APPENDIX C: TECHNICAL BACKGROUND

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1. OTHER WRIA 1 SALMONID POPULATIONS

1.1. General Salmonid Habitat Requirements

Salmonid habitat requirements vary by species, life stage, and time of year, although general patterns exist (Bjornn and Reiser 1991).

Upstream migrating adults generally require sufficient streamflow and suitable water quality throughout their migration to spawning grounds. High water temperatures and turbidities and low dissolved oxygen can impede or delay upstream passage, as can high velocities and structural barriers to passage (Bjornn and Reiser 1991).

Holding adults generally require deep, cool pools with complex cover, especially those species and stocks that hold during the summer, such as early chinook, summer steelhead, and bull trout. Habitat requirements for spawners include suitable substrate size, water depth, and velocity, as well as suitable water temperatures and sufficient space to build redds. Water depth, velocity and spawning area (and indirectly water temperatures) are all a function of streamflow. Many species prefer to spawn in pool tailouts, which are the transitional areas between pools and riffles (Bjornn and Reiser 1991).

Incubation success requires sufficient intragravel flow (water flow circulating through the redd) to supply oxygen and carry away waste. Intragravel flow is a function of both streamflow and proportion of fine sediments within gravels. This life stage is especially vulnerable to vertical or lateral channel instability – bedload movement can either scour or bury redds, while channel migration or avulsions can lead to redd dewatering. Salmonid embryos can survive some redd dewatering prior to hatching, but only if temperatures are suitable, fine sediment concentrations do not impede air flow, and humidity within the redds is near 100% within the redds (several authors, cited in Bjornn and Reiser 1991). Water temperature affects both the maturation rate of incubating embryos and dissolved oxygen levels within the gravel.

Newly emerged fry favor shallow, low-velocity habitats with cover to avoid predation. As fry grow, they tend to move into deeper, faster waters.

For juvenile salmonids that rear in freshwater for months to years, general distribution and abundance is controlled by the availability of suitable space, food resources, and water quality (e.g. temperature, turbidity, dissolved oxygen; Bjornn and Reiser 1991). Juvenile salmonids colonize available habitat downstream from spawning grounds – habitat quantity, however, can limit the number of juveniles that the freshwater system can support. Although depth, velocity, and habitat unit preferences vary by species and size class (Bisson et al. 1982), habitat quantity is generally a function of streamflow, channel morphology, and accessibility. Cover is an important habitat element to reduce predation risk, especially large wood but also water depth, water turbulence, coarse substrate (e.g. cobbles, boulders), undercut banks, overhanging vegetation, and aquatic vegetation (Bjornn and Reiser 1991). Food availability is critical, especially during the important growth period of spring and summer. Juvenile salmonids feed on drifting benthic invertebrates or terrestrial invertebrates that fall into the stream or river from overhanging vegetation; larger juveniles also eat other fish. During fall and winter, tributaries and off-channel floodplain habitats can provide refuge from high velocities, turbidity, and bedload movement associated with floods. Substrate can also provide overwinter habitat for some salmonids, provided fine sediment does not clog the interstitial spaces.

Outmigration to estuarine and nearshore marine environments varies by species and is apparently primarily regulated by photoperiod, although timing can vary depending on streamflow, freshwater habitat quantity, water temperatures, and fish size (Bjornn and Reiser 1991). Significant pulses in abundance of outmigrating juveniles are often associated with high flow events, due either to involuntary displacement (especially for smaller fish) or to voluntary outmigration during times of high velocities and turbidities that reduce travel time and predation risk.

Estuaries and marine shorelines are important to juvenile salmonids for feeding and growth, refuge from predation and extreme events, physiological transition to saltwater, and migratory corridors (Averill et al. 2004). Habitat use varies by species, population, and life history pattern (various authors, cited in Fresh, in prep.). Four general life history patterns are exhibited among salmonid populations with respect to juvenile rearing (Averill et al. 2004): (1) *Delta fry* migrate seaward soon after emergence and rear extensively in natal estuarine deltas; (2) *Fry migrants* also migrate seaward soon after emergence and rear in and along the nearshore, particularly in non-natal estuaries ("pocket estuaries"); (3) *parr migrants* rear in freshwater for up to 6 months before migrating to rear in their natal estuary; and (4) *yearling migrants* rear in freshwater for about 1 year before migrating seaward to Puget Sound; they pass quickly through deltas.

1.2. Coho Salmon[1]

Most of the current coho salmon habitat in WRIA 1 is in the Nooksack River watershed (69%), followed by the independent coastal tributaries (15%) and Fraser River tributaries (16%; Figure C10; Table C3).

The Nooksack Basin has one identified coho salmon stock, which is distributed in all accessible areas throughout the entire drainage, including all three forks of the Nooksack River (WDFW 2002). The stock is considered to be of mixed origin with composite production (both hatchery and natural spawning components) and has an unknown status (WDFW et al. 1994; WDFW 2002). For many decades, large quantities of hatchery coho salmon from various sources have been released at the Kendall Creek Hatchery on the North Fork Nooksack River and in the Nooksack River itself. In addition, coho salmon have been released at the Skookum Creek hatchery in the South Fork Nooksack Basin and from the Lummi Sea Ponds in Lummi Bay (WDFW et al. 1994). Genetic analysis is underway to develop a better understanding of the coho population (s) in the Nooksack Basin (Ned Currence, Nooksack Indian Tribe, personal communication). NMFS considers Puget Sound coho a candidate species, indicating that concern exists regarding population levels and other impacts but not enough concern to list the stock as threatened or endangered at this time (Weitkamp et al. 1995).

The independent North Puget Sound tributary coho stock is considered mixed-origin with wild production and an unknown status, and includes spawning coho in all accessible areas of Dakota, California, Terrell, Squalicum, Whatcom, Padden, Chuckanut, lower Oyster, Colony, and Silver Creeks (WDFW et al. 1994; WDFW 2002; WDFW spawning ground database 2002).

Sumas/Chilliwack coho salmon are native origin with wild production and unknown status, although the Chilliwack portion of the run appears to be healthy (WDFW et al. 1994). Some releases of Nooksack coho have occurred in these streams.

[1] Excerpted (except for first paragraph) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

1.3. Chum Salmon[2]

Most of the current chum salmon habitat in WRIA 1 is in the Nooksack River watershed (76%), followed by the independent coastal tributaries (16%) and Fraser River tributaries (8.2%; Figure C11; Table C3).

Two stocks of chum salmon have been identified within the Nooksack Basin. One stock spawns in the South Fork and mainstem Nooksack Rivers and tributaries (WDFW et al. 1994). It is described as native origin with wild production and an unknown status. Another stock of chum salmon spawns in the North Fork Nooksack River. This stock is described as native with wild production, but some hatchery releases of Hood Canal and Grays Harbor stocks have occurred in the past (WDFW et al. 1994), and limited hatchery production occurs from the Kendall Creek Hatchery (U.S. Forest Service 1995a). The stock is listed as "healthy", and spawns almost to the Nooksack Falls in the North Fork Nooksack River and to the diversion dam in the Middle Fork Nooksack River. In the South Fork, chum salmon are far less abundant than in the North Fork.

The Samish/Independent chum stock is listed as a hybrid population mixed with Hood Canal, Samish, and other stocks (WDFW et al. 1994). In addition, hatchery-origin chum from Hood Canal and Quilcene were released in Oyster and Colony Creeks. This plan include the segments of this stock that spawn in WRIA 1 streams such as in Chuckanut, Padden, Whatcom, Squalicum, Oyster, and Colony Creeks and in the Lummi River (Phinney and Williams 1975; WDFW et al. 1994). Overall, the stock is described as a mixed-origin stock with composite (hatchery and natural) production and a healthy status (WDFW et al. 1994). The Samish/Independent chum stock is more genetically similar to Hood Canal chum than to other North Puget Sound chum stocks (Phelps et al. 1995). The spawn timing of the Samish/Independent stock is also earlier than other North Puget Sound stocks, peaking in late November through early December compared to a peak in late December for Nooksack chum salmon stocks. Chum from Chuckanut Creek are bright skinned (Phelps et al. 1995).

The Sumas/Chilliwack chum stock is described as native-origin with wild production and an unknown status with a note that the Chilliwack part of the stock appears to be at healthy levels (WDFW et al. 1994). Spawning occurs in the Chilliwack and Sumas Rivers and in Sumas tributaries such as Saar, Breckenridge, and North Fork Johnson Creeks.

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[2] Excerpted (except for first paragraph) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

1.4. Pink Salmon[3]

Almost all of the current pink salmon habitat in WRIA 1 is in the Nooksack River watershed (98%), with the remainder in the independent coastal tributaries (Figure C12; Table C3).

Two stocks of odd-year Nooksack pink salmon were identified in the SASSI report, and it is important to note that small numbers of even-year pink salmon spawn in the South Fork Nooksack sub-basin (Ned Currence, Nooksack Indian Tribe, personal communication). One of the odd-year stocks spawns in both the North and Middle Fork Nooksack Rivers (WDFW et al. 1994). It was described in SASSI as a mixed origin stock with wild production, and the status was listed as unknown on one page and healthy on another. However, more recent genetic analysis shows that the Nooksack pink salmon stocks are unique (Shaklee et al. 1995), even though outside stocks have been released in the area, including a stock from Hood Canal (Dungeness origin). Also, the North Fork Nooksack Watershed Analysis reported that the stock has the potential to have a depressed status (U.S. Forest Service 1995a). Adults enter freshwater from July through August and spawn from late August through late September. Their distribution extends to Nooksack Falls (RM 65) in the North Fork Nooksack River and to the diversion dam in the Middle Fork Nooksack River. Upper North Fork tributaries including Thompson Creek, a Glacier Creek tributary, are also important pink salmon spawning sites. Pink salmon use Maple Creek to the falls and the lower reaches of other tributaries, many of which have flow-dependent use.

The second stock of odd-year pink salmon spawns in the South Fork Nooksack River up to RM 25 and in associated tributaries, including Hutchinson, Skookum, Cavanaugh, Deer, and Plumbago Creeks. The overall contribution of South Fork pink salmon to the Nooksack total escapement is thought to be small (WDFW et al. 1994). Historically South Fork odd year pink salmon were apparently very abundant. Morse Monthly (1883) described the pink salmon abundance in 1881 as "completely filling the South Fork; literally there were millions of them." Overall, Nooksack River pink salmon have an earlier run timing and unique genetic baseline compared to other Puget Sound stocks (Shaklee et al. 1995). They are native in origin with wild production and an unknown stock status (WDFW et al. 1994). Adults enter freshwater from late June through August and spawn from late August to early October (WDFW et al. 1994). They are also smaller in size (Shaklee et al. 1995). While not included in the SASSI stock description, pink salmon also spawn in the mainstem Nooksack River (Ned Currence, Nooksack Tribe, personal communication).

[3] Excerpted (except for first paragraph) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

1.5. Sockeye Salmon (and Kokanee) [4]

Most of the current sockeye salmon habitat in WRIA 1 is in the Nooksack River watershed (91%), followed by the Fraser River (7.8%) and independent coastal tributaries (1.5%) and Fraser River tributaries (7.8%; Figure C13; Table C3).

For decades, small numbers of riverine sockeye salmon have been consistently documented in the North and South Fork Nooksack Rivers (Gustafson and Winans 1999), and have occasionally been recorded in the Middle Fork Nooksack River (Ned Currence, Nooksack Indian Tribe, personal communication). WDFW scale readings from adult sockeye indicate that these fish leave the river as yearlings. They are not described in the SASSI report. Gustafson and Winans (1999) state that the Nooksack (along with the Skagit) drainage has the most persistent evidence of river spawning populations in Washington, and recent analysis of allozyme frequencies show Nooksack sockeye are genetically unique and cluster with other river-sea type sockeye populations in the Skagit River, Canada and Alaska.

A native population of kokanee reproduces in the Lake Whatcom watershed, and served as the broodstock for the Lake Whatcom Hatchery population, which is planted in area lakes and elsewhere (U.S. Forest Service 1995a). In 1974, the natural spawning population numbered 20,000, but in 1998, there were less than 100 spawners (Johnston 2000). Spawning areas include Brannian, Olson, Fir, Anderson, and to a lesser extent, Carpenter and Smith Creeks (DNR 1997). Hatchery-origin kokanee remain numerous, and are released in the watershed and throughout the State. The Lake Whatcom kokanee stock is the only WDFW source of kokanee eggs and fry in Washington State (DNR 1997).

1.6. Steelhead (and Rainbow Trout) [5]

Most of the current steelhead habitat in WRIA 1 is in the Nooksack River watershed (64%), followed by the independent coastal tributaries (23%) and Fraser River tributaries (13%; Figure C14; Table C3).

There are four separate steelhead trout stocks in this region. Three are winter steelhead, while one is a summer run steelhead stock. The three winter steelhead

[4] Excerpted (except for first paragraph) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.
[5] Excerpted (except for first paragraph) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

stocks are: 1) the Mainstem/North Fork stock, 2) the Middle Fork Nooksack stock, and 3) the South Fork Nooksack stock (WDFW et al. 1994). All are native origin with wild production and an unknown status. However, the SASSI report mentioned that these stocks may have a depressed status if the decline in index area redd densities are representative of the stocks. NMFS listed a declining trend in total escapement of –11.6 to –7.9, where trend is defined as percent annual change in total escapement or an index of total escapement (Busby et al. 1996). Summer steelhead spawn in the upper South Fork Nooksack River including upstream from RM 30.4, and are native with wild production and an unknown status, but the run has been historically small (WDFW 1998a). None of these stocks are currently listed under the ESA.

Dakota Creek winter steelhead are native-origin with wild production and an unknown status (WDFW et al. 1994). Historically, this run was small. Steelhead distribution was mapped for Terrell, Squalicum, Whatcom, Padden, and Chuckanut Creek and in the Sumas River, but these populations were not mentioned in the SASSI report (WDFW et al. 1994).

Native rainbow trout are found in the North Fork Nooksack drainage, and non-native rainbow are cultured at the Whatcom Falls Hatchery for releases throughout North Puget Sound. Their distribution is assumed to overlap with that of steelhead trout. (Figure C15).

1.7. Cutthroat Trout[6]

Most of the current cutthroat habitat in WRIA 1 is in the Nooksack River watershed (65%), followed by the independent coastal tributaries (23%) and Fraser River tributaries (13%; Figure C16; Table C3).

There is one stock of coastal cutthroat trout designated for the entire Nooksack Basin, and it is noted as mixed origin, supported by hatchery and natural production, and an unknown status (WDFW 2000). Anadromous cutthroat are native with wild production (WDFW 2000). Genetic analysis of cutthroat collected from a mainstem tributary (Double Ditch Creek) indicates they are significantly different from all other North Sound collections ($p<0.001$). All four life history forms (anadromous, resident, adfluvial, and fluvial) of the species are found in the Nooksack Basin. Most of the fluvial cutthroat are located upstream of Nooksack Falls on the North Fork and upstream of the diversion dam on the Middle Fork, while Maple Creek flowing from Silver Lake, supports adfluvial cutthroat. Anadromous adult cutthroat enter freshwater early, from August through October, and spawn from January through April (WDFW 2000). The

[6] Excerpted (except for first paragraph) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

other life history forms spawn from January through July. The anadromous coastal cutthroat are native-origin, supported by wild production. However, hatchery produced resident cutthroat have been released in various lakes throughout Whatcom, Skagit, and Snohomish Counties in the past (U.S. Forest Service 1995a).

Coastal cutthroat trout spawn in the Washington reaches of the Sumas River and tributaries. Both anadromous and resident forms of cutthroat trout are present. The anadromous cutthroat adults enter freshwater from August through October and spawn from January through April (WDFW 2000). The North Puget Sound tributary coastal cutthroat stock spawns in Dakota, California, Terrell, Squalicum, Padden, Chuckanut, and Oyster Creeks, and adfluvial cutthroat are found in Lake Terrell (WDFW 2000). The adults of this stock enter freshwater at a later time, from November through March, while spawning is similar to other nearby stocks, from January through April. The adfluvial segment spawns from January through May, and the resident forms spawn from January through July. Whatcom Creek coastal cutthroat consist of anadromous, resident, and adfluvial forms. Anadromous Whatcom Creek cutthroat are later-entry adults, returning from November through March. They spawn from January through April. Resident and adfluvial Whatcom Creek cutthroat spawn from January through mid-June (WDFW 2000). The native cutthroat population in Lake Whatcom has severely declined, decreasing 65% between 1987 and 1999 (Johnston 2000). The number of cutthroat spawners in Beaver Creek, a tributary to Lake Whatcom, dropped 92% in that time period. The primary 53 spawning streams for the Lake Whatcom cutthroat population are Austin, Beaver, Carpenter, Olson, and Smith Creeks (DNR 1997). Some non-native (Toutle Creek) releases of cutthroat have occurred in the Lake Whatcom watershed in recent years (DNR 1997).

2. HABITAT OVERVIEW

2.1. Watershed Overview

2.1.1. Climate

WRIA 1 lies within a convergence zone influenced by Pacific weather systems from the ocean and Arctic weather systems from the north (USFS 1995). Pacific systems dominate in summer months with mild, clear weather and low levels of precipitation. In winter months, Arctic systems bring storms, high levels of precipitation, and occasionally very low temperatures. Most (75%) of precipitation falls between September and May (USFS 1995), with much falling as snow in the higher elevations. Average annual precipitation ranges from 30 to 50 inches in the lowlands to 70 to 140 inches at higher elevations (Figure C2; Table C1). Rain-on-snow events, which are associated with the most severe floods and landslides (USFS 1995), generally occur from late October through January. Peak rain-on-snow zones occur throughout the North, Middle and South Fork subbasins, comprising 18.7, 15.2, and 24.2%, of the area in those subbasins, respectively (Figure C2; Table C1).

2.1.2. Geology

Geology and geologic processes shape salmon habitat development. An understanding of geologic history, geologic materials, and the geomorphic processes helps to shape a restoration template that is informed by historic habitat conditions. These same analyses are also essential to produce habitat project designs that are appropriate to the physical setting at a given site and that successfully include the temporal element in design. A simplified overview of WRIA 1 is provided here to help link underlying geology, landforms, and surficial processes to salmon habitat diversity and the limiting factors that were considered in recovery planning. The reader is referred to other resources (see for example, Tabor and Haugerud, 1999; Cox and Kahle 1999; Dragovich et al. 1997; Easterbrook 1976; or, Moen 1962) for more detailed descriptions of WRIA 1 geology.

The upper reaches of the Nooksack and Chilliwack River systems in WRIA 1 are characterized by high levels of precipitation and steep landslide-prone topography. Two stream hydrographs are typical. First are the a uni-modal hydrographs, such as Tomyhoi Creek, that reflects a higher elevation snow-dominated system characterized by spring and summer snowmelt that then tapers off to summer and fall low flows. Second are the bi-modal systems with fall and winter peaks due to rain and rain-on-snow events. The hydrograph then declines as the snow pack develops and then rises again with the onset of spring snowmelt (USU 2001). Overlaid onto these generalities are drainage-specific factors that must be considered in evaluating management strategies and in scoping habitat restoration projects. Examples from the North and South Fork illustrate this.

Glacier Creek, a tributary to the North Fork Nooksack River, has a bimodal hydrograph reflecting late fall and winter rainfall or rain-on-snow events and spring snow-melt runoff. This is then followed by a diurnally fluctuating flow during late summer and early fall when the glaciers kick in and produce turbid melt-water with a high suspended and bed-material load. Turbidity seems to be on the increase in recent years as the melt-water streams erode moraine material exposed as glacier retreat occurs. Although relatively infrequent, glacial outburst floods are also a consideration. Glacier Creek and other streams originating from the glaciers on Mount Baker and Mount Shuksan produce a significant proportion of the sediment load generated in the North Fork.

Across the valley, Canyon Creek is also bimodal, but lacks the glacier water sources during late summer. Hence summer flows can be critically low and are limited by the depth and volume of soil or Pleistocene deposits that store and release groundwater to the stream. Canyon Creek also contains the Jim Creek and Bald Mountain deep-seated landslides which correspond to structural weaknesses along geologic contacts. Both landslides introduce sediment to the stream through lateral erosion and through episodic movement of the slide mass. The latter, as well as smaller landslides from a well defined inner gorge landform, can produce landslide dams that fail catastrophically producing dam-break floods that can severely impact the stream morphology, damage fish habitat, and impact human infrastructure. Landslides from relatively shallow failures of the soil layer on steep (greater than 65 percent slope) hillsides, typically in convergent topography ("colluvial hollows"), can deliver to stream channels and then route as debris flows or sediment laden floods affecting both channel morphology and fish habitat. A combination significant precipitation and a suite of landslide processes produced large sediment laden flood events in November 1989 followed by back-to-back events in November 1990 (see for example the Canyon Creek Alluvial Fan Hazard Assessment at http://www.co.whatcom.wa.us/publicworks/pdf/riverflood/canyon_creek_final.pdf). All three events began as classic rain-on-snow events followed by substantial rainfall that produced road drainage structure failures and subsequent landslides throughout the Nooksack.

