their spawning period (Table 4).

Fall chum

Status: *Healthy*

Origin: Fall chum is considered a mixed origin, composite stock, supported primarily by the QNFH hatchery. In the Big Quilcene, it is an

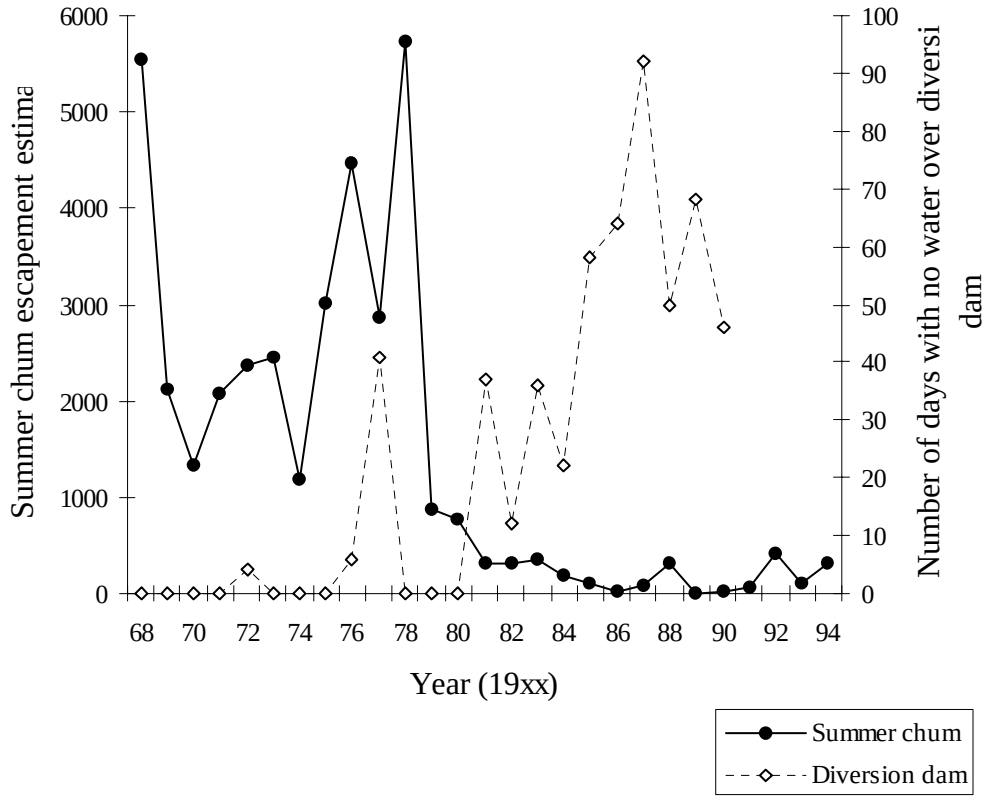


Figure 8. The effect of water withdrawal on Big Quilcene summer chum. Data source: chum- WDFW run reconstruction; water- USFS watershed analyis.

introduced stock from Wolcott slough (near the Dosewallips River).

Trend: Stable

Timing: WDFW uses October 30 as the cutoff date to delineate spawning summer chum from fall chum. Fall chum primarily spawn mid-November through January.

Historical Distribution: Currently spawns up to RM 2.8. It is also found in the Little Quilcene, Tarboo Creek, and Spencer and Jackson Creeks.

Habitat: same for summer chum

Obstructed Habitat: same for summer chum

Hydromodification: same for summer chum

Winter steelhead

Status: *Unknown*

Origin: Stock origin is unresolved (WDFW 1994). Hatchery origin smolts were stocked in the Big Quilcene River (5,000 to 15,000 annually from 1977 to 1990), however stocking has not occurred since 1991. These smolts originated from Bogachiel River brood stock, which in turn originated from Chambers Creek (near Tacoma).

Trend: Catch data shows a strong downward trend (Table 5), however escapement is not monitored and no goal has been set (WDFW 1994).