The upper South Fork, above Skookum Creek, lacks the glacial water source, and is habitat quality limited by summer low flows that exacerbate high summer stream temperatures. Although remnants of Pleistocene valley fill are present in the upper South Fork valley and store and contribute groundwater, the relatively thin soils associated with the Twin Sisters Range, largely an exposed slab of the Earth's mantle composed of dunite, produce a "flashy" hydrograph. Deep-seated landslides are present and associated with fault contacts, such as on the right bank at the river mile 30.5 barrier, and with failures in the glacial valley fill, and with slump-flow complexes and sakung features (Thorsen, G. W. 1989) associated with Shuksan Suite geologic units. Shallow-rapid styles of mass wasting are common in steep "head wall" areas of convergent topography and can fail and route to fish bearing streams as described for Canyon Creek above. While shallow-rapid failures are common throughout the upper watershed, they are particularly prevalent in areas underlain by the Chuckanut Formation.

Historic land management activities, primarily logging with some mining thrown in for good measure, has exacerbated natural mass-wasting processes and altered slope hydrology. Construction of roads and logging of inner gorges and colluvial hollows has affected shallow-rapid mass wasting increasing landslide rates and sediment delivery to streams due to concentration of road drainage onto inherently unstable landforms, by physically destabilizing the landform through creation of road cut and fill (sidecast) slopes, and by removing root strength critical to slope stability. Roading and removal of hydrologically mature timber has also altered the slope hydrology by concentrating road drainage across the upper watershed and by increasing groundwater inputs to deep-seated landslide features. The former has likely shortened the time of concentration in response to individual storm events. The latter has likely exacerbated movement of deep-seated features as road water was drained onto the landslide or groundwater inputs increased post-timber harvest. Road and landslide inventories (e.g. Zander 1996, 1997; Watts, 1996, 1997; Zander and Watts, 1998; Kirtland 1995) are available tools that have been used to identify unstable landforms and create cause-effect linkages to specific management practices such as forest roads and to identify and remediate management problems in high sediment yield areas.

The conventional wisdom is that the processes described above have altered the sediment flux such that stream channels throughout the mainstem Nooksack and its forks have filled as the result of landslide derived coarse sediment causing an increase in width to depth ratios and a decrease in pool frequency. For example, the upper South Fork active channel width (riparian opening) doubled during the period 1940 to 1991, as measured from aerial photographs by Kirtland (1995). Yet field investigations indicate that large-scale aggradation may not be the primary cause of channel simplification. In fact, a number of reaches exhibit signs of incision and of being sediment starved. Loss of large in-channel accumulations of woody debris combined with disconnection of the river from the flood plain and a lack of flood plain roughness elements must also be considered in analyzing, at the reach scale, current channel condition, historic condition, and desired future condition. At a larger scale, Collins (2004?) has documented historic changes to Nooksack River mainstem and fork channel morphology and describes historic conditions and processes that can be used as templates for restoration. These are the types of detailed analyses that are being conducted under the 5 to 10 year action to restore habitat processes in the forks, mainstem, and major early chinook tributaries.

The lower reaches of the South Fork and into the mainstem, lower mainstem tributaries and the coastal tributaries to the north of Bellingham, are less immediately affected by mass wasting. Riverine processes and the interconnections of the river and groundwater derived from, or lost to, the glacially derived deposits adjacent or underlying the river and streams become the prominent geologic considerations. Collins (2004) analysis of the mainstem Nooksack provides a historical template for recovery. An important element is the documentation of changes in certain reaches from an anastomosing pattern to that of a single thread or braided pattern. An understanding of the underlying causes of these changes and the relationships to the presence of in-channel roughness element (i.e. log jams), riparian forests, and flood plain connections are essential to developing river restoration plans and projects that will successfully restore not only habitat structure, but the habitat forming and maintaining processes as well. The detailed analyses that are being conducted under the 5 to 10 year actions will consider these factors.

The Pleistocene glacial deposits in western Whatcom County contain the major aquifers (Cox and Kahle, 1999) utilized for agriculture, municipal, and domestic uses. Seepage runs performed by the USGS (19??) and by Utah State University (200?) identify where were the mainstem Nooksack gains or loses water during summer low flow months. Temperature data for the South Fork (e.g. Lummi Nation, Nooksack Tribe) and mainstem (Nooksack Tribe) also indicates zones where groundwater enters the channel producing a cooling effect. An understanding of both the hydrogeologic and geomorphic setting is used to place this information into a restoration context. Examples include identifying priority areas for wetlands enhancement to supplement flows in small streams, for locating designed log jams to provide temperature refuge, and for protecting areas of emergent groundwater used for spawning by chum salmon and other salmonids.

Two final elements of WRIA 1 geology are where streams enter into marine waters and the marine shorelines themselves. Streams entering marine waters form estuaries which range from small creeks, such as Dakota Creek, displaying a drowned river mouth with little delta formation to, Terrell Creek which enters Birch Bay behind a bar, to the Nooksack River with its prominent prograding delta. Stream specific assessment is needed to identify physical processes and restoration needs. This effort includes the work on smaller estuaries in Bellingham Bay compiled under the Bellingham Bay Demonstration Pilot Project and that for the Nooksack delta contained in the draft Nooksack Estuary Assessment Report (April 2005). Additional assessments of estuary geomorphology and habitat function will be occurring under the estuarine and nearshore action item.

Coastal processes including analysis of drift cells, feeder bluff locations, substrate size and distribution are also essential to understanding habitat functions for salmonids and the forage fish species on which many species of salmonids depend. WRIA 1 possesses many reaches of marine shoreline that retain much of their historic function. However, shoreline function has been heavily altered around Bellingham Bay and south largely through shoreline armoring, marina construction, and placement of the major north-south rail line. Furthermore, anthropogenic changes to the shoreline often mask the historic condition of the shoreline. An understanding of the historic condition and the processes currently operating are essential to design of habitat restoration projects appropriate to the site. On-going and soon to begin analyses of the marine shoreline being conducted jointly by Whatcom County Planning, as part of the Shorelines Management Program update, and the Whatcom Marine Resources Committee will verify existing data on shoreline processes, provide ground truthing, and feed into the shorelines restoration plan.

2.1.3. Land Use

European-Americans began settling in the area in the 1850s, attracted by high quality timber coupled with an easy access to water transportation (Whatcom County Planning and Development Services Dept. 1997, as cited in Smith 2002). Logging, coal mining, and the clearing of 130,000 acres of lowlands for farm wrought substantial changes in the landscape (Smith 2002). Within the first few decades of Euro-American settlement, most of the lowland forests had been burned or logged and most wetlands had been drained and ditched; much of these lands were converted to agriculture (Collins & Sheikh 2004). Large channels were channelized and cleared of large woody debris (Collins & Sheikh 2004). By the early part of the century, various industries (lumber mills, shake mills, and fish processing plants) had been built in Bellingham and along Lake Whatcom. During this time period, logging companies sold logged-off lands to employees and immigrants for small farm development. From 1950 to 1990, commercial activity greatly increased and former agricultural lands were converted to residential, commercial, and industrial uses (Whatcom County Planning and Development Services Dept. 1997, as cited in Smith 2002). Coal mining ceased, but sand and gravel mining continued to accommodate development. Human population growth in Whatcom County increased by nearly 100% in this 40-year period (Whatcom County Planning and Development Services Dept. 1997, as cited in Smith 2002). From 1990 to 1995, the estimated annual human population growth rate ranged from 2.3 to 3.7% (Whatcom County Planning and Development Service Dept. 1997, as cited in Smith 20002).

Current land use/land cover in WRIA 1 (Figure C3; Table C2) is predominantly forested upland (63%), followed by agricultural land (herbaceous planted/ cultivated and dairy classes; 17%), barren land (largely bare rock/sand/clay or transitional; 6%), and developed land (4%). Forested lands are distributed throughout the Chilliwack and Samish Bay watersheds, as well as the upper Nooksack River, Sumas River, and Lake Whatcom watersheds. Agricultural lands (including both cultivated land and dairies) are distributed throughout the watersheds of the lower Nooksack and Birch Bay and Drayton Harbor tributaries, as well as the lower South Fork valley. Development is concentrated in the lowlands in and around cities and along the I-5 corridors.

2.2. Nooksack River Watershed Conditions

2.2.1. Watershed Conditions

Much of the watershed conditions information was excerpted from the Salmon and Steelhead Habitat Limiting Factors for Water Resources Inventory Area 1: Nooksack Watershed (Smith, 2002).

2.2.1.1. Land Cover

The Nooksack River watershed encompasses 3638 km^2 (832 mi^2), divided among the North Fork (36%), Middle Fork (12%), South Fork (22%), lower Nooksack (27%) and Lummi River (2.8%) subbasins (Figure C1, Table C4). The Nooksack River drains the slopes of Mt. Baker, Mt. Shuksan and the Twin Sisters. The North and Middle Fork Nooksack Rivers flow through moderate to low gradient valleys nested within a steep, mountainous landscape (22% in high and 46% in moderate slope classes and 44% and 50% in moderate slope classes; Figure C5; Table C4). Average elevations are 963 m (3159 ft, NF) and 990 m (3248 ft, MF) and maximum elevation is 3283 m (10771 ft, NF and MF). The South Fork Nooksack subbasin is slightly less steep, with 11% in high landscape slope class and similar percentage (48%) in moderate slope class. Average and maximum elevations are also lower, at 697 (2287 ft) and 2137 m (7011 ft), respectively. The Lower Nooksack and Lummi River basins are lowland systems, with average elevation less than 100 m (300 feet).

Land use/land cover in the Nooksack region differs substantially between the Forks subbasins and the lower Nooksack and Lummi River subbasins (Figure C3; Table C2). Forest uplands comprise 80-85% of the land cover in the North, Middle and South Fork subbasins. About 4-6% is in each of Barren and Shrubland/Non-Natural Woody/ Herbaceous Upland land cover classes. There is slightly higher proportions of land cover in Agriculture (i.e. Herbaceous Planted/Cultivated; 3.0%) and Dairies (0.74%) in the South Fork subbasin than in the North (1.5% Agriculture; no Dairies) and Middle Fork (none of either) subbasins. Developed land cover comprises 0.66%, 0.21% and 0.04% in the North, South, and Middle Fork subbasins, respectively. In forested lands of the three subbasins, late seral stage is concentrated in the upper watersheds, with a mix of mid-seral stage, early seral stage, and other forested lands throughout the mid to lower North and Middle Fork subbasins and throughout much of the South Fork subbasin downstream of the Mt. Baker-Snoqualmie National Forest boundary (Figure C6). Forested uplands are distributed similarly among forest cover classes in the North and Middle Fork subbasins, with 32-35% in late seral stage, 19-20% in mid-seral stage, 8-11% in early seral stage, and 38% in other forested lands (i.e. <10% coniferous crown cover; Table C5). By contrast, only 15% of the South Fork subbasin is in late seral stage, followed by 23%, 18%, and

44% in mid- and early seral stages and other forested lands (<10% coniferous crown cover), respectively.

Land cover in the Lower Nooksack and Lummi River subbasins is predominantly classed as Agriculture (i.e. Herbaceous Planted/Cultivated) or Dairies (Figure C3). Herbaceous Planted/Cultivated comprises 40 and 50% and Dairies comprise 14% and 7% of the Lower Nooksack and Lummi River subbasins, respectively, whereas Forested Uplands comprise only 26-28% of land cover (Table C5). Developed land covers 12% in the Lower Nooksack and 6.6% in the Lummi River subbasins. Among Forested Uplands, most (99% in Lummi, 68% in Lower Nooksack) have less than 10% crown cover and none are in late seral stage (Figure C6; Table C5). Early and mid-seral stage classes comprise 22% and 11% of the Lower Nooksack subbasin.

2.2.1.2. Mass Wasting

A recent inventory of landslides within the North Fork Nooksack Basin estimates 632 mass wasting sites from 1940 through 1995, and most of them (512) are shallow rapid (including debris flows) (Watts 1997). These types of slides along with small sporadic, deep-seated (slumps or rotational) landslides are more prone to deliver sediments to streams (Watts 1997). They are also the types of landslides that can be treated and for these reasons, are emphasized in this report. Seventy-four percent of shallow, rapid and small, deep-seated landslides delivered sediment to streams. The highest densities of these sediment-delivering landslides are located in the Cornell (11 events per square mile), Racehorse (11), Gallop (8), Boulder (6), Coal (5), Canyon (3), and Glacier (2) Creek Watersheds (Figure 11) (data from Watts 1997). Roads and clearcuts are associated with 36% and 28% of these types of landslides, respectively.
The number of landslides in the North Fork Nooksack Basin increased considerably in the mid-1960s with similar increases in the 1970s and 1980s, then increased to a greater extent in 1991. In general, most landslides occurred within 10 years of intense timber harvest in a given area (Watts 1997), and the landslide frequency correlates well to forest practice activity both temporally and spatially. However, significant climatic events also occurred during this time and were key triggers of both natural and management-related slope instability, sediment delivery to the channel network, and sediment transport.

Potential sources of sedimentation have been documented in the Middle Fork Nooksack Basin, but specific information regarding the quantity of sediment has not been estimated. Overall, 480 landslides have been identified in the Middle Fork Nooksack Basin, and sub-basin road densities are generally high with most roads unpaved (Watts 1998). The majority of the landslides are shallow, rapid landslides (82%), and these together with the small, sporadic deep-seated slides have the highest rate of sediment delivery to streams. Roads are associated with

36% of the landslides, while clearcuts are linked to 32% (Watts 1998). The numbers of mass wasting sites that delivered sediment to streams are highest along Clearwater Creek (77 landslides), Rocky Creek (54), Porter Creek (52), the mainstem Middle Fork Nooksack River (48 events), and Canyon Lake Creek (37), and landslide density (number of events per square mile watershed) is shown in Figure 19 (Watts 1998). It is noteworthy that the Middle Fork Nooksack sub-basin has the most watersheds with the highest percentages of slope instability in the entire Nooksack Basin.

Various landslide inventories have been conducted in the South Fork Nooksack Basin encompassing the entire drainage. When totaled, there is a conservative estimate of 1216 landslides in the South Fork Basin even though the percent of slope instability appears to be lower than for the Middle and North Fork Basins. The landslides include 346 in the Skookum Creek watershed, 191 in the Acme WAU (lower South Fork), 171 in the South Fork valley from Skookum to Howard Creeks, 444 in the upper South Fork, 55 in the Hutchinson Creek watershed, and 9 additional slides not previously inventoried in the Howard Creek watershed. The landslides listed in the report by Hale (1992) are not included in this total because the same events should also be compiled in Kirtland (1995) whose geographical area was greater and included the region summarized in Hale (1992).

Landslide density is very high in the Skookum, Acme, and Wanlick WAUs (data from Hale 1992, DNR 1994; Lunetta et al. 1997, Benda and Coho 1999 draft). A moderate landslide density has been estimated in the Hutchinson WAU (data from DNR 1998). However, densities were not estimated for Howard Creek and along the South Fork Nooksack River due to a lack of readily available data. The Acme WAU includes the mainstem South Fork Nooksack River from RM 0 to 13 and all tributaries downstream of RM 10, such as Jones, McCarty, Standard, Hardscrabble, Sygitowicz, Caron, Toss, Tinling, and Black Slough (Trillium 1996). The Wanlick WAU includes all waters upstream of the confluence Wanlick Creek and the South Fork Nooksack River.

2.2.1.3. Road Network

Road density for the entire North Fork Nooksack basin is estimated at 3.1 miles of road per square mile of watershed, and this level is considered to be high (data from Zander 1997). A detailed road inventory was conducted for the basin, and resulted in prioritized areas for road improvement work, such as road abandonment, drainage, upgrades, and studies (Zander 1997). Specific sediment and streambed conditions for individual sub-basins are discussed below, beginning with the upper North Fork Nooksack sub-basin and continuing downstream.

The Middle Fork Nooksack River has a naturally high sediment yield from the Deming Glacier, but past timber harvest activities have greatly increased sediment delivery to streams (Zander 1998). In 1909, railroad logging began in the lower valley, expanding upstream within the next few decades. By the late 1930s, the transport of timber shifted to trucks, and the railroad grades were reconstructed and extended as roads into steeper terrain especially into the Porter, Clearwater, and Falls Creek watersheds. Road construction peaked in the mid-1950s, but continued at high levels to the early 1980s (Zander 1998). Numerous road failures occurred from the 1940s through the 1980s due to sidecast technology, which is no longer used in forest practices (Zander 1998). Currently, more road miles consist of inactive or abandoned roads instead of active roads, and although maintenance of these roads is specified in the new Forests and Fish Agreement, many of the inactive roads are not maintained (Zander 1998).

In the South Fork Nooksack Basin, the conversion from railroad logging to trucks began around 1940 (Zander 1996). At this time, railroad grades became reconstructed into logging roads and were extended into steeper areas of the basin. Extensive road building spanned from the mid-1950s to the early 1980s, and many of the roads used side-cast technology, which is prone to trigger landslides. Road-related failures may be initiated by a number of mechanisms. Failures may happen where the road crosses and destabilizes, or side-cast material is placed on an unstable landform, such as a colluvial hollow or inner slope above a stream. A lack of drainage structure maintenance or concentrated intercepted drainage can result in failure of the structure or a side-cast fill or in the hydraulic loading of a slope feature with a resulting landslide. Failures from these aging side-cast roads are still contributing sediment to the streams today. Areas identified at a high risk of failure due to roads are: 1) the region bounded by the South Fork Nooksack River on the west and drainage divide and Goat Mountain on the east; 2) Deer, Plumbago, and Roaring Creek watersheds, 3) Jones, McCarty, and Sygitowicz Watersheds; 4) the upper reaches of Howard, Cavanaugh, Hutchinson, and Skookum Creek Watersheds; and 5) the east facing hillside above Howard Creek (Zander 1996). These areas have been targeted for road drainage improvement and abandonment/inactivation projects to reduce the potential for road failure and sediment delivery to the stream network (Nooksack Recovery Team 2001).

2.2.2. Access

A comprehensive WRIA-wide inventory of fish passage barriers and blocked habitat is currently underway and results are anticipated by June 2005. This project will also synthesize previously collected barrier information, which have been conducted in various watersheds and jurisdictions within the Nooksack

River watershed, and calculate Priority Index (PI) numbers using WDFW SSHEAR standardized methodology. PI numbers provide a means for ranking importance of passage improvement projects based on the quantity and quality of blocked habitat and priorities of affected salmonid stocks. Priority Index (PI) numbers have already been calculated for many of the blockages identified to date. Inventory and prioritization of these fish passage barriers are presented in *Salmon and Steelhead Habitat Limiting Factors in WRIA 1* (Smith 2002).

The three most serious chinook passage problems in the Nooksack River watershed are the Middle Fork diversion dam, the Canyon Creek blockage, and the disconnection of the Lummi River. The Middle Fork Nooksack River (RM 7.2) was built in 1960 to divert water into Lake Whatcom and blocks access to an estimated 20% of the habitat formerly available to North/Middle Fork early chinook, including 9 miles of habitat in the Middle Fork Nooksack River and 5.3 miles in tributaries (Currence 2000; see more detailed description in *Hydropower Overview*). Planning and design is currently under way to provide for anadromous passage upstream of the diversion. The Canyon Creek blockage was formed in 19XX when Whatcom County built a large dike on the right bank side near RM XX to protect streamside homes from debris flow and flood damage; the channel was relocated to the left and has since downcut to bedrock and formed a partial barrier. The Lummi River is a former distributary of the Nooksack River that, due to the failure of a culvert that once conveyed some flow through the western levee along the lower river, is now disconnected from the Nooksack River except at the highest flows, thereby blocking direct access of outmigrant salmonid smolts to the Lummi River estuary and upstream migrants to the Nooksack River watershed.

Other fish passage barriers exist throughout tributaries in the Nooksack River watershed. Analysis of existing readily available data, including recent versions of the WDFW SSHEAR and Whatcom County culverts databases, indicates that few other passage barriers to chinook salmon, but numerous barriers to coho, chum, steelhead, cutthroat trout, and rainbow trout have been identified (Figure C17; Table C8). Out of a total 878 culverts, fishways, and dams inventoried, 480 of those occurred in areas with known or possible fish use, less than half (48%) of which have been evaluated for passability. Of those evaluated for passability, most (61%) have been identified as barriers. To the extent that affected species have been identified (37% of barriers), the most impacted species is coho (150 identified barriers), followed by cutthroat and rainbow trout (138), steelhead (129), and chum salmon (105). Few passage barriers have been specifically identified for chinook (5), sockeye (20) or native char (28), although bull trout impacts are likely since potential bull trout foraging and migration habitat is generally assumed to co-occur with coho habitat. Most barriers identified in the

Nooksack River watershed occur in the Lower Nooksack subbasin, although barriers have also been identified throughout the lower Forks subbasins.

2.2.3. Channel Conditions

Impacts to the stream channel encompass a variety of problems such as channel incision, a widened, aggraded channel, and unstable streambed bottom material. An incised channel is a deeply cut channel that is disconnected from the surrounding floodplain. It has lost side-channel habitat and is lacking diverse habitat features. A widened, aggraded channel is characterized by an unstable, shallow channel with an elevated streambed that can cut laterally into adjacent slopes to trigger more sedimentation. Aggraded channels also flood more easily (reduced capacity), and are more likely to experience elevated water temperatures due to a lack of depth. Unstable streambed bottom material reduces salmonid incubation survival due to deposition and scour. Channel stability impacts are usually the result of excess sedimentation, a lack of large woody debris (LWD), a degraded riparian ecosystem, an altered hydrologic regime, altered floodplain, or a combination of these conditions. It is important to distinguish that these channel condition impacts differ from the natural stream channel changes that occur during high flow events. Channel changes that result from natural processes in an unaltered channel are not considered to be a habitat degradation.

A recent study of spawning and incubation habitat characteristics assessed bed scour and fine sediment deposition (Hyatt and Rabang 2003). This report concluded that redd scour during the incubation season does appear to be a significant factor limiting the population of Nooksack early chinook. Further, scour depths varied by habitat type and the intensity of seasonal floods. Based on recovered scour chains, it was estimated that 19% of the potential redd locations scoured to a lethal depth. Results of fine sediment deposition on incubation were inconclusive due to the variance in the data.

One of the causal factors often cited for the degraded channel habitat conditions is the loss of wood from the channels. Lummi Natural Resources staff collected data on the distribution of "key-sized" wood in the forks and mainstem of the Nooksack. These efforts found greatly reduced levels of wood in the channel compared to historic accounts and general guidelines for properly functioning habitat. Loss of wood recruitment due to degraded riparian and streambank conditions accounted for much of the lack of instream wood. Wood removal efforts began in the 1880s in the Nooksack River and continued for the next 100 years (Collins and Sheikh 2004).

2.2.4. Riparian Conditions

A riparian function assessment has been completed for fish-bearing and contiguous type 4 streams less than 20% gradient in the Nooksack River watershed (Coe 2001). Using 1:12,000 scale aerial photos (federal ownership, 1991 photo year; all other ownerships, 1995 photo year), riparian condition was classified in 100-foot-wide units beyond apparent channel migration zones along both right and left banks of relevant stream segments. For each riparian condition unit, percentage canopy shading, vegetation type, vegetation size class, and vegetation density were classified. Near-term LWD recruitment potential was derived from combinations of vegetation type, size class and density, summarized by geographic area and overlain with the Whatcom County zoning coverage to analyze land-use relationships.

2.2.4.1. Large Woody Debris Recruitment Potential

Overall, large woody debris recruitment potential (LWDRP) in Nooksack River basin riparian areas is predominantly low (50%); areas characterized by moderate and high LWDRP comprised 19% and 31%, respectively, of the total study area (Figure C22; Table C9). The Mainstem Nooksack subbasin was characterized by the worst LWDRP, with 76% of the riparian area in low LWDRP. Proportions of low LWDRP within other subbasins were substantially less (32% North Fork, 34% Middle Fork, 41% South Fork). The Middle Fork and North Fork subbasins had the greatest LWDRP, as evidenced by proportions of riparian area with high LWDRP (47%, 44%, respectively).

Most (55%) of the riparian area along the North Fork Nooksack with low LWDRP occurred downstream of Maple Creek , while most with high LWDRP (70%) occurred further upstream, between Glacier and White Salmon Creeks (70%). Along the Middle Fork Nooksack LWDRP was lowest upstream of Rankin Creek (71% low LWDRP) and highest between the Mosquito Lake Road bridge and Clearwater Creek in the middle reaches, 77% high LWDRP between MLR bridge and diversion dam; 56% high LWDRP between diversion dam and Clearwater Creek. No riparian areas with high LWDRP were found along the lower South Fork Mainstem Nooksack below the Saxon Rd. bridge. Most (71%) of the high LWDRP riparian area occurred in the uppermost reaches of the South Fork (upstream of RM 24.7 bridge), near the upper limit of anadromous use for most salmonid species. There were no riparian areas with high LWDRP along the Nooksack River downstream of the South Fork confluence.

The following North Fork tributary watersheds were predominantly low: Kendall (73% low LWDRP), Hedrick (70%), Hamilton (65%), Boulder (63%), lower North Fork (62%), and Racehorse (57%). LWDRP in Glacier, White Salmon, middle North Fork, Wells, Deadhorse, Anderson, Canyon, and Swamp was predominantly high (76%, 69%, 66%, 65%, 65%, 57%, 56%, 52%, respectively).

LWDRP within Middle Fork tributary watersheds was lowest for Rankin Creek and Lower Middle Fork, where 100% and 62% of the riparian area had low LWDRP, respectively. The highest LWDRP occurred in Upper Middle Fork, Ridley and Galbraith watersheds, wherein all riparian area assessed had high LWDRP, and to a lesser extent in Green (88% high LWDRP), Warm (75%) and Clearwater Creek (69%) watersheds. In the South Fork subbasin, LWDRP was predominantly low within Saxon (69% low LWDRP), Upper South Fork Nooksack – West (65%), Black Slough (59%), Heart Lake Area (59%), and South Acme Area (54%) watersheds. High LWDRP predominated in Elbow Lake (75%), Wanlick (74%), Bell (63%), Howard (58%), Skookum (55%), and Deer, Roaring & Plumbago (51%) watersheds. For lower Nooksack tributary watersheds, all but Anderson were predominantly low in LWDRP. LWDRP was worst in Lummi Peninsula West, Scott, Fishtrap, Kamm, and Schneider watersheds, in which proportion of riparian area with low LWDRP ranged from 98 to 100% and there was no high LWDRP. LWDRP was greatest among Nooksack Deming to Everson, Anderson, Deer, and Smith watersheds; proportions ranged from 15 to 40% of area with high LWDRP and from 31 to 69% of area with low LWDRP.

LWDRP for riparian areas in agricultural, urban and rural zoning classes was predominantly low (85%, 77%, 60% of area, respectively). Low LWDRP was also most common in Rural Forest and Commercial Forest riparian areas (41%, 37%), although proportions of high LWDRP differed, comprising 42% in Commercial Forest and 22% in Rural Forest zoning classes. By contrast, most of the riparian area in the Federal Forest (69%) and Federal Park (50%) zoning classes is characterized by high LWDRP.

2.2.4.2. Stream Shading Hazard

As with LWD recruitment potential, the stream shading function of riparian areas is also degraded. Stream shading hazard in riparian areas of Nooksack River tributaries basin[11] is predominantly either high (35%) or moderate (28%); only 24% of the riparian area is above target shade levels (Figure C23; Table C9). Mainstem Nooksack tributary riparian areas were characterized by predominantly high hazard for stream shading (77%), with only 3% above target shade levels. Relative stream shading hazard varied little among the North, Middle and South Fork subbasins, ranging from 11-16% with high hazard for stream shading, 31 to 38% with moderate, 18 to 19% with low, and 32 to 39% above target.

Among North Fork tributary watersheds, several were predominantly above target shade levels: Swamp and Upper North Fork (96%), White Salmon (90%), Anderson (71%), Bagley (68%), Middle North Fork (60%), Hedrick and Canyon (59%), and Wells (58%). While none were dominated by high hazard for stream shading, the following were predominantly high and moderate: Boulder (89%), Lower North Fork (89%), Coal (87%), Kendall (67%), Hamilton (66%), Maple (61%), Slide Mountain (58%), Bells (57%), and Racehorse (56%). The following Middle Fork tributary watersheds were predominantly above target shade levels: Galbraith, Warm, Green, and Upper Middle Fork (100% each); Rankin (82%); and Middle Fork Diversion (63%). Only one watershed, Lower Middle Fork, was predominantly (51%) high hazard for stream shading, although several were predominantly high and moderate: Porter (100%), Canyon Lake (94%), Heislers (76%), and Sisters (64%). In the South Fork, Saxon was predominantly high (69%), Deer, Roaring & Plumbago and Lower South Fork predominantly moderate (58-59%), and Edfro, Bell, Cavanaugh, Elbow Lake, Howard, and Wanlick predominantly above target shade levels (51-65%). All but three mainstem Nooksack River watersheds were predominantly high, especially Scott (100% high hazard), Kamm (98%), Wiser Lake/Cougar Creek (96%), Lummi Peninsula (95%), Schneider (94%), Tenmile (93%), and Nooksack River Delta (88%). The three with riparian area above target shade levels were Nooksack Deming to Everson tributaries (39% above target shade levels), Smith (15%), and Anderson (2%); most of the remaining riparian area, however, was characterized by either high or moderate stream shading hazard (47%, 70%, and 96%, respectively).

Stream shading hazard for riparian areas in agricultural, urban and rural zoning classes was predominantly high (85%, 73%, 65% of area, respectively), with less than 1 to 4% above target. By contrast, riparian areas in federal park zoning class were predominantly above target (70%); none had high hazard for stream shading. Stream shading hazard generally decreased from rural forest to commercial forest to federal forest zoning classes, with 80%, 52%, 35%, respectively, in high and moderate hazard and 20%, 48%, and 65% in low hazard or above target for stream shading. To some degree, these patterns were influenced by the distribution of zoning classes throughout the watershed (i.e. agricultural zoning class concentrated in lower elevations where target shade levels are higher).

2.2.5. Floodplain Conditions

Historical Conditions[7]

Historically, the greater Nooksack delta (including the Lummi and Nooksack rivers) included extensive estuarine and riverine-tidal freshwater wetlands (Figure C18a), primarily on the Lummi River side, which had been the dominant outlet to saltwater until the mid 1800s. Upstream of the delta, glacial processes created distinctly different valley topography in different parts of the study area,

[7] Excerpted from: *Historical riverine dynamics and habitats of the Nooksack River.* Final Report to the Nooksack Indian Tribe, Natural Resources Department, Deming, WA. Report by B.D. Collins and A.J. Sheikh, Dept. of Earth and Space Sciences, University of Washington, Seattle, WA. August 2004.

which in turn influenced the river morphology and valley landforms. Upstream of the delta, in the lower mainstem (to about Everson), the influence of a Pleistocene glaciation resulted in a broad, low-gradient valley. Holocene (post-glacial) deposition by the Nooksack River built up the river and its meander belt by typically 3-4 m above the valley bottom. Extensive wetlands (primarily with scrub-shrub vegetation and having numerous beaver dams) occupied low areas marginal to the meander belt (Figure C18a). Upstream of Everson (Figure C18b) and in the Forks, the valley narrows and steepens, and is associated with multiple channels, sloughs, and islands. The channel had a branching or "anastomosing" pattern, with multiple channels and sloughs, and forested islands. The lower South Fork also had an extensive system of wetlands, small channels and ponds in the Black Slough area.

The pre-Euro-American-settlement forest, according to GLO field notes, was dominated by hardwoods, most commonly red alder *(Alnus rubra)*. Western redcedar *(Thuja plicata),* while only one-fourth as common as alder, was the most common conifer, and also the largest tree. Among conifers, Sitka spruce *(Picea sitchensis*) grew in the lowest elevations, and western hemlock *(Tsuga hetero-phylla)* the highest. Among hardwoods, Pacific crabapple (*Malus fusca*), willow (*Salix* spp.) and birch *(Betula papyrifera)* grew in lower elevations, black cottonwood *(Populus trichocarpa)* in moderate elevations, and alder at all elevations. In the delta, red alder was the most common-streamside tree, but Sitka spruce was the only large-diameter tree and by far the dominant conifer by basal area. Small willow, crabapple, and alder dominated scrub-shrub estuarine wetlands, with Sitka spruce the only large tree; riverine-tidal wetlands were similar, with addition of western redcedar. In the lower mainstem, black cottonwood joined Sitka spruce as the most common large-diameter streamside trees, with western redcedar being the largest tree more distant from the riverbanks. In the upper mainstem and forks, alder was the most common streamside tree, with cedar the largest. Douglas fir *(Pseudotsuga menziesii)* and cedar were the largest trees in the red-alder-dominated forest distant from the river.

Wood jams were historically abundant and had a variety of geomorphic and habitat functions in the Nooksack, such as creating pools, causing avulsions and flow splits, and routing water and sediment at the valley scale. Species composition of logs in wood jams likely reflected not only local wood recruitment but upstream sources of large wood as well. The GLO bearing tree data indicate that the species that would have provided very large wood to rivers, and potentially function as key pieces in jams, would have been limited to Sitka spruce on the delta. In the lower mainstem, black cottonwood would have augmented spruce, and in the upper mainstem, cedar would have been the most common potentially-recruitable key piece, and secondarily spruce, fir, and cottonwood. In the forks, cedar and fir would have been the most commonly available large wood, and secondarily cottonwood and maple.

Changes to Historical Conditions[8]

The Nooksack valley's forests and wetlands were transformed within the first few decades of Euro-American settlement (Figure C19a, Figure C19b). Most of the native forest had been burned or logged by the beginning of the 20th century, and most wetlands, especially estuarine and riverine-tidal wetlands formerly extensive on the Lummi River delta, and historically extensive palustrine wetlands in the lower mainstem, had been diked and ditched. In the delta and lower mainstem, these burned or logged lands were almost entirely converted to agriculture by 1938, while in the upper mainstem and forks, some of this burned or logged land was converted to agriculture and the remainder returned to forest.

Early in the 20th century, dikes closed off deltaic distributary and blind-tidal channels from water influx. In the lower mainstem to RM 24, meanders were cut off, diminishing the Nooksack River's length; tributary creeks were ditched and log jams were removed. Between ~1880 and the 1930s, the upper mainstem and much of the forks (Figure C19b) were transformed from an anastomosing channel to a much wider, braided channel, with extensive gravel bars, coincident in time with the logging of the streamside forests. The channel in most cases has narrowed since, although remaining wider than in ~1880; in the North and Middle Forks, the widening trend has continued throughout the period of record.

Quantitative estimates of summer- and winter-inundation of wetlands made primarily from GLO field notes for ~1880 conditions indicate that winter-inundated freshwater wetland historically exceeded the total freshwater bankfull channel area and summer-inundated area was nearly as great as bankfull channel area. Comparing ~1880 and 1998 mapping (Figure C20) indicate that winter inundated freshwater wetland in 1998 was about 5% of that in ~1880, and summer inundated freshwater wetland was about 1% that of the ~1880 estimate. Estuarine wetland area in 1998 was about 30% that in 1880; this reflects substantial loss in estuarine wetland on the Lummi River delta from diking, but also substantial increase in wetland area on the Nooksack River delta from deltaic progradation.

[8] Excerpted from *Historical riverine dynamics and habitats of the Nooksack River.* Final Report to the Nooksack Indian Tribe, Natural Resources Department, Deming, WA. Report by B.D. Collins and A.J. Sheikh, Dept. of Earth and Space Sciences, University of Washington, Seattle, WA. August 2004.

Constraints on Channel Migration

Field surveys of bank hardening and levees[9] have documented over 63 miles of hydromodification through the lower South Fork (to RM 13.5) and mainstem Nooksack Rivers (Figure C21), or hydromodification of approximately 63% of river length (NNR, unpublished data). Downstream of Everson, virtually the entire mainstem Nooksack River is leveed and/or riprapped, whereas upstream only about 20% hydromodification of river length is evident from field surveys. Over one-third (35%) of the lower South Fork has been hydromodified.

Using the mapped floodplain area (Collins and Sheikh, in prep.) as a foundation, along with field surveys of hydromodifications and knowledge of infrastructure, a coarse-scale analysis of constraints to channel migration has been conducted along the Nooksack River and unconstrained reaches of the Forks (Figure C21). This is not a rigorous geomorphic or hydraulic analysis of channel-floodplain interaction, but provides an index of the extent of floodplain process impairment. Most (62%) of the total 3.03km^2 of historical floodplain in the Nooksack River and lower Forks is currently unavailable for channel migration. Most impaired is the mainstem Nooksack River (74% of area unavailable), followed by the lower South Fork (61%), North Fork (41%), and Middle Fork (36%). Downstream of Everson, a full 86% of the historic floodplain is unavailable for channel migration, even when the Nooksack/Lummi delta is excluded. Given that this reach of the Nooksack River was historically meandering and channel locations were relatively stable over recent geologic time (Collins and Sheikh, in process), these figures likely overestimate the area of floodplain needed for channel/floodplain function. Nonetheless, the extent of confinement is clear.

Constraints to channel migration in the Nooksack River valley include existing land uses and infrastructure, including the transportation network. Transportation network density in the historic floodplain (Figure C21) is highest in the lower South Fork (93km/km^2), followed by the lower Mainstem (73 km/km^2), lower Middle Fork (34 km/km^2) and lower North Fork (13km/km^2). Total road and railroad lengths in the historic floodplain are greatest in the lower Mainstem (113 km) and South Fork (55 km) and low in the North (7.3 km) and Middle Forks (8.9 km).

2.2.6. Water Quantity[10]

2.2.6.1. Low Flows

The North and Middle Fork Nooksack river watersheds are glacial-dominated systems, with high flows during spring and early summer due to snowmelt and

[9] Field surveys may fail to notice hydromodification, especially older projects, and thus may underestimate the total length.

[10] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

sustained flows through summer and fall due to glacial runoff. Peak flows can also occur in fall and early winter due to heavy rain or rain-on-snow events. Lower flows occur in the late fall and winter when cold temperatures prevent glacial melt (DOE 1995), which can lead to dewatering of redds, especially in side channels (Doug Huddle, personal communication).

Many of the streams within the North Fork subbasin are closed to further water allocations. Year-round closures exist for White Salmon, Kendall, and Bell Creeks, while partial-year closures include the North Fork Nooksack mainstem River and Canyon, Thompson, Gallop, Cornell, Maple, and Racehorse Creeks (DOE 1995). In the Middle Fork subbasin, Porter and Canyon Lake Creeks are also closed to further water allocations in the low flow period (DOE 1995).

The South Fork Nooksack River has a large runoff in fall and early winter with a second high flow period in late spring due to snowmelt (DOE 1995). The low flow period spans from late summer through early fall. Low stream flows are a major concern in the South Fork Nooksack sub-basin. The South Fork Nooksack River mainstem is on the 303(d) list for low instream flows (DOE 2000). Deficient stream flows also affect critically warm summer and fall water temperatures and the lack of pool habitat. The South Fork Nooksack River and Hutchinson and Skookum Creeks are closed to further water allocations during late summer and early fall (DOE 1995).

The average annual rainfall in the lower Nooksack Basin ranges from 35 to 45" (Figure C2), with 70% falling between the months of October through March (U.S. Dept. Agriculture Soil Conservation Service 1993). This results in low stream flows in the summer months, especially in the tributaries. These flows are worsened by the reduction in wetlands, mature forest, and channel complexity that would normally allow some water storage and recharge. In addition, both surface and ground water withdrawals are numerous and further impact low stream flow conditions. Ground water withdrawals are considered to degrade salmonid habitat because the shallow aquifer in the region contributes significant water to streams in the summer months (Erickson et al. 1995). Many of the streams in the Nooksack Basin are closed to further water allocations, at least during the summer and early fall. Streams closed to further water withdrawals during the low flow months include (DOE 1995): Silver, Wiser Lake, Tenmile, Deer, Fishtrap, Bertrand, Kamm, Smith, and Anderson Creeks. Bertrand and Fishtrap Creeks are on the 303(d) List for low instream flows (DOE 2000). This area has a very dense quantity of surface and ground water rights primarily for agricultural purposes. It is also estimated that perhaps as high as 50 percent of agricultural uses are unpermitted. In this region, irrigation has increased 380% from the late 1950s to the mid-1980s (Whatcom Conservation District 1986), and Tenmile Creek has had 87.5 cfs appropriated with a minimum base flow of 5 cfs

(U.S. Dept. Agriculture Soil Conservation Service 1993). Historically, water storage occurred in the numerous wetlands in this area (U.S. Dept. Agriculture Soil Conservation Service 1993). However, drainage and stream channelization has been extensive, particularly in Bertrand, Fishtrap and Kamm Creeks, and this has reduced water storage capacity (Whatcom Conservation District 1988a).

2.2.6.2. Peak Flows

Changes in the hydrological regime that are typical of forested uplands with forest management are expected of the North and Middle Fork subbasins, as well as the mid to upper South Fork subbasins. Changes to forest cover that reduce hydrological maturity, especially in peak rain-on-snow zones (Figure C2), as well as road-building that effectively extends the channel network, can accelerate runoff delivery to streams, thereby increasing peak flows, bed scour, and channel instability. The mainstem North Fork Nooksack River generally responds to large flood events, while the tributaries are more sensitive to smaller storms and disturbances (U.S. Forest Service 1995a). Rain-on-snow events are common from late October through January, and they often trigger debris-laden floods in tributary watersheds, especially in those disturbed by timber harvest and roads. Most of the clearcuts and road-building has occurred in the privately owned lands. Because of the timber harvest and road construction on steep slopes and associated mass wasting, high flow events that trigger channel changes are a major concern for salmonids that spawn in the mainstem North Fork Nooksack River. The extent of the impacts varies with location. In the upper Nooksack sub-basin (upstream of the confluence with Canyon Creek), 17% of the land contains 16,000 acres of clear-cut and 900 acres of roads and much of this is on the private lands in the lower portion of this sub-basin (U.S. Forest Service 1995a).

In examining flow trend data, no trends were noted over time for frequency or magnitude of peak flows from 1937 through 1991 in the upper North Fork Nooksack River (U.S. Forest Service 1995a). The upper North Fork Nooksack sub-basin has naturally limited water storage capabilities and high runoff rates due to the steep landforms, porous soils, and large areas of non-forested land (bare rock and snow and ice fields). Because of this, clear water tributaries and groundwater fed side-channels provide important flood refuge habitat for salmonids in the North Fork Nooksack sub-basin. Glacier Creek is very sensitive to rain-on-snow events due to its elevation, resulting in landslides that block channels, causing debris torrents or dam break floods in confined channels (U.S. Forest Service 1995a). Hydrological conditions are likely impaired due to hydrological immaturity of forest cover in: (1) North Fork: lower Canyon, West Slide, Aldrich, Big Slide, Wildcat, Hedrick, West Cornell, Cornell, Gallop, and Kenny Creeks; (2) Middle Fork: lower Middle Fork, Clearwater Creek; (3) South Fork: Hutchinson Creek, Skookum Creek; Howard Creek (data from DNR 1995). Impervious surfaces are less than 3% throughout the North Fork, Middle Fork, and South Fork subbasins (data from Whatcom Conservation District maps, unpublished data, 2000).