Timing: Winter steelhead migration occurs from December to May, with spawning from mid-February to May.

Historical Distribution: Most biologists agree that the natural barrier to migration is at the cascades at RM 7.4. However, some question whether this barrier is surmountable under ideal conditions. The barrier at RM 7.4 is a 20 ft. falls with a steep bedrock face composed of several drops (L. Telles, personal communication). No pool exists directly below to assist fish in surmounting the falls (L. Telles, personal communication). During one electroshock survey, only rainbow trout was found above the barrier at RM 7.4 (Dames and Moore 1984). Rainbow trout are stocked as a put and take fishery between RM 7.4 and the diversion dam at RM 9.4 (USDA 1994).

Lost Habitat: Approximately 1.7 miles of small tributary, 1.2 miles of side channel slough, at least 0.8 miles of lost distributary slough (Figure 2), and 22.2 acres of isolated wetlands (Figure 3).
Obstructed Habitat: The QNFH weir (RM 2.8) blocks upstream passage from June to January, impinging slightly on the migration period for steelhead. For steelhead, the 5.12 miles of Penny Creek is the only significant obstruction (Figure 7).
Hydromodification: In the lower 2 miles of the Big Quilcene River, 1.1 miles of bank have been diked or protected through riprap. Between RM 2 and 4, 0.6 miles have been modified (Figure 5).
Other impacts: Below RM 3.5, spawning is most likely impacted by a mobile and aggrading channel bed. Decreased water volumes, channel simplification and loss of pool habitat will have a negative effect on rearing.

Coho

Status: *Depressed*
Origin: This is a mixed origin, composite stock, supported by releases from the QNFH. About 400,000 yearlings are released annually from the hatchery, with an additional 360,000 pre-smolts supplied to netpens in Quilcene Bay (USFWS 1994).
Trend: Data was highly variable and limited (1984-1992) with a downward trend for returns (WDFW 1994).
Timing: The Quilcene-Dabob stock returns beginning in mid-August and spawns from November to January (Jamestown S'Klallam 1994). The stock includes runs on the Big and Little Quilcene Rivers, Spencer, Marple, Donovan and Tarboo Creeks.
Historical Distribution: From RM 4.8 through RM 7.4, the Big Quilcene River has numerous potential natural barriers to coho passage. "Car body falls" (RM 4.8) was identified as a barrier to all salmonids except steelhead (USDA 1994). Electrofishing and snorkel surveys above this barrier found only rainbow trout and steelhead, while coho were found below (Dames and Moore 1984, Strober and Steward 1983, as referenced in Hosey and Associates 1985). Historically, coho most likely utilized up to RM 4.8 on the Big Quilcene and all of Penny Creek (M. Parton, personal communication).
Lost Habitat: Approximately 1.7 miles of small tributary, 1.2 miles of side channel slough, at least 0.8 miles of lost distributary slough (Figure 2), and 22.2 acres of isolated wetlands (Figure 3).
Obstructed Habitat: The QNFH blocks all upstream access to Penny Creek, obstructing 5.0 miles of small tributary habitat. The QHFN fish weir also blocks upstream coho access to an additional 2 miles of large tributary habitat. To partially mitigate the effects of the weir, the hatchery annually releases approximately 25,000 coho fry above the weir.
Hydromodification: In the lower 2 miles of the Big Quilcene River, 1.1 miles of bank have been diked or protected through riprap. Between RM 2 and 4, 0.6 miles have been modified (Figure 5).

Table 5. Big Quilcene winter steelhead harvest (PNPTC-WDFW-MAKAH 1995). The number includes both the river and marine sport and tribal harvest.