There have been extensive changes in land cover in the lower South Fork and Nooksack River watersheds that may contribute to increases in peak flows. The extensive floodplain forests of the Nooksack River lowlands have largely been converted to agriculture, wetlands have been drained and tributaries channelized and straightened (Collins & Sheikh 2004). The loss of mature forest can increase the rate of water entering the streams because mature forests can temporarily capture 24 to 35% of the precipitation (Dingman 1994). Impervious surfaces, ditching, channel straightening, and loss of wetlands in the lowlands and dense road drainage networks in the forested uplands also accelerate runoff delivery to streams. Impervious surface estimates are low relative to the independent coastal tributaries, at >3% for much of the Lower Nooksack subbasin, with elevated percentages (3-10%) for Wiser Lake, Deer Creek, and Scott Ditch watersheds where more urbanization has occurred (data from Whatcom Conservation District maps, unpublished data, 2000).

2.2.6.3. Other Changes to Hydrology

The Middle Fork diversion dam at RM 7.2 occasionally diverts surface water from the Middle Fork Nooksack River to Lake Whatcom for the City of Bellingham's water supply. In the past, up to 80% of the summer water input to Lake Whatcom originated from the Middle Fork Nooksack River (Walker 1995). However beginning in 1998, the amount of water diverted from the Middle Fork Nooksack River has been reduced to help maintain instream flows in the Middle Fork (Matthews et al. 2001).

The flow through the Lummi River has also been severely altered. Historically, much of the Nooksack River flowed through the Lummi River to empty into Lummi Bay (People for Puget Sound 1997). However, in the late 1880s, a diversion was constructed to permanently reroute the Nooksack River to empty into Bellingham Bay. Currently, the Lummi River serves as an overflow channel for the Nooksack River during high flows.

2.2.7. Water Quality[11]

North and Middle Fork subbasins

Warm water temperatures are the greatest water quality concern in the upper Nooksack River watershed. Water temperatures in the upper North Fork are

[11] Excerpted from: (1) South Fork: *South Fork Nooksack River Acme-Saxon Reach Restoration Planning: Analysis of Existing Information and Preliminary Recommendations*. Lummi Natural Resources and Nooksack Natural Resources. November 26, 2002. (2) Others (with edits and incorporation of additional information): *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

generally cool due to the glacial influence and functional riparian areas, with average daily maximum temperatures are 11.3°C at RM 63.2 near Glacier Creek (data from USGS 2001). The lower North Fork Nooksack River (RM 41.6) is warmer with a peak high of 17°C in 1996 and 39% of the July and August samples exceeding 16°C (data from USGS 2001). Further downstream (RM 37.2), 59% of the samples in July and August of 1996 exceeded 16°C. Temperatures are substantially warmer in tributaries to the North Fork. Racehorse, Lower Boulder, Gallop, Canyon, and Cornell Creeks are on the 303(d) List for warm water temperatures (DOE 2000). In Racehorse Creek, 71% of the samples exceeded 20°C, and there was a peak high of 24°C (data from Neff 1992). Water temperatures as high as 22.5°C and 21°C have been recorded in Cornell and Gallop Creeks, respectively (U.S. Forest Service 1995a). Peak high temperatures were 16.9°C in Hedrick and Kenney Creeks in 1996 (USGS 2001). Generally better water quality conditions are found in the upper reaches of streams whose lower reaches have been degraded by human activities.

Water temperatures were measured in the mainstem Middle Fork Nooksack River near RM 4.8 in 1996 (USGS 2001), and most (80%) of the temperature samples were less than 14°C. However in 1992, water temperatures in the mainstem Middle Fork near the mouth of Canyon Lake Creek peaked at 17.5°C, and 44% of the samples were warmer than 16°C (data from Neff 1992). Upstream of the Porter Creek confluence, the mainstem Middle Fork temperatures were cooler with a peak of 16.4°C (data from Neff 1992). Canyon Lake Creek, a tributary to the Middle Fork, is on the 303 (d) List for warm water temperatures (DOE 2000). Peak temperatures in 1992 were 22.5°C and 92% of the were warmer than 16°C (Neff 1992).

South Fork subbasin

Warm water temperatures are a critical problem for salmonids in the South Fork Nooksack River, which is on the 303(d) List for warm water temperatures (DOE 2000). Recently, summer temperatures in the South Fork have regularly exceeded water quality standards (WQS) of 18°C for downstream of Skookum Creek (Class A) and 16°C for upstream of Skookum Creek (Class AA) (Chapter 173-201A Washington Administrative code; 11/18/97). During August 1985, daily temperature maxima in a holding pool at river mile (RM) 14.7 ranged from 16.9°C to 19.2°C, and minima remained above 16.1°C (Doughty 1987). In August 1986, Schuett-Hames et al. (1988a, as cited in Neff 1993) recorded a maximum water temperature of 21.7°C at RM 18.45. In August 1990, Sullivan et al. (1990, as cited in Neff 1993) recorded a maximum water temperature of 19.1°C. Neff (1993) reported that, in summer 1992, the South Fork (RM 19) exceeded WQS on 29 of 31 of the days monitored; on 12 of these days (3 occasions of 4 days each), daily minima even exceeded WQS. Maximum temperature recorded for the South Fork (RM 19) in 1992 was 24°C. During 1993, a maximum/minimum thermometer placed at the Acme bridge recorded excursions from WQS on 5 of 7 days (Lummi Natural Resources, unpublished data). Of 6 instantaneous measurements taken in the South Fork between 7/19/94 and 8/17/94, 5 exceeded WQS. Temperatures measured at four locations from Acme Bridge to Larson's Bridge in the South Fork during 1995 (7/20/95 to 9/18/95) indicated exceedances of at least 1 day; maximum temperatures were 21.8°C at Saxon Bridge (8/3), 18.3°C at Acme Bridge (7/20), 17.8°C at Larson's Bridge (9/18), and 17.8° at New Bridge (9/18) (Shull 1996). From continuously recording thermographs deployed in the South Fork near Potter Road Bridge from 7/17/96 to 7/31/96, 37% of the temperature measurements exceeded the WQS (LNR unpublished data, cited in USU's WRIA 1 Surface Water Quality Data Collection and Assessment, Phase II Summary Report (Preliminary Draft)). Similarly, temperatures exceeded WQS at 3 sites along the South Fork (near Hutchinson and McCarty Creeks and at Potter Road bridge) in 1998. Indeed, South Fork temperatures exceeded 18°C on 30 days during the summer of 1998, with a peak temperature above 22°C; these data underestimate temperature degradation in the reach, given that thermographs were deployed 8/15/98 to 9/21/98 (Soicher 2000). From 8/5/99 to 9/21/99, South Fork temperature exceeded WQS for 8 days, with a max recorded temperature of 19.4°C (Soicher 2000). Finally, in 2001, maximum temperatures ranged from 20.3° to 22.3°C, with exceedances on from 18 to 42 days, at all 11 sites sampled in the South Fork from the confluence to RM 20.7, with the exception of the site at RM 13.9, downstream of Skookum Creek (no exceedance, max temp 17.6°C; Nooksack Natural Resources, unpublished data).

Continuous longitudinal temperature profiles (Figure C25) were created from surface temperature data obtained during an overflight of the South Fork and lower Nooksack Rivers on 8/20/01, using a thermal infrared sensor mounted on a helicopter, along with a visible band color video camera to aid in interpretation. Near the wilderness boundary (river mile 38.8), water temperatures in the SF Nooksack River were relatively cool at 9.7oC. From river mile 38.8 to 37.0, stream temperatures remained consistently near 9.7oC (±0.3oC). Five surface water inputs were sampled within this 1.8-mile segment and each contributed water that was cooler than the mainstem. Stream temperatures increased to 11.9oC between river miles 37.0 and 35.5 before showing an apparent decrease (1.0oC) at river mile 34.4. A spring at river mile 34.6 contributed to the observed decrease in mainstem temperatures. Downstream of river mile 34.4, water temperatures warmed more rapidly reaching a local maximum of 15.1oC at river mile 31.0. Wanlick Creek, an unidentified tributary, and the outflow of Three Lakes Creek were sampled through this reach and each contributed water that was cooler than the main stem. However, these inputs did not have a detectable influence on the observed warming trend. Four apparent springs were detected between river mile 31.2 and 30.7; these springs were not documented on the USGS 7.5' topographic map, but likely contribute to the slight decrease in mainstem temperatures observed between river mile 31.1 and 30.3. At river mile 30.3, a tributary originating from Bear Lake, directly lowered water temperatures in the South Fork by 1.0oC.

Downstream of the Bear Lake inflow, water temperatures in the South Fork increased steadily from 13.4oC at river mile 30.3 to 16.3oC at river mile 25.7. Howard Creek (12.9oC) at river mile 27.3 was the only tributary sampled through this reach and contributes cooler water to the South Fork. Moving downstream, water temperatures remained consistently near 16.4oC (±0.4oC) over the next four miles (river mile 25.7 to 21.7) and no tributaries or other surface water inflows were sampled through this reach. From river mile 21.7, stream temperatures increase steadily reaching a local maximum of 18.7oC at river mile 17.3. Plumbago Creek, Deer/Roaring Creek and an unidentified tributary enter the South Fork through this reach, but did not have a detectable impact on the prevailing temperature trend. Between river miles 16.0 and 13.1, stream temperatures decreased from 18.6oC to 15.9oC. Five surface water inputs were sampled through this reach, which contributed to the observed cooling trend. However, since three of the inflows occurred between river mile 13.5 and 13.1, the overall trend cannot be attributed entirely to tributary influence. Since this reach is located within relatively confined Dye's canyon, terrain may play a role in defining the temperature pattern.

Moving downstream from Skookum Creek at river mile 13.5, water temperatures in the South Fork increased steadily to river mile 8.2 (15.9°C to 18.6°C) and continued to increase, reaching 19.1°C at river mile 7.4. Between river miles 7.4 and 4.0, sampled temperatures remained consistently near 18.8°C (±0.4°C). An apparent temperature drop (1.0oC) was observed from river mile 4.0 to 3.4 before stream temperatures increased again to 19.5°C.

Soicher (2000) measured instantaneous turbidity at various locations during 1998 and 1999, including the South, Middle and North Forks, as well as tributaries to the South Fork. The lower South Fork (Potter Rd. Bridge) had the highest measured turbidity, at 632 nephelometric turbidity units (NTU), whereas maximum turbidity in the glacially turbid North and Middle Forks were 66 NTU and 36 NTU, respectively. Minimum and mean turbidity levels among forks were comparable, at 0.2 NTU (SF, Potter Rd. Bridge) to 1.0 NTU (NF) and 6.8 (NF) to 9.5 NTU (SF, Acme bridge), respectively. In most cases, South Fork turbidity exceeded that of either Middle or North Forks, often significantly. Turbidity levels in the mainstem river sites responded dramatically during storms. In the South Fork, during a storm in November 1998, turbidity fluctuated from 951 NTU to 99 NTU to >1000 NTU. In the South Fork at the Acme bridge in 1999, turbidities were 1.5 to 74.8 NTU (19.3 NTU mean) and 2.5 to 13.1 NTU (6.1

NTU mean) during fry emergence (February through May) and adult holding and upstream migration (June through September), respectively. Anecdotal observations indicate high turbidities, which limit spawn and snorkel surveying, can persist in the South Fork through mid to late summer.

Lower Watershed

The lower Nooksack River and tributaries thereto exhibit degraded conditions for numerous water quality parameters. Problems with ammonia, phosphorous, dissolved oxygen, and fecal coliform levels are common, as well as violations in pH and water temperatures. Agriculture, failing septic systems, and urban stormwater runoff are major causes (DOE 1995), particularly because Whatcom County has the highest concentration of dairy farms in Washington State (Dickes 1992). Groundwater contamination is a concern, given the close hydrologic connectivity between surface and ground water within the Nooksack River watershed (Erickson et al. 1995). Elevated levels of pesticides, nitrates, and volatile organics (1,2 dichloropropane and ethylene dibromide) have been found in the Abbotsford-Sumas Aquifer, which underlies the Fraser and Nooksack valleys. Overall, groundwater contamination (solvents, degreasers, pesticides, and fumigants) has been documented at 25 sites and suspected at another 26 sites (DOE 1995).

Compared to other rivers in the Puget Sound region, the Nooksack River near Ferndale has among the highest levels of nitrogen (including ammonia and nitrate), phosphorous, turbidity, and suspended solids (DOE 1995). Using data from 1988-1993, the Nooksack River basin had the highest animal manure application rates (5.3 tons N[12] per square mile per year, 0.9 tons P[13] per square mile per year), the second highest agricultural fertilizer rates (3.0 tons N $\cdot mi^{-2} \cdot yr^{-1}$; 0.33 tons P $\cdot mi^{-2} \cdot yr^{-1}$), and the fourth highest nutrient yield (1.8 tons IN[14] $\cdot mi^{-2} \cdot yr^{-1}$; 0.3 tons P $\cdot mi^{-2} \cdot yr^{-1}$) among sixteen Puget Sound river basins (Inkpen and Embrey 1998). From 1979 to 1991, turbidity has increased between 1 to 2% per year in the lower mainstem Nooksack River (Erickson et al. 1995). Scott and McDowell (1994) report that the lower Nooksack River has elevated levels of metals and fecal coliform due to agriculture, highway runoff, surface mining, and solid waste disposal. Industrial and commercial activities have increased concentrations of heavy metals and toxins, including phenol, mercury, phthalates, pentachlorophenol, metholphenol, benzoic acid, chlordane, copper, PAHs, lead, and zinc (DOE 1995). Further, effluent from three wastewater treatments plants has been found to have concentrations of toxic constituents above detectable levels: (1) Everson: ammonia (0.26 mg/L), chloride (52 mg/L),

[12] Total nitrogen.
[13] Total phosphorus.
[14] Inorganic nitrogen.

aluminum (0.076 mg/L), boron (0.22 mg/L), iron (0.12 mg/L), manganese (0.01 mg/L), oil/grease (3 mg/L), surfactants (512 mg/L), di-n-butylphthalanate (35 ug/L; reporting limit=10 ug/L), and bis(2- ethylhexyl)phthalate (2.8 ug/L; reporting limit = 10 ug/L) (data from Bruce Barbour, Dept. Ecology). In addition, organochlorine pesticides and PCBs have been detected, such as delta-BHC (0.032 ug/L; reporting limit = 0.011 ug/L), gamma-BHC (0.061; reporting limit = 0.011 ug/L) (data from Bruce Barbour, WA Department of Ecology, personal communication); (2) Lynden: arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc (Bruce Barbour, WA Department of Ecology, personal communication); (3) Ferndale: chloride, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, silver, and zinc are above detection limits (Bruce Barbour, Dept. of Ecology, personal communication).

Warm water temperatures are evident in the mainstem Nooksack River

Water temperatures in the Nooksack River near North Cedarville (RM 30.9) were warmer than 16$_{o}$C for 54% of the samples in 1996 and 1997 (data from USGS 2001). Conditions worsen downstream near Everson (RM 23.2) where 65% of the samples are warmer than 16$_{o}$C, and the peak temperature was 19$_{o}$C. Near the mouth (RM 3.4), 60% of the samples were warmer than 16$_{o}$C in July and August of 1996 and 1997 (data from USGS 2001). The FLIR overflight described above for the South Fork also continued downstream to the Nooksack River. At the South Fork confluence (mainstem river mile 36.0), water temperatures in the Nooksack River were 14.6oC. The South Fork was considerably warmer at 18.6oC resulting in mainstem temperatures of 15.5oC downstream of the visible mixing zone. From the forks downstream, stream temperatures showed a steady decrease reaching 13.1oC at river mile 29.3, which was located roughly 1.0 mile downstream of Nugent's Corner. Stream temperatures remained relatively constant, 13.5°C (±0.4oC), over the next 18.5 river miles to river mile 11.1. Bertrand Creek and Stickney Slough were sampled through this reach and each had surface water warmer than the main stem. However, neither inflow had a detectable (i.e. >0.5oC) influence on the observed temperature patterns in the Nooksack River. Stream temperatures increased to 15.4oC from river miles 11.1 to the mouth of the Nooksack River.

Water quality conditions in the lower Nooksack River tributaries are characterized by generally high temperatures, low dissolved oxygen, and elevated levels of ammonia and fecal coliform. Anderson, Bertrand and Deer Creeks, Kamm/Stickney slough, Mormon Ditch, and Silver Creek are 303-d listed for dissolved oxygen; Deer Creek, Kamm/Stickney slough, and Mormon Ditch are also 303d-listed for pH. Severe water quality problems in the Bertrand and Fishtrap Creek watersheds have resulted in fish kills (Scott and McDowell 1994; Hardy et al. 2001 draft). The herbicides 2,4-D", Atrazine, Bromacil, DCPA, Dichlobenil, MCPP, and Simazine and the fungicide Pentachlorophenol have all been detected in Fishtrap Creek, albeit at levels below existing State or Federal freshwater aquatic life criteria; all are generally associated with agricultural uses (Bortleson and Davis 1997). Pesticides have also been detected in Fishtrap Creek streambed sediments (Whatcom Conservation District 1988a; Scott and McDowell 1994). In the early 1980s, high ammonia and phosphorus levels were measured in Kamm Creek, conditions, which can promote an algal bloom that deplete dissolved oxygen levels (Whatcom Conservation District 1986).

High water temperatures have been documented in Bertrand, Fishtrap, Schell, Silver, Fourmile, Anderson and Smith Creeks. Low dissolved oxygen (as low as 3 mg/L in Duffner Ditch, a tributary to Bertrand Creek.) levels have been documented in the Bertrand, Tenmile, Kamm, Silver Creek watersheds. Potentially toxic levels of ammonia were measured in the Duffner Ditch drainage (Dickes 1992).

2.3. Independent Coastal Tributaries Watershed Conditions

2.3.1. Watershed Conditions

The Coastal region encompasses 623 km^2 (241 mi^2), divided among the Drayton Harbor (24%), Birch Bay (10%), Georgia Strait (4.2%), Bellingham Bay (47%), West Bellingham Bay (5.8%), and Samish Bay (8.8%) subbasins (Figure C1, Table C4). Tributary watersheds in the Drayton Harbor, Birch Bay and Georgia Strait subbasins are lowland systems, with elevations ranging from sea level to 117 m (384 ft) and landscape slope predominantly low (Figure C5; Table C4). Relatively more mountainous are the upper ends of Bellingham Bay tributary watersheds , much of Samish Bay watersheds (maximum elevation 702 m, 2303 ft), and parts of Lummi Island, with maximum elevations of 1029 m (3376 ft), 702 m (2303 ft), and 507 m (1663 feet), respectively. Landscape slope in these subbasins are nonetheless predominantly (67%-75%) low.

Land use/land cover in the Coastal region (Figure C3; Table C2) is predominantly Forested Upland (56%), followed by Developed (15%); Herbaceous Planted/ Cultivated (18%); Water (4.2%); Shrubland/Non-natural woody/Herbaceous Upland (2.9%); Dairy (2.9%); Barren (1.3%); and Wetlands classes (0.52%; Figure C3; Table C2). Proportions of subbasins in the Forested Upland classes is greatest for West Bellingham Bay (79%), Samish Bay (74%), and Bellingham Bay (63%) subbasins. Proportion of land in Developed classes is greatest in Bellingham Bay subbasin (20%) and lowest in Samish Bay subbasin (2.5%). Most of the Dairy class is concentrated in the eastern Drayton Harbor subbasin, where it comprises 11% of the land use/land cover. Agriculture (i.e. Herbaceous Planted/Cultivated) classes comprise over a third of land cover in the Drayton Harbor (37%) and Birch Bay (35%) subbasins, and less (21%) in Georgia Strait and Samish Bay subbasins (16%). Within forested lands of the Coastal region (Figure C6; Table C4), most (68%) have less than 10% coniferous crown cover, and very little (1%) is in late seral stage. About 40% of Bellingham Bay, West Bellingham Bay and Samish Bay subbasins have at least 10% coniferous crown cover, with highest proportions of mid-seral stage (32%) in West Bellingham Bay.

Road density for the Drayton (includes Dakota and California Creeks) and Birch Bay (includes Terrell creek WAUs is estimated at 3.6 and 3.3 miles of roads per square mile of watershed, respectively (data from Lunetta et al. 1997). Other indications of sediment impacts include noted erosion from cropland, road construction, and livestock access in the uplands of the Dakota Creek watershed (Whatcom Conservation District 1988b).

In the tributaries to Lake Whatcom, surface erosion is relatively minor compared to landslide impacts, and most of the landslides are associated with timber harvest on steep slopes or with roads (DNR 1997). Clearcuts less than 20 years old account for 27% of the identified landslides in the watershed while 31% are associated with roads and road/stream crossings (DNR 1997). Geographically, landslides are common in upper Olson, Blue Canyon, Smith, and Austin Creeks. In Anderson Creek, increased sediments have been introduced through the diversion of the glacial Middle Fork Nooksack River. The amount of water diverted into Anderson Creek has decreased recently, and if the reduction is maintained, the input of fine sediments should be reduced.

The Lake Whatcom WAU has 281 miles of roads; 63% are residential and 56% are paved (DNR 1997). Even though paved roads usually produce less sediment, many of these roads have ditches or storm drains that deliver sediment directly to streams. Significant road sediment problems (>100% over background sediment levels) are found in the Beaver, Carpenter, and Squalicum watersheds while moderate (a 50-100% increase over background levels) problems occur in the Brannian and Geneva watersheds. The types of road/sediment problems include: a high road density, inadequate culverts, poorly drained roads, road surfaces with highly erodible native rock, roads that parallel streams, and recreational use of native surface roads (DNR 1997). Several of the tributaries to Lake Whatcom have experienced channel impacts. A large dam-break flood occurred in Olson Creek after extensive logging, which resulted in scour and channel instability (DNR 1997). In Smith Creek, numerous scouring debris torrents and dam-break floods have occurred, and most of the tributaries to Smith Creek with the exception of Quiet Creek, have been scoured to bedrock. These impacts have led to the construction of dikes along the Smith Creek alluvial fan to protect homes, creating further salmonid habitat problems . Debris flows have also occurred in Blue Canyon and Brannian Creeks while debris torrents have occurred in South Bay, Beaver Creek, and Austin Creek (DNR 1997).

Road density in the Oyster and Colony Creek WAU is 2.4 road miles/sq. mile (data from Lunetta et al. 1997).

2.3.2. Access

A comprehensive WRIA-wide inventory of fish passage barriers and blocked habitat is currently underway and results are anticipated by June 2005. This project will also synthesize previously collected barrier information, which have been conducted in various watersheds and jurisdictions of WRIA 1, and calculate Priority Index (PI) numbers using WDFW SSHEAR standardized methodology. PI numbers provide a means for ranking importance of passage improvement projects based on the quantity and quality of blocked habitat and priorities of affected salmonid stocks. Priority Index (PI) numbers have already been calculated for many of the blockages identified to date. Inventory and prioritization of these fish passage barriers are presented in *Salmon and Steelhead Habitat Limiting Factors in WRIA 1* (Smith 2002), including that for Dakota Creek, California Creek, Squalicum Creek, Chuckanut, and Padden Creek watersheds. Dakota Creek, Squalicum Creek have been rated poor for access conditions (Smith 2002).

Some inventories of fish blockages in the Lake Whatcom sub-basin have been completed with more scheduled. Areas of concern include the North Shore, South Bay, Blue Canyon, and Geneva Interbasin areas (DNR 1997) where increased development has occurred and culvert impacts are more likely (Smith 2002). Plugged culverts have been noted in Carpenter Creek. Other access problems include seasonal sub-surface flows in Carpenter, Olson, Smith, and Brannian Creeks, and while the flow problem could be natural, it is thought to be worsened by excess sedimentation. Excess sediment from upstream sources has created access problems in the past at the mouth of Brannian Creek, requiring excavation. Fish access conditions in the Lake Whatcom sub-basin have not been rated due to a lack of data and analysis.

For this Plan, the existing readily available data on fish passage barriers was analyzed, including recent versions of the WDFW SSHEAR and Whatcom County culverts databases (Figure C17; Table C8). Out of a total 1164 culverts, fishways, and dams inventoried, 532 of those occurred in areas with known or possible fish use, less than half (45%) of which have been evaluated for passability. Of those evaluated for passability, most (60%) have been identified as barriers. Affected species have been identified for most (65%) of barriers). The most impacted species is rainbow trout (105 identified barriers), followed by coho (99), cutthroat trout (91), steelhead (85), chum (74), and sockeye (2). No barriers have been identified for chinook or native char, although bull trout impacts are likely since potential bull trout foraging and migration habitat is generally assumed to co-occur with coho habitat. Identified barriers are most numerous in Bellingham Bay subbasin, followed by Drayton Harbor and Birch Bay subbasins.

2.3.3. Channel Conditions

California Creek has been described has having few gravel spawning areas and many channelized areas (Nelson et al. 1991). Pool habitat depth was measured in various reaches throughout the Dakota Creek watershed, and only one reach (the lower two miles of North Fork Dakota Creek) had abundant deep pools that were greater than 1 meter (data from Nooksack Salmon Enhancement Association Intern monitoring program). Other North Fork Dakota Creek reaches with low proportion of pool habitat are the middle and upper reaches of the North Fork and tributaries 01.0032, 01.0036, and 01.0030.7. Several mainstem Dakota Creek tributaries (01.0004, 01.0005, 01.0008, 01.0009, 01.0010, 01.0021) and one South Fork tributary (01.0033) had very low numbers of deep pools. No pool habitat data for California Creek and no data regarding instream LWD levels for either Dakota or California Creeks were found.

Squalicum Creek was rated as unstable in two different years of sampling, and serious bank cutting was documented (Schuett-Hames and Schuett-Hames 1984a). In addition, livestock access increased bank erosion in Squalicum Creek, and the percent of fine sediment has averaged 11% (data from Schuett-Hames and Schuett-Hames 1984b). Road density in the WAU that includes Squalicum and Silver Creeks is 3.7 mi roads/sq. mi. watershed (data from Lunetta et al. 1997). Pools are generally shallow with most pools less than 1 meter deep (data from Nooksack Salmon Enhancement Association Intern monitoring program). Large wood was quantified throughout Squalicum Creek and three of its tributaries (data from Nooksack Salmon Enhancement Association Intern monitoring program). All sampled reaches had less than 1 piece of wood per bankfull width.

In Whatcom Creek, few data were available to assess streambed and sediment conditions. Stream stability in Whatcom Creek was rated as stable in two samples and as moderately unstable in a third sample in the 1980s (Schuett-Hames et al. 1988a). The level of fine sediments was 8.7% in the 1980s. Data regarding instream levels of LWD and pool habitat were not found.

Considering that most of the landslides in the Lake Whatcom watershed were associated with timber harvest (DNR 1997), fine sediments are a concern in Lake Whatcom tributaries. Most of the sampled reaches in the tributaries to Lake

Whatcom are below target levels of LWD (DNR 1997). Carpenter, Olson, most of Smith, Blue Canyon, lower Cub, lower Anderson, lower Fir, Brannian, Austin, and Beaver Creeks had less than 1 pc/bankfull width. Percent pool habitat is lowest for Carpenter, lower Olsen, Blue Canyon, lower Cub, and lower Fir Creeks, followed by middle Olson, Smith, and middle Austin Creeks. Relatively high percent pool habitat exists in Anderson, lower Austin, and Beaver Creeks. (data from DNR 1997).

No information on channel conditions is available for Oyster and Colony Creeks.

2.3.4. Riparian Conditions[15]

Riparian vegetation data for many of the independent coastal tributaries are only available on a broad-scale. Much of the riparian vegetation along low-gradient response reaches (streams <4% gradient) has been converted to non-forest lands, indicating degraded riparian conditions in the following watersheds: Terrell Creek (58%); Dakota and California Creeks (61%); Squalicum and Silver Creek watersheds (61%); Whatcom, Padden and Chuckanut Creeks (56%; data from Lunetta et al. 1997). In Lake Whatcom tributary watersheds, the riparian vegetation is predominantly (71%) hardwood or cleared forestland. Non-forest land comprises 18% of the riparian buffers, and much of this is residential land use. Only 3.9% of the riparian reaches consist of mid-seral stage conifer with no reported late seral stage conifer. About 48% of the riparian response reaches in the Oyster and Colony Creek watersheds have been converted to non-forestland (data from Lunetta et al. 1997). Most of the land conversion has occurred in the lower Colony Creek drainage where agricultural lands predominate (Whatcom Conservation District maps, unpublished data, 1991). In riparian areas with forest land remaining, much is either open or consist of hardwoods or brush. However, it is likely that some of the hardwood/open category in this WAU includes forested wetland areas that would naturally not sustain conifer. Considerable wetland habitat has been noted in Dakota Creek by Nelson et al. (1991), and a map of hydric soils indicates that both Dakota, California, Whatcom, and Padden Creeks have large areas of partially hydric soils that might have would naturally sustain hardwoods (Whatcom Conservation District maps, unpublished data, 2001). It is also likely that some of the hardwood riparian is a natural condition in the wetland areas of upper Oyster Creek.

2.3.5. Floodplain Conditions[16]

Wetlands are common in the Drayton Harbor Basin, comprising 16% of the forested areas. If mudflats are included, wetlands total 21% of the area (Nelson et

[15] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.
[16] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

al. 1991). Of these, 34% are freshwater marshes and wet meadows (Nelson et al. 1991). Hydric soils indicate that wetlands covered up to 34% more area than presently. The loss of wetlands in this area is due to artificial drainage and replacement of wetlands with pasture and hayland. The causes of loss from highest to lowest order include draining, filling, excavating, grazing, hay production, buildings and roads (Nelson et al. 1991). These impacts result in degraded floodplain conditions for Dakota and California Creeks. Floodplain conditions within Terrell Creek are unknown.

Specific floodplain surveys are not available for Squalicum, Whatcom, Padden, and Chuckanut Creeks. However, many sites of riprap were noted in a habitat survey of Squalicum Creek (Nooksack Salmon Enhancement Association Internship Program). Quantification of floodplain impacts is needed. There has been substantial historic filling of Whatcom Creek floodplain for the majority of length downstream of Whatcom Falls Park. In the Lake Whatcom sub-basin, most streams are naturally limited in floodplain habitat due to confinement in steep valley walls, except for the alluvial fan deltas near where they enter Lake Whatcom. Significant human-caused problems in these areas have been noted. Of particular significance is the impact to the Smith Creek alluvial fan by numerous dikes that were constructed to protect homes. Also, Austin Creek has riprap, a levee, and is artificially entrenched due to excess sediment transport.

No data on floodplain conditions were found for Oyster or Colony Creeks.

2.3.6. Water Quantity[17]

2.3.6.1. Low Flows

The stream flows in WRIA 1 lowland streams closely mirror annual precipitation patterns with low flow concerns in the late summer through early fall (DOE 1995; Whatcom Conservation District 1988b). Average annual precipitation is 40″ near the coast and 60″ in the hills (Figure C2) with about 80% of the precipitation falling from October through mid-June (Nelson et al. 1991). Watersheds with closures to future water allocations during at least part of the year include Dakota (full-year closures), California(full-year closures), Terrell, Squalicum, Whatcom, Padden, Chuckanut, and Oyster Creeks. Surface water rights are numerous around Lake Whatcom, but the streams draining into Lake Whatcom are not closed to further water withdrawals (DOE 1995).

2.3.6.2. Peak Flows

Changes in the hydrological regime are also manifested in increased peak flows during fall and winter months. The loss of mature forest can increase the rate of

[17] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

water entering the streams because mature forests can temporarily capture 24 to 35% of the precipitation (Dingman 1994). Impervious surfaces and ditching and loss of wetlands also accelerate runoff delivery to streams and reduce the opportunities for groundwater recharge, with associated reduction in summer base flows. Most of the original land cover vegetation of old growth forests has been converted to agricultural uses and urbanization, especially in the Drayton Harbor, Birch Bay, Georgia Strait, and lower Bellingham Bay subbasins (Figure C3, Figure C6). Impervious surface percentages have been estimated using land use information: Terrell Creek 19.35%, California Creek 6.46%, Dakota Creek 2.37%, Lake Whatcom 3%, Oyster Creek 2.6%, Colony Creek 12.6% (Whatcom Conservation District maps, unpublished data, 2000). Impervious surface percentages were unavailable, but likely high, for the Squalicum, Whatcom, and Padden Creek watersheds.

2.3.6.3. Other Changes to Flow Conditions

The natural hydrology within the Lake Whatcom watershed has been considerably altered. The natural hydrology consisted of several small tributaries draining into Lake Whatcom with the outflow draining into Whatcom Creek to Bellingham Bay. However, a dam was built near the Whatcom Creek lake outlet in 1911 to stabilize lake levels (DNR 1997) and to buffer high flows into Whatcom Creek (Matthews et al. 2001). In addition, Anderson Creek, a tributary to Lake Whatcom, is used as the channel to divert water from the Middle Fork Nooksack River into Lake Whatcom for municipal uses. Because of this diversion, up to 80% of the water input to the lake in the summer originated from the Middle Fork Nooksack River (Walker 1995). Beginning in 1998, the amount of water diverted from the Middle Fork Nooksack River has been reduced to help maintain instream flows in the Middle Fork (Matthews et al. 2001).

2.3.7. Water Quality[18]

The following streams in the Coastal region are 303(d) listed (DOE 2000): (1) high water temperatures: Whatcom Creek; (2) low dissolved oxygen: Dakota Creek; Tennant Creek (3) high fecal coliform: Dakota Creek; Whatcom Creek; Silver Beach Creek.

Potentially toxic levels of ammonia have been measured in the North Fork Dakota Creek watershed, and low levels of dissolved oxygen have been documented in both the North Fork and South Fork watersheds (Dickes 1992). Livestock access and waste runoff are the major suspected causes of the water quality problems in Dakota Creek with 29 dairy farms in the watershed (Dickes 1992). Two fish kills (one in the North Fork and another in the South Fork) have

[18] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

occurred due to over-application of dairy animal waste on fields (Nelson et al. 1991). In addition, potentially harmful levels of cadmium have been found in both the sediments and surface waters in Dakota Creek. The source of cadmium is not known, especially because the primary land use is dairy farming (Erickson et al. 1995). Many ditches have been constructed to drain into California Creek, and livestock access has been a documented problem along these ditches (Nelson et al. 1991). Livestock waste and failing septic systems are the likely causes for elevated fecal coliform and nutrient levels in California Creek (Nelson et al. 1991; Scott and McDowell 1994). However, specific water quality measurements were not found for California and Terrell Creeks and given the land use surrounding these streams, water quality impacts are likely.

Several years of sampling have indicated high temperatures and low dissolved oxygen levels throughout Squalicum Creek and in lower Baker Creek, a Squalicum tributary (City of Bellingham 1999). Turbidity exceedances have been noted after rainfall in all of the sampled sites with occasional pH problems in the middle reaches of Squalicum Creek and in lower Baker Creek (City of Bellingham 1999). Stream bank modification, the loss of riparian vegetation, urban storm water, and agricultural impacts are some of the likely causes of these water quality problems (Scott and McDowell 1994). Squalicum Creek also has high fecal coliform levels resulting from agriculture, urban storm water runoff, landfills, and failing septic systems (Scott and McDowell 1994; City of Bellingham 1999). Mercury, lead, zinc, and copper have been documented in Squalicum Creek with urban and industrial storm water runoff a suspected source (DOE 1995).

The City of Bellingham (1999) sampled water quality parameters at six different locations within the Whatcom Creek watershed, and those results show pervasive warm water temperatures at all three sampling sites within Whatcom Creek, with some water temperatures exceeding 21°C. In some years, low levels of dissolved oxygen also occurred at these sites. Tributaries to Whatcom Creek, such as Cemetery, Lincoln, and Fever Creeks, have warm water temperatures and low dissolved oxygen levels, and turbidity exceedances were noted in Fever Creek. Mercury, lead, zinc, and copper have been documented in Whatcom Creek, and urban and industrial storm water runoff is the suspected source (DOE 1995). Other toxins such as pentachlorophenol (PCP), have been detected at in the sediments at two different sites in Whatcom Creek, and methylene chloride has been detected at a lower reach site. Samples from the lower site resulted in mortality in a bioassay (Cubbage 1994). Sources of water quality degradation include the forty storm water inputs into Whatcom Creek and the loss of riparian vegetation (DOE 1995).

In the Lake Whatcom watershed, the streams that receive residential runoff (Austin Creek, Silver Beach Creek, and Park Place drain) have more degraded water quality conditions compared to those in forested areas (Smith, Wildwood, and Blue Canyon Creeks) (Matthews et al. 2001), but warm water temperatures have been documented in all of the sampled streams. In the forested creeks, peak water temperatures ranged from 16.5 to 17.0°C ("poor") (Matthews et al. 2001). In the streams degraded by residential development, the water temperatures were worse with peak 1990 temperatures ranging from 17.0 to 23.0°C. Other water quality problems have also been documented in the Lake Whatcom tributaries, likely due to runoff from residential developments (DOE 1995). Some of the samples have shown high levels of phosphorous, nitrogen, and fecal coliform levels (Scott and McDowell 1994), and problems with turbidity, dissolved oxygen, and metals have been noted (DOE 1995). In Lake Whatcom, in all but the shallowest areas, the lake stratifies in the summer with warm water in the upper layer and cool water containing low oxygen levels comprising the bottom level (Matthews et al. 2001). Even though this stratification is natural, there has been a decreasing trend in oxygen levels at all sampled depths greater than 12m from 1988 to 1999. The trend has no simple, direct relationship to temperature or lake water levels, although these likely play a role in oxygen levels (Matthews et al. 2001). The low oxygen levels can result in a release of phosphorus and nitrogen from the sediments, which can trigger an algal bloom and deplete oxygen levels in the upper layer, leading to a fish kill. Metals and organics can also be released from the sediments in lower oxygen conditions (Matthews et al. 2001). Elevated levels of ammonia, phosphorus, iron, and hydrogen sulfide have been measured in Basins I and II of the lake, and these elevated levels are a symptom of low oxygen conditions. Mercury has also been noted in Basin I (Matthews et al. 2001).

High water temperatures were documented in two years at the mouth of Padden Creek (data from City of Bellingham 1999). Fecal coliform levels did not meet Class A standards for most of the years except for the Padden Creek site at 38th Street (City of Bellingham 1999). In addition, mercury, lead, zinc, and copper have been documented in Padden and Connelly Creeks, and urban and industrial storm water runoff is the suspected source (DOE 1995). Low dissolved oxygen levels and warm temperatures have been documented in Chuckanut Creek (RM 0.2). No water quality data were found for Oyster or Colony Creeks.

2.4. Fraser River Tributaries Watershed Conditions

2.4.1. Watershed Conditions

Fraser River watershed area south of the US/Canada border is 607 km^2 (234 mi^2), divided among Chilliwack (71%), Sumas (29%), and Other Fraser (<1%)

subbasins (Figure C1, Table C4). The Chilliwack subbasin is a steep, mountainous upland system draining the north slopes of the North Cascades range, with 81% of the area in high and moderate slope classes and average and maximum elevations of 1226 m (4022 ft) and 2739 m (8986 ft; Figure C5; Table C4). The Sumas subbasin is a predominantly lowland system (average elevation 122 m or 400 ft; 85% low landscape slope class) except in the east where it drains Sumas Mountain and elevations reach 1040 m (3412 ft).

Geology in the Chilliwack subbasin[19] is predominantly (76%) competent. Tertiary and Pre-Tertiary rock types (Oligocene tonalite and granite, Miocene granodiorite, and Permian-devonian metasedimentary and metavolcanic rocks) with some Pleistocene glacial deposits (continental glacial drift) in river valleys (11% of subbasin area). In the Sumas subbasin, the dominant rock type is Quaternary alluvium (40% of area; including some peat deposits in the northeast), followed by glacial deposits (30%; includes continental glacial drift, outwash and till), less competent sedimentary (12%; continental sedimentary deposits of the Huntingdon formation), competent (9.5%; pre-Tertiary metasedimentary and metavolcanic rocks), and pre-Tertiary ultrabasic rock types (3.1%).

Land use/land cover in the Fraser region differs substantially between Sumas and Chilliwack subbasins (Figure C3; Table C2). Chilliwack subbasin is predominantly Forested Upland (68%), followed by Shrubland/Non-natural woody/Herbaceous Upland (11%), and Water (4.2%). Developed and Agriculture (i.e. Herbaceous Planted/ Cultivated) classes comprise only 0.65% and 0.47% of the subbasin and occur only north of the US/Canada border. In the Sumas subbasin, land cover is 42% Forested Upland, 32% Agriculture (i.e. Herbaceous Planted/ Cultivated), 18% Dairy, and about 3-4% each of Developed, Barren, and Shrubland/Non-natural woody/Herbaceous upland classes. Over half of the forested lands of the Chilliwack subbasin are relatively intact, with 60% in late seral stage, although 34% has less than 10% coniferous crown cover. By contrast, only 4% of the Sumas subbasin is in late seral stage and almost half has less than 10% coniferous crown cover; the remainder is divided among mid (23%) and early (25.4%) seral stages.

2.4.2. Access

A comprehensive WRIA-wide inventory of fish passage barriers and blocked habitat is currently underway and results are anticipated by June 2005. This project will also synthesize previously collected barrier information, which have been conducted in various watersheds and jurisdictions within the Nooksack River watershed, and calculate Priority Index (PI) numbers using WDFW

[19] Data only covers US portion of subbasin.

SSHEAR standardized methodology. PI numbers provide a means for ranking importance of passage improvement projects based on the quantity and quality of blocked habitat and priorities of affected salmonid stocks.

For this Plan, the existing readily available data on fish passage barriers was analyzed, including recent versions of the WDFW SSHEAR and Whatcom County culverts databases (Figure C17; Table C8). Out of a total 248 culverts, fishways, and dams inventoried, all occurred in the Sumas subbasin but only 20% of those occurred in areas with known or possible fish use. Of those evaluated for passability, most (60%) have been identified as barriers.