Year	Number of fish caught
1979-80	124
1980-81	152
1981-82	63
1982-83	44
1983-84	61
1984-85	79
1985-86	35
1986-87	42
1987-88	18
1988-89	15
1989-90	24
1990-91	6
1991-92	0
1992-93	2
1993-94	0
1994-95	8

Discussion

Major habitat issues on the Big Quilcene Watershed are:

1) Overallocation of water during low flow periods can negatively affect summer chum spawning, and winter steelhead and coho rearing.
2) Gravel aggradation from RM 3.5 to the mouth impacts all stocks.
3) Hydromodification to the channel including erecting dikes, armoring banks with rip-rap, dredging the channel, and removing LWD also impacts all stocks. Coho and winter steelhead are affected at several life stages.
4) The QNFH obstruction to fish passage on Penny Creek affects coho and to a lesser extent, winter steelhead and sea-run cutthroat production. The fish weir affects coho, and to a lesser extent winter steelhead and chum.

Water withdrawal—The effects of water withdrawal on summer chum was extensively discussed in that stock's section. An instream flow study for winter steelhead recommended a spawning discharge of 165 cfs, and rearing discharge of 50 cfs (Beecher 1980, cited by Hiss 1993). Coho rearing and spawning requires slightly less flow than steelhead (letter from R. Boomer USFWS, cited by Jamestown S'Klallam 1994). Based on USGS regression equations, the spawning discharge is achievable, but the rearing discharge is impossible given the water diversion (Williams et al. 1995).

Consistently low discharge decreases potential production by reducing the amount of physical space to rear, increasing the probability of predation through reduced cover, and increasing average stream temperature by reducing water velocity and decreasing the area shaded by riparian vegetation. Compounding low flows is gravel aggradation below RM 3.5, where most rearing occurs. Gravel aggradation creates a wider, shallower channel (Findorff et al. 1993) capable of conveying significant subsurface flows.

Aggradation—A 1993 report on sedimentation of the lower Big Quilcene River found that the channel had aggraded 2-7 ft. between RM 0 and RM 1.0 during the previous 22 years (Collins 1993). The higher sediment load of the Big Quilcene has increased the lateral migration rate of the channel (especially below RM 2.8) which has resulted in more armored banks and erected dikes. In these active reaches of the lower Big Quilcene River, dikes are often breeched during high flows.

In December 1993 following one such breech, a contractor rebuilding the dike under an emergency HPA also dredged 1800 ft of channel without a permit. The Washington Department of Fisheries reported that all redds in this reach were destroyed, with the highest impact to summer chum. Lost production of summer chum represented 29% of the 1993 wild spawning production. To avoid litigation, Jefferson County agreed to begin assessing options for restoring the lower Big Quilcene River. The feasibility study recommended dike removal to restore floodplain function (Williams et al. 1995). Dike removal will increase the area available for gravel storage, thus decreasing the need for future dredging (Williams et al. 1995). A portion of the northern dike was removed in 1995.

The ultimate solution to the gravel problem lies with the Forest Service. Much of the watershed below Buckhorn Wilderness was roaded from the 1940's to 1960's using balanced road construction. Under this technique, wood and sediment debris is either used in the road prism or is side-cast. Roads built on slopes over 55% have been a continual source of sediment to the channel (USDA 1994). Some of these sub-basins show decades of disturbance from landslides and debris flows without vegetative recovery (USDA 1994). For example, the Mile and Half Creek sub-basin is a 3rd order creek with slope gradients greater than 55%, and three layers of stacked roads. Roads cross this creek and its tributaries in at least nine places, all using culverts. The Forest Service has identified roads and sub-basins with a high probability of failure

(USDA 1994). An aggressive resolution to repeated culvert failure should include retiring roads, building bridges, or using concrete aprons in place of culverts.

Hydromodification—The lower Big Quilcene River contains no side channels or distributary slough habitat. This is a byproduct from decades of attempting to control channel migration through LWD removal, bank armoring and erecting dikes.