The City of Abbotsford B.C. operates this flood control system by a network of dikes, canals and a large pump station at the mouth of the river, with floodgates closing the mouth of the Sumas River in early to mid-May to Sept. 15. During this period the Sumas River waters are pumped through the pump station and over the dike, when the Vedder Canal or Fraser River surface water elevation exceed about 3 meters elevation (Wright, Abbotsford Superintendent of Diking, Drainage, and Irrigation, pers. comm. 2003). In addition to preventing flooding, this permits Sumas River water to be used for agriculture. During years of low snowpack when spring meltoff ends earlier the floodgates still remain closed so more water is available for irrigation (Frank Wright, pers. comm. 2003). Floodgates are reopened Sept. 15, to permit upstream migration of salmon, and left open, unless the Fraser River or Vedder Channel rise 3.5 m above the local datum (Healey 1997). During this lengthy period when floodgates are closed, or during other times of the year when flood risk leads to closing the floodgates, the resident pumphouse operator watches for adult salmon that want to move up the Sumas River milling outside the station pumphouse (Wright, pers. comm. 2003). When adults are observed, the procedure is to open the gates for three to four hours to allow fish to move upstream, and they apparently quickly do so. This has been the standard operating procedure at the pumpstation for many years. The original pump from the 1920's was replaced with a Stork pump in 1983 that operates at only 117 revolutions per minute (Wright, pers comm. 2003). The pump was selected due to its large capacity and environmental friendliness, and there doesn't seem to be much impact on downstream migrating fish as observed juvenile mortality rates are small (Wright, pers. comm. 2003).

Additionally, during periods when the river is pumped over the dike, upstream migrating adults or foraging sub-adult bull trout cannot access the Sumas River, although if their numbers are substantial they will probably be observed and the floodgates opened to enable their migration with only temporary delays. Adults that migrate between Sept. 15 and mid-May are not delayed, unless the risk of flooding leads to unscheduled closures. This occurred in October 2003, but milling adults were observed and the gates were opened for about six hours, and the fish apparently moved upriver (Wright, pers. comm. 2003).

Another possible impact during periods when the river water is pumped over the dike is to downstream migrating salmon and trout smolts, post spawning adults (steelhead, cutthroat), or to foraging or overwintering bull trout. While observed juvenile mortality rates are low, some level of outmigrant salmon and trout mortality likely still occurs, but presumably less than before the facility improvements occurred in 1983. In recent years Canada has begun to prioritize and correct facilities for fish passage where improvements are needed, and over time any problems with this facility will probably be corrected (Brad Fanos, Department of Fisheries and Oceans, pers. comm. 2003).

2.4.3. Channel Conditions[27]

Beginning in 1997, habitat monitoring has occurred in the Chilliwack River by the U.S. Forest Service, National Park Service, Province of British Columbia, and University of British Columbia. In reaches of the upper Chilliwack River that have never been disturbed, the focus of the monitoring effort, most of the substrate is not embedded (43-71% of sampled area not embedded), with 6 to 29% embedded (data from Reed Glesne, National Park Service). Most sampled areas had frequent deep pools, and LWD ranged from an average of 7.6 to 22 pieces per 100 meters. More data should become available as the program continues. Road densities are low in the Chilliwack subbasin (excepting Frost Creek watershed) at less than 0.1 miles/sq. mile and fair in the Sumas River and Frost Creek watersheds at 2.3 miles roads/sq. mi. watershed (data from Lunetta et al. 1997).

The Sumas River has channel incision, excess fine sediments, and low levels of LWD in its lower reaches (David Evans and Associates 1998). The fines are believed to stem from a landslide in Swift Creek. The tributaries to the Sumas River have variable habitat conditions. Sumas Creek has numerous impacts in its lower reaches where it drains into Johnson Creek, including low levels of LWD and few pools (averaging less than 10% of wettable area) (David Evans and Associates 1998). The pools are also shallow due to fine sediment filling. The middle reaches of Sumas Creek are degraded by fine sediments that are believed to arise from upstream dredging activities. Upper Sumas Creek has better habitat, with its headwaters arising from a spring-fed wetland. More pools are available and adequate spawning gravel appears to exist. In general, the salmonid habitat in Johnson Creek is less degraded than in the Sumas River. Impacts include dredging in the upper reaches of Johnson Creek, and a lack of LWD and pools in the urban area. Upper Johnson Creek has adequate pool and LWD components (David Evans and Associates 1998), and are rated “good”. North Fork Johnson Creek has good spawning gravel and a good pool:riffle ratio

(U.S. Dept. Agriculture Soil Conservation Service 1993), but more data are needed to assign ratings. Bone Creek is lacking spawning gravel, LWD, and pools, and fine sediments have impacted pool habitat (David Evans and Associates 1998).

Between 1919 and 1923, Sumas Lake was drained for flood control and to create additional farmland. At low water, the lake covered 3,200 to 4,000 hectares (8,000 to 10,000 acres), but grew to as much as 12,000 hectares (30,000 acres) when the Fraser River was in flood (Carlson et al. 2001). The size and shape of the lake rarely appeared the same on early maps and freshets frequently tripled the size of the lake each year (Carlson et al. 2001). An elaborate system of pumps, dikes and canals drained all the water from the lake, enabling the fertile lake bottom to be farmed. In addition to the loss of the lake, the low elevation of the Sumas Prairie (the bed of the former lake), and potential for flooding of it from the Fraser River or Vedder Canal, have led to a complicated water management system in Canada to prevent flooding (Healey 1997).
The loss of Sumas Lake most likely dramatically impacted salmonids that utilize lakes or wetlands during one or more life history stages including coho, and possibly a former sockeye run

2.4.4. Riparian Conditions[20]

Riparian vegetation data for many Fraser River tributaries are only available on a broad-scale. Much of the Chilliwack subbasin likely has functional riparian areas. The Washington State reaches of the Chilliwack River are within National Park boundaries and in a natural condition. The broad-scale analysis indicates that 69% of the riparian areas along response (<4% gradient) stream reaches are in a late-seral conifer stage (data from Lunetta et al. 1997). The Washington State reaches of Damfino and Silesia Creeks are mostly within U.S. Forest Service boundaries, except for the uppermost reaches of Silesia Creek, which are in the National Park. Much of the Forest Service land in this WAU is in the Mount Baker Wilderness. Human impact is minimal in these areas, and the watersheds are considered to be natural. Riparian vegetation conditions appear functional, with 78% in a late seral conifer stage. The non-forest components in these areas are natural, consisting of sub-alpine and alpine meadows or glaciers associated with mountain elevations.

Riparian conditions are more degraded in the Sumas subbasin and Frost Creek watersheds. Riparian areas are mostly non-forestlands (52%), followed by hardwood or open forestland (36%) (data from Lunetta et al. 1997). It is likely that many of the riparian areas of Saar Creek historically supported a hardwood

[20] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

riparian because of the partially hydric nature of the surrounding soils (Whatcom Conservation District map, unpublished data, 2001). The Washington State riparian reaches of the Sumas River show an even greater conversion to non-forest use (85%) (data from Lunetta et al. 1997). Historically, wetland prairies dominated the region (DOE 1995), but currently agriculture and rural residences comprise most of the watershed. The Sumas River reaches that are within the City of Sumas boundaries are impacted by a loss of riparian and invasion of Reed canarygrass (David Evans & Associates 1998). The riparian vegetation along Sumas Creek is lacking forest canopy cover in the lower and middle reaches where the riparian consists of willows shrubs, Reed canarygrass, and blackberry. Johnson Creek is also lacking riparian vegetation in the urbanized reaches, but has a mix of riparian conditions outside of the urban areas (David Evans & Associates 1998). Bone Creek also has a mix of riparian conditions with some reaches surrounded by Reed canarygrass.

2.4.5. Floodplain Conditions[21]

Very limited information was found for floodplain habitat in the Fraser River tributaries. In the Sumas River watershed, little habitat diversity exists in the urbanized reaches of the Sumas River, Johnson Creek, and lower reaches of Sumas Creek (David Evans and Associates 1998). The urbanized reaches of the Sumas River are also impacted by channel incision. Extensive wetlands provide good habitat in upper Sumas Creek. Another wetland near the mouth of Johnson Creek was documented, but urban impacts to that wetland have occurred. Wetland loss likely occurred throughout the Sumas watershed because extensive amounts of partially hydric soils cover the land, yet few wetlands have been documented.

2.4.6. Water Quantity[22]

Water quantity conditions are likely unimpaired in the Washington portion of the Chilliwack, Damfino, Tomyhoi, and Silesia watersheds. The Chilliwack River is within the North Cascades National Park and is relatively undisturbed, and the Silesia watershed is within the U.S. Forest Service Mt. Baker Wilderness boundaries. The Tomyhoi and Damfino watersheds are also within the U.S. Forest Service boundaries, and have been minimally disturbed. In these forested regions, the percent of mature conifer is 44% for the Chilliwack WAU and 51% for the WAU consisting of Damfino, Tomyhoi, and Silesia watersheds (Figure C6; data from Lunetta et al. 1997). Although these percentages might appear low for areas that are primarily natural, much of the remaining land cover in these

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[21] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.
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WAUs consists of alpine meadows and glacial areas, which are naturally lacking in mature conifers.

In contrast, most (64%) of the original land cover in the Sumas River WAU has been converted to agricultural uses and to a lesser extent, urbanization (Figure C3). Historically, this area consisted of wetland prairies with 200 square miles of wetlands containing low shrubs, ferns, and sedges. Much of this land has been drained and urbanized or converted to agricultural use (DOE 1995). The loss of wetlands impacts stream flows due to the ability of wetlands to buffer high flows and recharge streams during low flows. Impervious surface percentages have been estimated using land use information, with less than 1% impervious surfaces for the Sumas River, Saar Creek, and Johnson Creek watersheds (Whatcom Conservation District maps, unpublished data, 2000). Numerous surface and ground water rights exist throughout the Sumas River watershed, and the Sumas River and Saar Creek are closed to further water allocations (DOE 1995).

2.4.7. Water Quality[23]

While Chilliwack subbasin is relatively undisturbed, water quality degradation is evident in the Sumas subbasin. Levels of nitrogen (including ammonia) and phosphorous in the Sumas River are among the highest levels in the Puget Sound region (DOE 1995), and high levels of nutrients can lead to algal blooms that deplete oxygen levels and lead to fish kills. Riparian loss has been noted in the urban areas along the Sumas River and along the middle reaches of Sumas Creek where residential developments exist (David Evans and Associates 1998), although no water temperature data were found. The following are 303(d)-listed for failing to meet water quality standards (DOE 2000): (1) high fecal coliform: Sumas River, Sumas Creek, Johnson Creek, Clearbrook Creek, Squaw Creek, Pangborn Creek; (2) low dissolved oxygen: Sumas Creek, Johnson Creek, Clearbrook Creek, Squaw Creek, Pangborn Creek; (3) pH exceedance: Squaw Creek, Pangborn Creek. Low dissolved oxygen levels (24% of the samples violated standards) in the Sumas River near Huntingdon, British Columbia and high levels of ammonia in Johnson Creek have also been detected (Erickson et al. 1995). High levels of ammonia have been detected in Johnson Creek (Erickson et al. 1995). Waste load allocations have been recommended for the Sumas wastewater treatment plant and for non-point ammonia, BOD, and fecal coliform (Erickson et al. 1995). Ground water contamination with banned pesticides, such as ethylene dibromide and 1,2-dichloropropane are also a concern in the Sumas subbasin (Hardy et al. 2001).

[23] Excerpted (with edits) from *Salmon and Steelhead Habitat Limiting Factors in WRIA 1, the Nooksack Basin*. C.J. Smith, Washington Conservation Commission, Lacey, WA. July 2002.

2.5. WRIA 1 Estuarine/Nearshore Conditions

The Nooksack Estuary has seen dramatic changes throughout the historic period (Bortleson et al. 1980). Maps drawn prior to 1860 show the Nooksack River discharging the bulk of its flow to the Lummi Bay delta, with secondary distributaries contributing flow to the Bellingham Bay delta around either side of the Lummi Peninsula, then an island (Wahl 2001). Around 1860, the majority of the flow shifted, or was shifted, to the Bellingham Bay delta. Whether this was a natural event or was caused by human intervention is unclear. The result of this change is evident on surveys completed in the 1880s that show the Lummi delta and floodplain with well-developed saltmarsh habitat and extensive tidal and distributary channels, while on the Bellingham Bay delta the Nooksack River discharges directly to a sandflat with virtually no saltmarsh or scrub-shrub habitat present. The connection to the Lummi Bay distributary was closed to mainstem flow at this point, and freshwater to Lummi Bay was contributed only by floodplain tributaries and during larger flood events when levees were overtopped. For juvenile salmon leaving the Nooksack River, this time period likely represented the most limiting estuarine habitat conditions because complex estuarine habitat had not had a chance to form on the Bellingham Bay delta.

Development of the floodplain and the main channel followed quickly on the heels of the isolation of the Lummi Delta. The portion of the mainstem below the modern Kwina Slough was shortened for better navigation in 1908 and nearly 50 years of habitat formation on the Bellingham Bay delta was again disturbed. By the first aerial photos in 1933, levees lined the Nooksack River downstream to Marine Drive and nearly 80% of the estuarine floodplain was converted agriculture (Brown et al. 2005). The upstream connection of the Lummi River was isolated by an earthen dike and an armored seawall was constructed across the mouth of the Lummi Bay, facilitating the reclamation of virtually the entire Lummi delta. These installations blocked fish passage into all virtually all of the tidal channels and wetlands present on the Lummi delta. In these early aerial photos, results of the 1908 diversion were still apparent as the delta began to rebuild into Bellingham Bay. The main channel was braided across the exposed sandflat, with limited saltmarsh and scrub-shrub habitat present. This period shows very low habitat diversity in the estuary, and likely represented limiting conditions for transitioning juvenile anadromous salmon.

From the 1933 aerial photos to the current time, the delta has continued to expand into Bellingham Bay and create habitat without human management. Habitat abundance and diversity has increased dramatically as the main channel has formed and abandoned channels across the delta, creating a diverse network of distributaries and blind channels. While habitat quality on the Lummi Bay delta has not improved from the 1930s and is heavily impacted by land use, limited freshwater connection of the Lummi River was established when a culvert was put in the dike at the connection to the Nooksack River in 1951 (Wahl 2001). The Nooksack delta now represents one of the most pristine major estuaries in the Puget Sound, and likely some of the highest quality habitat that anadromous juvenile salmon encounter as they move down the Nooksack River (Smith 2002). Riparian zones in the estuary are maturing and conifers are present in the undergrowth of the deciduous stands, indicating that wood recruitment is recovering in the estuary. Abundant logjams, created from both upstream sources and local recruitment, affect habitat formation and provide complex cover in the edge habitat used by rearing juvenile salmon. In spite of these rapidly improving conditions in the estuary, salmon stocks, particularly chinook populations, have declined.

The habitat-forming processes that continue to create and maintain the habitat on the Bellingham Bay delta are dominated by sediment, wood and water quality attributes. Changes in these values through time have had a direct impact on the quantity and quality of habitat in the estuarine environment. From historical analysis, it is expected that the trends in channel development and closure in the delta since the 1930s will continue and the Bellingham Bay delta will continue to grow due to the naturally high sediment load produced by the Nooksack basin. While the delta progrades into Bellingham Bay, more distributary channels will continue to form, increasing the abundance and diversity of habitat available to salmon. The increased number of channels may also lead to a decrease in the ability of the channels to transport sediment, given the fixed amount of flow to maintain the channels and ultimately to a narrowing and shallowing of some of the major distributary channels. Further, the amount of delta front that is not actively maintained by distributary channels will increase, likely leading to greater blind tidal channel development. With a greater proportion of the delta subject to marine forces, it is expected that the saltmarsh and shrub-scrub zones will widen as the gradient of the delta lessens.

Coupled with the changes in sedimentation, the ecological and geomorphic value of wood in the delta has changed considerably through time, from the pre-development conditions described in the mid-1800s, through the massive influx of wood from milling operations, to channel cleaning shortly after the turn of the century (Collins and Sheikh 2002). Since the 1930s, it appears that wood function is increasing in the estuary, as local sources for recruitment expand and logjams are allowed to develop and persist in the channel. With the rapidly growing delta, it is expected that wood will play a greater role in habitat development and maintenance. Improving riparian conditions in the watershed, along with attempts to preserve adequate channel migration areas for the channel, will improve long-term recruitment of wood to the estuary and likely provide important habitat benefits that are currently lacking.

Given the changes in wood and sediment delivery to the estuary and the development of the floodplain, the distribution and abundance of habitat classes has changed as well. Habitat in the estuary is defined by both landscape and channel characteristics. The most dramatic change between conditions in the 1880s and 2004 was the increase in agriculture, which eclipsed 6000 acres of the estuarine floodplain by 1933 (Brown et al 2005). This change was accompanied by a decrease in saltmarsh, scrub-shrub and forested habitat types. This represents 77% of the habitat on the Lummi Bay delta and 63% of the habitat on the Bellingham Bay portion of the estuary (Brown et al. 2005). Since 1933, the Lummi Bay delta has seen little change, while the prograding delta on the Bellingham Bay side has led to a dramatic increase in forested floodplain, shrub-scrub, saltmarsh, and tide flat.

These changes in landscape through time also affect the habitat quality of the channels that pass through these broad zones. The aspects of cover, food resources, wood recruitment and function and water quality are all impacted by changes in the landscape habitat type. The conversion of much of the floodplain to agriculture and the active progradation of the delta into Bellingham Bay have led to a marked change in channel habitat characteristics since the 1880s. The Lummi Bay delta changed from the dominant outlet of the Nooksack River in the 1860s to an intermittent distributary by the 1880s. Following the isolation of the Lummi delta from the Nooksack River and from tidal influence in the 1930s, all of the tidal channels were lost and only one intermittent distributary channel remained. The floodplain channel network is now dominated by drainage ditches, most of which are blocked by levees from connection to natural freshwater channels (Brown et al. 2005). Freshwater sources to the delta were reduced to the two perennial tributaries: Jordan and Schell creeks. While the Lummi Bay delta has seen a loss in channel habitat diversity, active prograding of the Bellingham Bay delta has led to a rapid increase in distributary channel length since the 1930s. Accompanying the increase in distributary channel length has been an increase in blind channels as the delta front widens and a greater proportion is subjected to tidal influences. The blind channels on the Nooksack Delta provide important food resources and undercut bank refuge; however, the water quality usually found in these habitats is of higher salt content, usable by juveniles more advanced in their smoltification.

Water quality, particularly water temperature and salinity, is another important habitat factor in the estuary determining habitat use. Water temperatures in the Nooksack estuary during the juvenile salmonid migration period vary temporally and spatially following seasonal patterns, and extent of saltwater and mainstem influence (Brown et al. 2005). Seasonally, the ideal conditions for salmon to effectively rest, feed and grow occur in winter and spring juvenile out-migration periods. The bulk of juvenile migrants enter the estuary between early May and early June while water temperatures are ideal throughout the estuary. Starting in June, water temperature rises above preferred levels in habitat types not directly influenced by the mainstem Nooksack or saltwater. Virtually all of the floodplain tributaries and blind channels reach lethal temperatures during the day, due to low flow and high exposure to the sun. Channels crossing the exposed flats of the estuary fluctuate wildly as the channel is cooled by the saltwater as the tide rises and heats as the sun warms the water on the falling tide. The variability of water temperature through the delta means that the opportunity for refuge from the influence of high water temperatures are present in different areas of the delta at different times in the year. Channels that were strongly influenced by the mainstem Nooksack River or saltwater maintained lower temperature water into the summer months. These moderating influences appear to be beneficial to migrating, rearing and transitional juvenile salmon.

Periods of lethally high temperature in various habitats render them seasonably unsuitable for juvenile salmon (Brown et al. 2005). Not coincidentally, many of the salmon species that use the Nooksack River estuary for early smoltification, such as chinook, chum and pink fry migrants, do so between December and May. During the warmest months of the migratory period, only the mainstem Nooksack River, its distributaries, and the nearshore environments maintain temperatures below sub-lethal limits. To ensure survival through summer months (June, July, and August), migrating salmon must reside in one of these three habitats. The limited extent of these habitats may effectively limit juvenile residency time in otherwise productive habitats. Fish that migrate rapidly from the estuary and into the nearshore environment will find a marine environment that is consistently lower in temperature than river and tidal channel habitat during warm weather.

Salinity is another aspect of water quality that defines habitat in the estuary. Saltwater intrusion into estuarine channels is critical for providing diverse transitional habitat for juvenile salmon. The further upstream the saltwater can penetrate into estuarine channels, the greater the number of habitat types that the fish will be able to use for transitioning to saltwater. In the case of the Nooksack River estuary, the maximum extent of the freshwater-saltwater interface includes side channel, distributary, and main channel habitat types through the sand flat, salt marsh, scrub-shrub and forested floodplain habitat types. The relative degree to which saltwater can penetrate the estuarine channels depends largely on the freshwater flow carried through the channel and through much of the delta salt penetrates only as far as the upstream extent of the saltmarsh. This creates refuge areas for transitioning juveniles in smaller distributaries that maintain adequate water temperature from mainstem flow and a variety of landscape types in the transition zone. The best example of high quality transition habitat occurs in Kwina Slough, where saltwater penetrates far into the forest zone of the estuary (Brown et al. 2005). Currently, the greatest saltwater penetration occurs on the Lummi Bay delta, where reduced freshwater flow creates over 3 miles of tidally influenced transitional area in the Lummi River. This area is isolated from mainstem connectivity, has poor in-stream habitat quality and water temperatures quickly approach lethal limits in the summer.

The patchwork of refuge areas throughout the estuary provides unique habitat values for a variety of species that use the estuary for different lengths of time at different times of year (Brown et al. 2005). The Nooksack estuary provides migration, rearing and transitional habitat for emigrating anadromous juveniles, as well as spawning habitat for marine species such as longfin smelt. Among the out-migrating anadromous species in the Nooksack are several stocks of chinook salmon, which are listed as Threatened under the Endangered Species Act. Estuarine habitat provides for a diversity of life-history strategies among out-migrating chinook juveniles including fry migrants, delta fry, parr migrant fingerlings and yearlings. These diverse life-history strategies help the broader stock endure disturbance events.

3. HARVEST OVERVIEW

3.1. Overview

Harvest reduces population abundances, but healthy populations can usually support substantial harvest without appreciable declines due to their high productivity. However, when harvest rates continue while population productivity declines due to reduced habitat capacity and productivity, or when harvest targets abundant hatchery fish with inadequate provisions made for co-mingled wild populations, the cumulative effect can be much greater. While rates and locations of harvest can vary, harvest to some extent has occurred for thousands of years. What has changed is the population productivities and to some extent the spatial distributions (upper Middle Fork for example), and the increase in abundances from hatchery propagation that could mask the declines of wild salmonids.

3.2. Early Harvest

It would be nearly impossible to attempt to reconstruct historical harvest rates on wild populations due to the lack of complete, specific records, because much of the harvest occurred in mixed stock fisheries, and because of the history of hatchery fish over the past 105 years. In September 1903 or 1904 an investigation up the South Fork reported excellent spawning grounds with a number of spring Chinook spawning, a number through spawning and decaying, and still others which had spawned earlier and were scattered along the river, and Indians had caught a large number of these in August and early September, and were smoking them for their winter supply (Kershaw 1904). This indicates chinook harvests were appreciable prior to any hatchery supplementation and substantial habitat declines, that this was ongoing and sustainable.

Puget Sound canneries grew dramatically in the early 1900's, and Whatcom County was number one in salmon canning (citation). Harvests were very large, but mostly in marine waters with pound nets, and it is impossible to sort out the relative contributions from individual basins, although Fraser River would have produced most of the sockeye. Undoubtedly the Nooksack River and smaller streams in WRIA 1 also contributed to these early strong catches. Pound nets were initially the means through which the majority of Puget Sound salmon catches occurred from 1913 thorough 1928, but by 1915 purse seines began to rival the pound nets (Dept. of Fisheries and Game 1930).

While habitat changes were already occurring, catch data from 1935-1948 roughly correlate to the period when hatchery releases were negligible in the

Nooksack River (and were prior to advances in survival were discovered through longer rearing). During those years the average gill net chinook catch for Nooksack River was 3,827, and the average coho catch was 14,851, while total Puget Sound/Coastal total commercial catches averaged 234,187 chinook and 669,560 coho annually (WDF 1948). Additionally, from 1938-1941 the average sport catch in Puget Sound was estimated to be 76,275 chinook and 163,350 coho annually, of which 2,000 chinook and 10,000 coho were estimated to have originated annually from the Nooksack populations (WDF and WDG 1948). Even in the absence of data from Canadian fisheries (Canada was only mentioned as having a vital economic interest in Nooksack Chinook and coho) this suggests the Nooksack River, with little to no hatchery supplementation, supported large annual Washington harvests of chinook and coho. The Washington Departments of Fisheries and Game (1948) estimated Nooksack River annual commercial salmon production contributions to in-river, Puget Sound, and Coastal commercial catches from 1938-1944 as 13,289 chinook, 73,151 coho, 22,788 chum, and 20,671 pink salmon annually, estimating that 40% of the Nooksack coho run was caught in the Coastal fishery, 13% in the Puget Sound fishery, and 15% in the river mouth gill net fishery (total Washington commercial exploitation rate of 68%), and estimating that 40% of the chinook run was caught on the Coast, and 10% of the equivalent of 10% of the in-river numeric catch was caught in Puget Sound (no clear Washington commercial exploitation rate but probably at least 50%). The chum Washington exploitation rate was estimated at 67%, evenly split between in-river and Puget Sound, and the pink salmon exploitation rate was estimated at 65%. When sport estimates are added, annual Nooksack origin chinook catches in Washington were 15,289, and coho catches were 83,151. It should be noted that commercial catches for Chinook and coho from this period are diminished from Puget Sound District catches from 1913-1928, especially for coho (Dept. of Fisheries and Game 1930).

In 1938 the Nooksack in-river steelhead commercial catch was 3,850, and the Washington Game Commission estimated the average annual Nooksack sport steelhead catch to be 1,500 (WDF and WDG 1948). The Nooksack sport catch of cutthroat was only described as several times higher than the number of steelhead taken, and the sport cutthroat were described as anadromous cutthroat. The Nooksack River ranked 5th in the state in the catch of sport steelhead in the late 1940's, and it was described as having one of the largest runs of winter steelhead in Washington (Bradner 1950). This indicates the river in the late 1930's supported catches of about 6,000 steelhead without any precipitous decline observed a decade later.

While substantial habitat changes had already occurred in much of the watershed by the mid-1930's to late 1940's, this indicates that population productivity, and the habitat to support it, was still sufficient to support substantial harvests of a high percentage of the wild run sizes without sharp declines over the period.

3.3. Harvest since 1950

During the period when there was no hatchery in the Nooksack watershed (late 1930's to 1950) fish culture techniques advanced with marking programs showing that coho and chinook survival was improved through rearing (Dept. of Fisheries 1942). Not only were larger numbers fish generally released than in the earlier years of propagation, but they also probably survived better, and included large numbers of non-native late chinook and coho. Fisheries undoubtedly began to target these hatchery returns, and co-mingled wild populations were likely harvested at rates exceeding the replacement rate, especially with reducing habitat capacity and productivity. Additionally, off-station releases of late chinook and coho were common, through the 1980's and the addition of non-native strays into wild populations while harvesting at high rates with declining habitat conditions at some point began to reduce genetic diversity for native late chinook and coho.

After the *United States v. Washington* Boldt Decision in 1974, fisheries co-management began, and the Puget Sound Salmon Management Plan was initiated. *United States v. Washington* provided the legal framework for coordinating hatchery and harvest programs, defining hatchery production and stock objectives, and maintaining treaty fishing rights though the court-ordered Puget Sound Salmon Management Plan (PSSMP). This plan outlines that escapement goals for salmon are derived for natural and hatchery management units, and if the primary management unit is determined to be the hatchery, the escapement goal is the number of spawners needed to meet the needs of the artificial production programs at the hatcheries (PSSMP 1985). Escapement goals are only established for natural stocks, and Bellingham Bay natural runs of coho and chinook (late-timed) were determined by Washington Department of Fisheries to not be viable (*United States v. Washington* Memorandum Adopting Salmon Management Plan 1977). This may have been how the primary management unit for coho and late-timed chinook in the Nooksack/Samish terminal area watersheds was agreed to be the hatchery stocks (Equilibrium Brood Document 1993), and therefore no spawning ground escapement goals were established. This is important for considering the effects of artificial propagation on abundance and genetic diversity, as the escapement goals established for coho and late-timed chinook are the number of spawners needed at the hatcheries, not specific spawning ground escapement goals. When abundant hatchery stocks are targeted for high harvest, less abundant wild stocks cannot withstand the high exploitation rates, resulting in under-escapement of wild fish (Flagg et al.NOAA technical memorandum). In contrast, to the primary management unit for coho and late chinook being designated as the hatchery escapement needs, the primary management unit for early chinook, chum and pink salmon was the natural stocks (Equilibrium Brood Document 1993).

3.4. Recent Harvest Trends

{Note: To better developed}

Nooksack early chinook management unit harvest from 1998-2000 averaged 16%, and in 2001 to 2003 averaged 17%, while in 1983-1987 the adult equivalent harvest rates were appreciably higher, estimated at 43% (post-season FRAM estimates for 1983 – 2000, preseason estimates for 2001- 2003; Table C27).

The most recent harvest distributions are shown in Tables C12 and 3.13.

Commercial fisheries directed at coho salmon, also occur throughout Puget Sound and in some rivers. Coho are also caught incidentally in fisheries directed at chinook, sockeye, pink, and chum salmon. In the last five years total landed coho catch has ranged from 107,646 to 315,124, with over 40% of the catch taken in central and south Puget Sound, and 20% taken in each of the Nooksack – Samish, and Snohomish regions (Table C14). Catch in every region has increased since 2000 relative to the late-1990's, but is still below the levels of the early 1990's, when the total harvest exceeded one million coho.

4. HATCHERY OVERVIEW

4.1. Introduction

As habitat conditions declined, wild salmon abundances and productivity (the number produced in the next generation) have diminished. As these declines occurred, tribal, state, and federal governments became increasingly dependent on artificial propagation (hatcheries) to provide a meaningful level of harvest for tribal and non-tribal fishers, and meeting tribal treaty harvest obligations that have been affirmed through Federal court rulings (HSRG 2003). Hatcheries currently provide over 80% of Washington's trout, over 90% of inland resident salmonids, 70% of salmon harvested in Puget Sound, approximately 75% of all coho and chinook, and 96% of all steelhead harvested statewide (HSRG 2003). Providing harvest opportunities is an important, legally defined role for hatcheries, for in *United States v. Washington* the court concluded:

> "The hatchery programs have served a mitigating function since their inception in 1895. 506 Supp. at 198. They are designed essentially to replace natural fish lost to non-Indian degradation of the habitat and commercialization of the fishing industry. Id. Under these circumstances, it is only just to consider such replacement fish as subject to allocation. For the tribes to bear the full burden of the decline caused by the non-Indian neighbors without sharing the replacement achieved through the hatcheries, would be an inequity and inconsistent with the Treaty." *United States v. Washington*, 759 f.2d 1353m 1360 (9th Cir)(en banc), cert. Denied, 474 U.S. 994 (1985).

Artificial propagation can also play a role in salmon recovery. Kendall Hatchery's North/Middle Fork chinook rebuilding program is an example of this in WRIA 1.

While serving a mitigating role to replace declines in natural production, hatcheries also have the potential impact native salmon and trout populations. The scientific literature indicates that artificial production risks to wild salmonid populations include: 1) genetic impacts, which affect the loss of diversity within and among populations and reproductive success in the wild; 2) ecological impacts, such as competition, predation, and disease; and 3) demographic impacts, which directly affect the physical condition, abundance, distribution, and survival of wild fish (PSTT and WDFW 2003). Hatchery impacts can also be exacerbated by fisheries management objectives for stocks, including whether or not they are managed to meet minimum spawning ground escapement goals. When abundant hatchery stocks are targeted for harvest, less abundant wild stocks frequently cannot withstand the high exploitation rates, resulting in under escapement of wild fish (Flagg et al. NOAA Technical Memorandum XX). When habitat degradation occurs this situation is exacerbated because the number of wild spawners produced in the next generation diminishes.

The history of artificial propagation (hatchery supplementation) in WRIA 1 varies tremendously by species. Species that had higher commercial (i.e. chinook, coho) or sport (i.e. steelhead, kokanee, trout) value have been propagated more extensively than other species. Early fish culture is often considered to have resulted in low survival rates, as fish culture techniques were less refined than they are today. For example, juvenile releases sometimes occurred at sizes or seasons that are now considered sub-optimal for survival, including fry releases and autumn releases. Artificial propagation has been an evolving science, and former practices had little or no knowledge about genetic uniqueness and adaptation of stocks to local conditions, and it was common practice to transfer fish within or between watersheds and from hatchery to hatchery. Discussion of hatchery factors contributing to the decline or recovery of salmonids in WRIA 1 requires a review of the diverse history of artificial propagation.

4.2. Early Artificial Fish Propagation in WRIA 1

Artificial propagation of salmon in WRIA 1 began with the Nooksack (Kendall) Hatchery on North Fork Nooksack River, which began operations in 1899. This was one of the early hatcheries in Washington, and the Samish Hatchery also started in 1899. The Samish Hatchery is relevant as there is a lengthy history of egg or fry exchange between Kendall and Samish Hatcheries. The Lake Whatcom kokanee program began in 1907 (HSRG 2003), and the original program, run by Whatcom County Game Commissioner, involved kokanee broodstock collection from several lake tributaries, then later only from Brannian Creek (Looff 1994). The only known release of non-native kokanee was with Lake Sammamish kokanee released into Lake Whatcom in 1922 (Looff 1994). Small hatchery “eyeing stations” were also established on the South Fork Nooksack River near Hutchinson Creek in 1908 (Washington state Department of Fisheries and Game 1910) and in the Middle Fork Nooksack River near, or on, Canyon Lake Creek in 1911 (Department of Fisheries and Game 1912).

At first, the Kendall Hatchery primarily took local chum as there were insufficient numbers of coho. Due to their commercial value coho were the target species (Washington Department of Fisheries and Game 1924). Kendall Creek was the adult broodstock collection site for this hatchery (Washington Department of Fisheries and Game 1914), although Norgore and Anderson

(1921) mention that the State maintained a trap at the mouth of Kenney and Bell Creeks (North Fork tributaries), and the eggs (probably coho) were taken to Kendall Hatchery. By 1913, a large increase in coho occurred, and by 1922 the number of coho exceeded Kendall Hatchery's capacity and chum were simply passed upstream (Washington Department of Fisheries and Game 1924). In 1913 Kendall and Middle Fork Hatcheries and the South Fork eyeing station respectively released chum, coho, and steelhead; chum and coho; and coho (Washington Department of Fisheries and Game 1913). By 1914 the egg eyeing station on the Middle Fork was replaced with a hatchery, and eggs were shipped into Kendall Hatchery and Middle Fork Hatchery from other, unspecified hatcheries, and eyed eggs from the South Fork were transferred to the Middle Fork Hatchery (Department of Fisheries and Game 1914). Reportedly Kalama River and Wind River (Columbia River stocks) chinook (presumably late-timed) were released between 1914 and 1925, but no eggs were taken from returning adults (WDFW and PSTT 2003). Operations were abandoned at the South Fork egg eyeing station in 1915, and after 1922 the Middle Fork Hatchery did not spawn fish (coho, chum), but did hatch the excess fish transferred there from Kendall Hatchery (Washington Department of Fisheries and Game 1924).

Small numbers of steelhead were also cultured in the early years at Kendall Hatchery, and from 1909-1939 steelhead were spawned each year with the number of females spawned varying from a low of 6 to a high of 76 (Ernst, Washington Dept. of Game 1950). Norgore and Anderson (1921) report that Kendall Hatchery steelhead broodstock was collected from Racehorse Creek, which is a large tributary located on the opposite side of the river.

Prior to establishing the South Fork eying station in 1908, a field investigation of the feasibility for South Fork Nooksack chinook production occurred on Sept. 18, 1903 or 1904 (Department of Fisheries and Game 1904). Hutchinson and Skookum creeks were both considered excellent sites, with Skookum preferable, except that a substantial number of spring chinook spawned in the reach between the creeks so less would be available at Skookum Creek (State Fish Commissioner 1904). The South Fork egg eying station was apparently established to culture chinook, although in 1908 the South Fork rack was put in after most chinook had passed upriver, then log drift and shingle bolts moving during a freshet washed out the rack enabling all chinook to escape (Washington Department of Fisheries and Game 1908). Due to the immense quantity of shingle bolts driven down the South Fork they decided to rack Hutchinson Creek instead, and it furnished all the "fall" salmon needed as well as a few chinook (Department of Fisheries and Game 1911). In 1914 six South Fork creeks were racked to obtain broodstock, with Skookum Creek being most promising.

Kendall Hatchery releases at Nooksack from 1925-1930 indicate chinook, coho, chum, and steelhead propagation, with most, but not all, eggs taken from fish collected from the Kendall Hatchery, rather than imported from other hatcheries (36th and 37th annual report 38 and 39 annual report and 40th and 41st annual report-Division of Fisheries). Kendall Hatchery was destroyed by a fire in 1934, and replaced with a modern hatchery with an improved water system and six concrete rearing ponds (*need citation page*). Records for 1935-1937 indicate egg takes of chinook, coho, chum, steelhead, and pink salmon (pinks during odd years), although in 1935 it was noted that success was lower than at other hatcheries. By 1938 only modest numbers of chum, coho, and steelhead were propagated, and only steelhead in 1939, when Kendall Hatchery was among the hatcheries closed due to doubtful efficiency, water supply issues, and inadequate funding (*need to track down citation page*). While no Nooksack River hatchery operated during the 1940's, the Nooksack River is among the streams that received what were probably small releases from Samish Hatchery in at least the mid and late 1940's (*need to track down citation page*).

4.3. Artificial Propagation in WRIA 1 since 1950

4.3.1. Chinook

While Kendall Hatchery restarted operations after 1950 with spawning local coho and pink salmon, this was not the case for chinook. After the very small egg take of what was likely two early-timed and two late-timed female chinook in 1951 (Washington Department of Fisheries 1952), much larger chinook releases began in 1953 with late- timed chinook from Spring Creek (Lower Columbia River) released from Kendall Hatchery (Young and Shaklee 2002). After this, late-timed chinook production at Kendall Hatchery essentially was reinitiated with Green River stock (1954-56, 1963,1966, 1967, 1970, 1971, 1976, 1978-1982), and Samish Hatchery stock, which obtained its original broodstock from Green River (1955, 1957, 1959, 1964, 1972, 1976, 1977, and nearly annually through 1995). Late-timed chinook that returned to Kendall Hatchery were also spawned from 1955-1965, and 1967-1994. Releases into the South Fork Nooksack River occurred from Kendall Hatchery in 1957, 1959, 1961, 1962, 1964, 1965, 1969, 1970, 1975, and 1976 (Young and Shaklee 2002). Skookum Hatchery released late-timed chinook into the South Fork from 1974-1985 and in 1987 (Young and Shaklee 2002).

Kendall and/or Samish Hatchery late-timed chinook were also formerly released from Bellingham Technical College's Maritime Heritage Hatchery into Whatcom Creek starting in 1985 (Myers et al. 1998), and chinook releases from this facility to Whatcom Creek ended in 2001 with releases from Squalicum Harbor net pens (Pacific Fishery release records-*get exact citation*). The Kendall Creek hatchery late-timed Chinook program was terminated in 1998 due to concerns with hybridizing with native Nooksack Chinook (HSRG 2003). Releases in 1996-1998 were to the lower Nooksack River (Young and Shaklee 2002).

In 1993 late-timed chinook release goals were 5.0 million fingerlings released from Kendall Hatchery, 2.0 million into the lower Nooksack River and 2.0 million to Lummi Bay, 5.2 million fingerlings to the Samish River, 700,000 to Whatcom Creek, 100,000 to Padden Creek, 50,000 to Squalicum Creek and 75,000 to Squalicum Harbor (Equilibrium Brood Document 1993).

Currently all late-timed chinook releases in or near the Nooksack River are from broodstock collected at the Samish Hatchery, then released into the lower Nooksack River and Lummi Bay or from the Samish Hatchery. Releases are limited to 4.0 million fingerlings and 100,000 yearlings to the Samish River, 500,000 fingerlings to lower Nooksack River and 500,000 fingerlings to Lummi Bay (WDFW and PSTT 2003).

In contrast to this extensive post 1950 use of non-native broodstock for late-timed chinook, early-timed chinook releases included small numbers of Sol Duc early-timed chinook in 1977, 1978 and 1980 (Young and Shaklee 2002). Then the North Fork early-timed chinook run rebuilding program began with a 1981 release of early chinook collected from North Fork early-timed chinook (WDFW North Fork Nooksack Chinook Restoration Program HGMP). The initial broodstock was collected from 1980-1984, at Wick's Slough at RM 46-47 and has been maintained from adult returns to Kendall Hatchery since then (WDFW and PSTT 2003). Abundances were very low when the program began and this rebuilding program has steadily increased the number of adult returns. As returns increased the program expanded to include off-station release strategies in addition to releases at the hatchery, the first of which was in 1988 at a temporary river enclosure near Boyd Creek (WDFW and PSTT 2003).

To track performance of the different release strategies Kendall Hatchery began differentially marking the juvenile releases by release location through unique otolith marks created by chilling incubating eggs or young fry at different temperatures for short periods starting with the 1992 brood (Kirby 2002). This creates distinct patterns on the otolith (ear bone) that is distinguishable the rest of its life. Acclimation sites used in recent years have included Kidney Creek (in Canyon Creek drainage), Deadhorse Creek, Excelsior tributary, Excelsior side-channel, remote site incubators (RSI's) and more recently Middle Fork releases. Duration of the hold times prior to release has varied from none to up to about a month. Beginning in 2000 adult returns surplus to program broodstocking needs have been transported back to the North or Middle Forks and released to spawn in the wild (WDFW North Fork Nooksack Chinook Restoration Program HGMP 2003).

With the significant increase in returns due to this program, a small percentage of the returns were detected as strays into the South Fork with significant detections first occurring in 1999 (Kirby 2002). Analysis of otoliths shows that a significant percentage of early-timed South Fork spawners have been Kendall program strays each year since 1999. While the Kendall program stray rate has been low, the South Fork early-timed chinook population is quite small (and not artificially propagated), so this led to a co-manager evaluation of survival and return locations for the various release strategies used in brood years 1996 and 1997 (Kirby 2002). As virtually all releases strayed to some extent to the South Fork, the Kendall rebuilding program release goal was reduced from 2.1 million to 800,000 beginning with the 2003 release to address straying concerns into the South Fork Nooksack, and North/Middle Fork rearing capacity concerns. As on-station releases from Kendall Hatchery strayed at somewhat higher rates than off-station releases from acclimation sites due to higher survival, the station releases were decreased the most. The analysis also showed that a much higher proportion of off-station releases spawned naturally than Kendall on-station releases, which mostly returned to Kendall Hatchery.