A secretary of War report in the mid-1800's identified the Big Quilcene River as one of many Northwest rivers with log jams completely blocking the channel for a distance of 100 to 1500 m. (Sedell and Luchessa 1982). The Army Corps of Engineers in the 1800's, and more recently, the Washington Department of Fisheries (WDF), removed all the log jams in the lower Big Quilcene River. Two major log jams present in 1975 (at approximately RM 1.5 and 4.0) are no longer there (Williams et al. 1975). An active program of LWD removal still exists today (Figure 4). Large woody debris creates holding pools for coho and steelhead, offers overwintering habitat, creates side channels, and in general increases the complexity of flow.

Side channels offer critical overwintering habitat for coho, and to a lesser extent steelhead, and provide spawning habitat for chum. The most significant factor restricting side channel development is the use of rip-rap and dikes. Maps and aerial photos from 1936 and 1957 (respectively) indicate 1.2 miles of side channel habitat between RM 1 and 2.8. More recent aerial photos show dikes and riprap in those locations and no side channels.

QNFH obstructions— Penny Creek contains 5.0 miles of prime spawning and overwintering habitat for coho, steelhead, and cutthroat. The QHFH blocks access because: (1) no studies have shown coho ever used it, and (2) coho may cause disease problems at the hatchery. First, coho utilize similar streams in other watersheds. Second, a healthy resident cutthroat population already exists in Penny Creek (personal communication, Mike Parton).

Restoration and protection strategies

Restoration projects for the Big Quilcene River may consider:

1) Reduce sediment input into the channel, and or increase channel sediment storage capabilities.

a) The prescriptions from Watershed Analysis (USDA 1994) will correct many of the problems on Forest Service land associated with fine and coarse sediment introduced from unstable sidecasts or poor road drain age. However, the Forest Service has multiple steep sub-watersheds with several layers of roads. In these areas, they need to consider the initially expensive option of replac ing culverts with bridges, concrete aprons, or by pulling the culverts and closing the road.

b) The Forest Service and the City of Port Townsend should examine the costs and benefits of removing or moving one of the access roads to the diversion dam. The road is located in the Big Quilcene River flood plain for about a mile below the diversion dam (RM 9.4). Whether side channels existed prior to road building is unknown. However, restricting channel movement decreases the amount of sediment storage in this sediment transport dominated canyon, guaranteeing transport to inhabited areas down stream.

c) In 1995, a portion of the northern dike was removed below approximately RM 0.4. This potentially opens access to an old distributary slough moving in a northeastern direction from the channel. If activated, the distributary slough would provide additional gravel storage, and valuable chum and coho spawning and rearing habitat.

2) Develop new hydraulic permit criteria to encourage a reduction of HPA's for construction of new dikes and banks armored by riprap. In some cases, this could include using LWD jams to protect banks in place of rock. Historical aerial photo analysis below RM 2.8 shows a progression of new construction on the floodplain followed by bank armoring.

3) Work with floodplain landowners between RM 1.0 and 2.8 for creation of side channel habitat. This reach historically contained significant side channel habitat as shown on topographic maps and aerial photos from 1936 and 1957 respectively. An increase in side channel habitat would benefit all species, especially overwintering juvenile coho and steelhead.

4) Develop new hydraulic permit criteria to reduce or eliminate HPA's for LWD removal. This could be combined with a public education program highlighting the biological importance of LWD. It is suspected that most LWD is removed illegally without an HPA. Large woody debris recruitment potential for the lower watershed is already poor and composed of mostly deciduous species (USDA 1994). Current LWD levels are only 5 pieces per 100 m from the mouth to RM 7.4 (USDA 1994). In a study contrasting reaches with old growth riparian vegetation to clear-cut riparian vegetation, clear-cut reaches most frequently contained 0 to 20 pieces per 100 m and old growth 60 to 100 pieces per 100 m (Montgomery et al. 1995). While some of the lower Big Quilcene riparian forests have been converted to houses and farms, a sizable percentage of timberland remains available for LWD recruitment.

5) Restore fish access to Penny Creek. This has been proposed before (e.g. USDA 1994) and merits further study. Penny Creek has 5.0 miles flow gradient spawning and rearing habitat suitable for coho, steelhead, and searun cutthroat.

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