The Skookum Creek Hatchery attempted a rebuilding program for the South Fork early-timed chinook population beginning with releases in the early 1980's and ending in the early 1990's (Young and Shaklee 2002). The release goal was 100,000 juveniles. Adult mortality, low returns from juvenile releases, and broodstock collection problems led to termination of this program (WDFW and PSTT 2003).

The Chilliwack River hatchery (in British Columbia) was built in 1980 and is located approximately 20 km downriver of Chilliwack lake. As there was no indigenous "white" (late-timed) chinook in the Chilliwack river, a late stock from Harrison River was used for the initial broodstock and returns continue to be propagated (Peter Campbell, DFO, Chilliwack River hatchery operations manager, pers. comm. 2003). Additionally, an early-timed "red" chinook stock that was brought in from the Nicola River is also cultured at this facility. While there is a very small indigenous run of early-timed chinook in Chilliwack River, their numbers are considered insufficient for artificial propagation. The indigenous early timed chinook spawn about a month later than the non-native Nicola River chinook and spawn higher in the river, about 10 km downstream of Chilliwack Lake (Campbell, DFO, pers. Comm. 2003).

4.3.2. Coho

In 1950 Kendall Hatchery again commenced operations, with the first eggs taken in 13 years at the trap (Department of Fisheries 1950?). In 1951 Kendall egg takes included local coho (Department of Fisheries 1952). Coho eggs were again taken at Kendall in 1952 and in 1953, showing initial broodstock use was from local fish (Department of Fisheries 1954). However, various non-native hatchery-origin stocks, including Baker (Skagit), Skagit, Skykomish and Dungeness coho, were released into Kendall Creek on the North Fork Nooksack between 1952 and 1992 (WDFW 2003). No out-of-basin coho have been released at Kendall Hatchery since 1992 (WDFW Kendall Creek Coho HGMP). Between 1950 and 1992 out of basin coho stock transfers to Nooksack River occurred from Samish and Skagit stocks in 15 years (each), although more than ten times more coho released were from Skagit Hatchery stock than Samish stock (Weitkamp et al. 1995). Occasionally other coho stocks were released into the Nooksack basin including Skykomish (four years), Green River (three years), and Sol Duc, Cascade (Oregon), and Kalama Falls stocks (one year each) (Weitkamp et al. 1995). Overall, over three times more Skagit Hatchery stock coho have been released into the Nooksack River since 1950 than all other out-of basin sources combined.

These releases were not all from Kendall Hatchery production, as Skookum Creek Hatchery began coho propagation in 1977, and has operated continuously since then (Lummi Nooksack Hatchery Coho HGMP 2003). Many out-of-basin coho stocks were initially included for Skookum Hatchery coho, but the 1987 and 1988 coho brood year classes were destroyed as a precautionary move to a viral detection (Lummi Nooksack Hatchery Coho HGMP 2003). New broodstock was brought in, and since then all coho broodstock have been from returns to Skookum Hatchery, except for receiving surplus coho from Kendall Hatchery one or more years.

Kendall Hatchery release goals in 1993 were 1.3 million on-station yearling coho, 2.0 million fingerling coho to various tributaries in the Nooksack drainage, and if available, 773,000 eyed eggs transferred to various schools or regional enhancement groups for release into Haynie, Reservoir, Fishtrap, Deer, Terrell, Silver, Squalicum, and Connelly creeks (Equilibrium Brood Document 1993). Current releases are a maximum of 300,000 on-station yearling coho, and about 177,000 eyed eggs to schools and regional enhancement groups for various off-station releases including 100,000 to Fishtrap Creek.

Skookum Hatchery releases outlined in 1993 included two million station releases of yearling coho to the South Fork, two million for release into Lummi Bay, and a million fingerlings evenly divided for release to Bells, Racehorse, Kenny and Hutchinson creeks (equilibrium Brood Document 1993). Current releases are a maximum of one million yearling coho to the South Fork, one million to Lummi Bay, and no fingerling releases (Lummi coho HGMP 2003).

A small coho program also exists at the Maritime Heritage Hatchery on Whatcom Creek. This program started in 1979 and releases coho that are transferred from Kendall Hatchery (WDFW Whatcom Creek Coho HGMP 2003). This program is currently limited to 5,000 yearlings released to Squalicum Harbor to teach net pen fish culture. The program was formerly much larger, with a goal of 75,000 released into Whatcom Creek, 100,000 into Squalicum Harbor, and 400,000 into various Nooksack tributaries (Equilibrium Brood Document 1993).

In the early to mid 1990's Kendall, Skookum and Maritime Heritage hatcheries routinely released fry or fingerlings into various Nooksack and Independent streams. The collective off-station coho release goals described by co-managers in 1993 for these three programs totaled 3.4 million coho released to tributaries in the Nooksack watershed (Equilibrium Brood Document 1993). Off-station releases are now limited to the 177,000 from Kendall for school programs and regional enhancement groups and the 5,000 to Squalicum Harbor.

Coho fry from Kendall Hatchery were also released into the Sumas drainage in the 1970's (Don Hendrick, WDFW pers. comm. 2003). These releases ended in 1985 and were unfed fry whose survival was thought to be poor (WDFW 2003). No genetic analysis has been done on Sumas/Chilliwack coho spawning in Washington, and the relationship of this stock to other Fraser-system coho is unknown (WDFW 2003). Sumas/Chilliwack coho are considered a native stock with wild production, although coho ascending through Chilliwack Lake may be of mixed wild and hatchery origin (WDFW 2003). The Chilliwack River Hatchery (in British Colombia) has propagated coho, using indigenous broodstock from Chilliwack River, for at least 20 years (Peter Campbell, DFO, pers. comm. 2003). So while upper Chilliwack River coho may include hatchery fish they are fish native to the Chilliwack River.

4.3.3. Steelhead

While early steelhead artificial propagation at Kendall Hatchery used native fish through 1939, the Department of Game began stocking hatchery smolts annually into the Nooksack River in 1972, using broodstock from Chambers Creek in southern Puget Sound (WDG 1983). This stock has been selectively bread for early return run timing, and most adults return to Nooksack in December and January (WDG 1983). Kendall Hatchery steelhead re-initiated in 1978, also using Chambers Creek origin early return steelhead (HSRG 2003), with eggs supplemented from Skagit and Bogachiel broodstock, which also utilize Chambers Creek source broodstock. While releases had been to the North and Middle Forks in recent years, in 2003 WDFW shifted the total 150,000 release to the North Fork at Kendall Creek, for a variety of reasons including inability to consistently obtain enough broodstock at Kendall Hatchery, an avulsion shifting most Middle Fork water away from the side-channel used for release which created the potential for stranding and residualization, and to minimize genetic concerns. Maritime Heritage Hatchery on Whatcom Creek began a small steelhead program in 1979, also releasing Chambers Creek origin winter steelhead obtained from Kendall, Tokul Creek, or Bogachiel Hatcheries. Current release goal is 5,000 yearlings (WDFW Whatcom Creek HGMP).

The Chilliwack River Hatchery (in British Colombia) also propagates steelhead, but instead of using an introduced stock selected for early run timing, they use local broodstock originally collected from Chilliwack River steelhead across the full run timing (December through April) (Peter Campbell, DFO, pers. comm. 2003).

There have apparently been no releases of summer-run steelhead into WRIA 1 streams including the South Fork Nooksack River.

4.3.4. Chum

Kendall Hatchery restarted a chum program using broodstock from native North Fork Nooksack chum in 1978, and the release has been supported by returns to Kendall Hatchery. This program is now terminated (HSRG 2003), although Kendall Hatchery is continuing to provide chum eggs to Maritime Heritage Hatchery on Whatcom Creek to replace their former broodstock which came from Samish Hatchery. The Maritime Heritage Hatchery chum program started in 1979, and is continuing to convert to use of North Fork Nooksack chum broodstock, as the Samish chum stock is considered a mixture of native and non-native origin due to past hatchery releases including Quilcene and Hood Canal chum releases (WDFW 2002). After 2003 this transfer will be complete and broodstock will no longer be collected at Kendall hatchery. Chuckanut, Whitehall (Colony Creek tributary) Oyster, and Dakota Creeks have also had non-native chum releases (WDFW 2003), and Maritime Heritage Hatchery also had a goal of releasing chum to Padden and Baker Creeks (Equilibrium Brood Document 1993). Kendall hatchery chum broodstock was also used by the Nooksack Tribe for incubation and rearing at Rutsatz Creek staring in 1980 (Nooksack Rutsatz Slough Chum HGMP 2000), and for hydraulically planting eyed eggs in other creeks including Anderson Creek (Nooksack Fish and Wildlife Dept. 1990). Kendall chum broodstock were also used for other off-station releases, for example for in Smith Creek. There is currently no artificial propagation of chum in the Nooksack drainage, and Maritime Heritage Hatchery releases are a maximum of 2.0 million chum to Whatcom Creek (PSTT and WDFW 2003).

Chilliwack River Hatchery (in British Colombia) also cultures chum, using indigenous broodstock from the Chilliwack River (Peter Campbell, DFO pers. comm. 2003).

4.3.5. Pink salmon

When Kendall Hatchery restarted operations in 1950 they cultured pink salmon in 1951 and 1953 from local broodstock (WDF 1952; WDF 1954). However, in 1977 the Washington Department of Fisheries conducted an egg box program in Gallop Creek using 800,000 non-native pink salmon from Hood Canal Hatchery (Shaklee 2001). In 1993 Kendall Hatchery had a goal of taking eggs from pinks returning to the hatchery for use by regional enhancement groups within the Nooksack watershed (Equilibrium Brood Document 1993). There is no longer a pink salmon program at Kendall Hatchery. The only pink salmon that are currently artificially propagated in WRIA 1 are at Maritime Heritage Hatchery. This facility began a pink salmon program in 1997 with broodstock collected from the Middle Fork Nooksack River that year and in 1999 (HSRG 2003). This program uses returns from these releases to Whatcom Creek, and has a maximum release of 1.0 million pink fry into Whatcom Creek (PSTT and WDFW 2003).

There is no artificial propagation of even-year pink salmon in WRIA 1 and the small numbers observed for the past three brood cycles appear to be colonizing on their own, similar to other North Puget Sound rivers such as the Snohomish, Skagit and Stillaguamish Rivers.

4.3.6. Other salmonids

Bull trout and Dolly Varden trout have never been artificially propagated in WRIA 1 as they have not traditionally been considered highly regarded as sport or commercial salmonids.

There has apparently been no history of sockeye artificial propagation in WRIA 1 streams (Gustafson et al. 1997). In the Chilliwack River drainage, the Department of Fisheries and Oceans has initiated a captive brood program using indigenous sockeye from Sweltzer Creek (Peter Campbell, DFO, pers. comm. 2003). Sweltzer Creek lies between Cultus Lake and the Chilliwack River, and the intent is to save this small run of indigenous sockeye that reached a low abundance of perhaps 50 adults. These will be released to Cultus Lake.

Lake Whatcom kokanee continue to be cultured at WDFW's Lake Whatcom Brannian Creek hatchery, for release back into the lake to provide fishing opportunities, to obtain future broodstock and for release into about 36 lakes in Washington annually (Parametrix 2003). The egg take goal is 13 million, and if adequate numbers are collected they are transferred to Idaho and California as well (2003 future Brood Document). The WDFW Bellingham Trout Hatchery regularly stocks lowland lakes in Whatcom and Skagit Counties with catchable trout, and regularly stocks at least 14 lakes each year with rainbow trout fry

(Parametrix 2003). The original broodstock was apparently collected in California.

An anadromous cutthroat hatchery program in Puget Sound was started in 1973 using Stillaguamish and Hood Canal cutthroat, but this program was discontinued in the late 1970's (WDFW SASI 2000). In 1949 non-anadromous wild cutthroat were caught from Lake Whatcom tributaries, and placed in a captive brood program at the Tokul Creek Hatchery in the Snoqualmie River drainage. This strain of cutthroat has been widely released in western Washington streams, lakes, and beaver ponds, but presently resident cutthroat releases are limited to lakes and ponds that are not directly accessible to anadromous fish (WDFW SASI 2000). This stock was released back into Lake Whatcom in the late 1990's in an attempt to boost abundances, but this was discontinued after 2000 due to increased numbers of fish observed on the spawning grounds (Mark Downen, WDFW, in litt. 2004).

A number of non-native trout species have been released in streams, lakes and ponds in WRIA 1 over the years. While brook trout have historically been propagated and released into local lakes, including high elevation lakes, they are no longer propagated for release in WRIA 1 (Mark Downen*, in litt.* 2004). While no longer artificially propagated they are successfully established in some areas downstream from their probable release locations including the upper North Fork Nooksack. Brown Trout have been introduced into Squalicum Lake (Anchor Environmental 2003). In 1900 lake trout were released to Lake Whatcom and in 1915-1916 Beardslee trout fry (sub-species of rainbow trout) were released there (WDNR 1997).

5. HYDROPOWER OVERVIEW

5.1. Nooksack River watershed

5.1.1. Middle Fork Diversion

The City of Bellingham operates a water diversion facility on the Middle Fork Nooksack River (river mile 7.2) that diverts water to Lake Whatcom to augment the city's municipal water supply. The diversion dam is 12 to 14 feet high and was built in 1960 without provisions for fish passage. The dam is located approximately 250 feet upstream of Box Canyon, a 0.8 km (0.5 mi) bedrock gorge that is considered passable at discharges below 1000 to 1500 cubic feet per second, based on limited numeric modeling of discharges and velocity refuges continuing to exist behind large boulders (Zapel, pers. comm., 2003). There are no other natural barriers to adult migration in the Middle Fork Nooksack River to at least river mile 17.5, approximately 0.4 kilometers (0.25 mile) upstream of Ridley Creek, and the average gradient over its lower 17.4 miles is 2.4% (STS Heislers Creek Hydro L.P. 1994). The lowest gradient river reach upstream of the dam is between Clearwater and Wallace Creeks, averaging 2 to 3 percent (STS Heislers Creek Hydro L.P. 1994). Habitat in the Upper Middle Fork Nooksack River is generally believed to be in good and improving condition, since 90 percent of the area is managed under U.S. Forest Service Late Successional Reserves or Washington Department of Natural Resource's Habitat Conservation Plan (Currence 2000).

Salmon and trout, including a pink salmon, what were presumably chinook and steelhead, what appeared to be a bull trout, and possibly a coho (based on November timing), have been incidentally observed jumping at or over the diversion dam in 1986, 1992, 1993 (STS Heislers Creek Hydro L.P. 1994; Currence 2000), and in 2001 (Manuel del Corral, *in litt*. 2001; E. Zapel, Northwest Hydraulics Consultants, *in litt*. 2001). Additionally, there are anecdotal reports of early timed chinook use in the upper Middle Fork in the 1930's and 1940's (STS Heislers Creek Hydro L.P. 1994), and coho were also reported to use the upper Middle Fork (B. Kelly Sr., pers. comm. 2000, D. Huddle pers. comm. 2000). While two of these adults were observed successfully getting over the dam, the dam essentially precludes use of the upper Middle Fork by anadromous fish. It also separates a once connected population of bull trout into two separate groups, one primarily isolated above the facility and one containing anadromous bull trout below.

While the diversion dam does not have a reservoir behind it, nor interrupts routing of sediment or large woody debris, it blocks most upstream migration and use of the majority of the Middle Fork's former habitat for chinook, anadromous bull trout, steelhead, and probably coho. Potential chinook and steelhead habitat has been estimated to extend to the confluence of the Middle Fork and Rankin Creek (9 miles above the diversion dam), and Clearwater, Warm and Wallace Creeks were also considered suitable for chinook (STS Heislers Creek Hydro L.P. 1994). Total former chinook habitat lost has been estimated at 11.8 or 14.3 miles (Currence 2000). An additional 1.6 miles of habitat was considered coho habitat, and Sisters Creek is suitable for chinook. Recent surveys of additional tributaries have found additional streams that are suitable and accessible for anadromous fish, such as Ridley Creek (Nooksack Tribe, unpublished data). While a pink salmon was observed jumping at the dam in 1993, chum and pink salmon are not expected to have substantially utilized the upper Middle Fork, due to their reluctance to ascend the cascades and in Box Canyon.

While the diversion dam is screened, these are not to current standards, and may entrain outmigrating juvenile fish including bull trout. Additionally, 67 cubic feet per second is diverted from the river when in operation (and initially more when first diverting), and the current facility does not have the ability to ramp changes in flow. This may adversely affect salmonids in reaches downstream through stranding juveniles. The degree of downstream stranding and even redd loss from not ramping were likely higher in the past, when instream flow requirements were lower than currently agreed upon, while the same quantity of water was being diverted. Increased temperatures in the lower Middle Fork may have also resulted. The lower Middle Fork is currently included on the Department of Ecology's 303(d) list. The diversion of water may also contribute to thermal problems in the lower river, or even the lower North Fork and mainstem, although low instream flows during this period may preclude diverting water.

While substantial increases in minimum flows in the lower Middle Fork have resulted from voluntary agreements between resource agencies, the Tribes and the City in recent years, the recommended flows do not explicitly consider the needs of either listed species (chinook or bull trout), and almost certainly need to be revised for both, as the agreed to minimum instream flows are lower during the period when chinook spawning occurs, and change during the period when bull trout spawning would be expected (need to double check 1993 agreement). Diverting water during earlier years when less instream flow was agreed to be retained in the lower Middle Fork likely substantially reduced salmon production as the water right issued to the City required very little (10 to 15 cfs) be retained.

The diversion pipeline that carries the water to Mirror Lake was buried under the South Fork Nooksack River and Hutchinson Creek, but without adequate accommodations for channel migration. Riprap placed to protect the pipeline where it crosses the South Fork (upstream from the Hutchinson Creek confluence) constrains the South Fork channel migration area width from 1200 feet to 200 feet, effectively halting the downstream migration of two meanders and severely impacting habitat-forming processes in the reach (Maudlin et al. 2002). The pipeline crossing of Hutchinson Creek further upstream also did not provide for channel movement, and rock was placed in 2003 to protect the pipeline.

5.1.2. Excelsior/Nooksack Falls hydropower facility

At Excelsior/Nooksack Falls (North Fork Nooksack River), there is a very old hydropower facility that was damaged in a fire in the 1990's, and abandoned, but restarted in 2003 without appreciable upgrades which are needed to adequately protect salmon and anadromous and resident trout. The intake is located upstream from Nooksack Falls, and the powerhouse and tailrace are located on the North Fork Nooksack River downstream of Wells Creek. The facility, as it is currently operated, probably impacts salmonids in several ways. First, the facility lacks tailrace protection to exclude fish that are likely to be attracted to it. Pink salmon have been observed congregating in the tailrace outfall flow when the facility was formerly operating (D. Schuett-Hames, Cooperative Monitoring and Evaluation Committee, pers. comm., 2003). Additionally, minimum instream flows need to be established and implemented to assure that all life stages of anadromous salmon and trout are adequately protected. The facility also does not ramp changes in flow, and likely strands juveniles downstream when operations cease, and possibly fish within the bypass reach when operations commence. The bypass reach appears to be an adult staging area for bull trout, and spawning may also occur in this reach. It is unclear what volume of water is diverted through the penstock, or what volume is retained in the bypass reach including the contribution from Wells Creek, so the magnitude of impact is currently unclear. The water intake above the falls also lacks adequate screening to prevent entrainment of resident fish. The company currently operating it maintains the facility is grandfathered, and exempt from FERC jurisdiction. FERC recently issued a draft navigation report calling the river navigable to Nooksack Falls, which would trigger FERC jurisdiction, and another party is pursuing a FERC license to operate it, but thus far FERC has not made a decision on the final navigation report, abandonment, or on operations on Federal lands, any of which would lead to a requirement of FERC licensing.

5.1.3. Small hydroelectric facilities

While the number of small hydroelectric facilities in salmonid streams is comparatively small in WRIA 1, they do exist in a few areas including Kenney Creek and Sygitowicz Creek. A substantial number of projects have been proposed in recent years in fish bearing portions of important salmon and trout streams, including Glacier, Wells, Boulder, Canyon, Clearwater, Warm, and Skookum Creeks. While these proposals have not been granted licenses to date, the interest in small hydroelectric production is likely to continue. If facilities are proposed in salmonid streams, they are likely to be detrimental to fish.

Existing small hydroelectric facilities in salmonid streams need to have instream flows, ramping, and other operations revisited, with improvements and revisions made as appropriate to avoid impacting salmonids. Instream flow requirements need to be adhered to. The facility on Sygitowicz Creek is in an unusual setting in that the intake generally retains flow during the summer while the tailrace area dries up. Dead juvenile rainbow trout/steelhead have been observed in the tailrace where it dried up, after diversion operations ended and water again flowed in Sygitowicz Creek (Nooksack Tribe, unpublished data). There is apparently no ability to ramp changes in flow when operations start or stop. Existing small hydroelectric facilities located in salmonid streams should be evaluated and facility upgrades made and operations adjusted as necessary to avoid any impacts to salmon and trout. Specific areas to evaluate include ramping changes in flow, screening (if salmon or trout are present at the intake), minimum instream flows and how these are determined, and tailrace protection.

5.2. Fraser River Tributaries

5.2.1. Sumas pump station

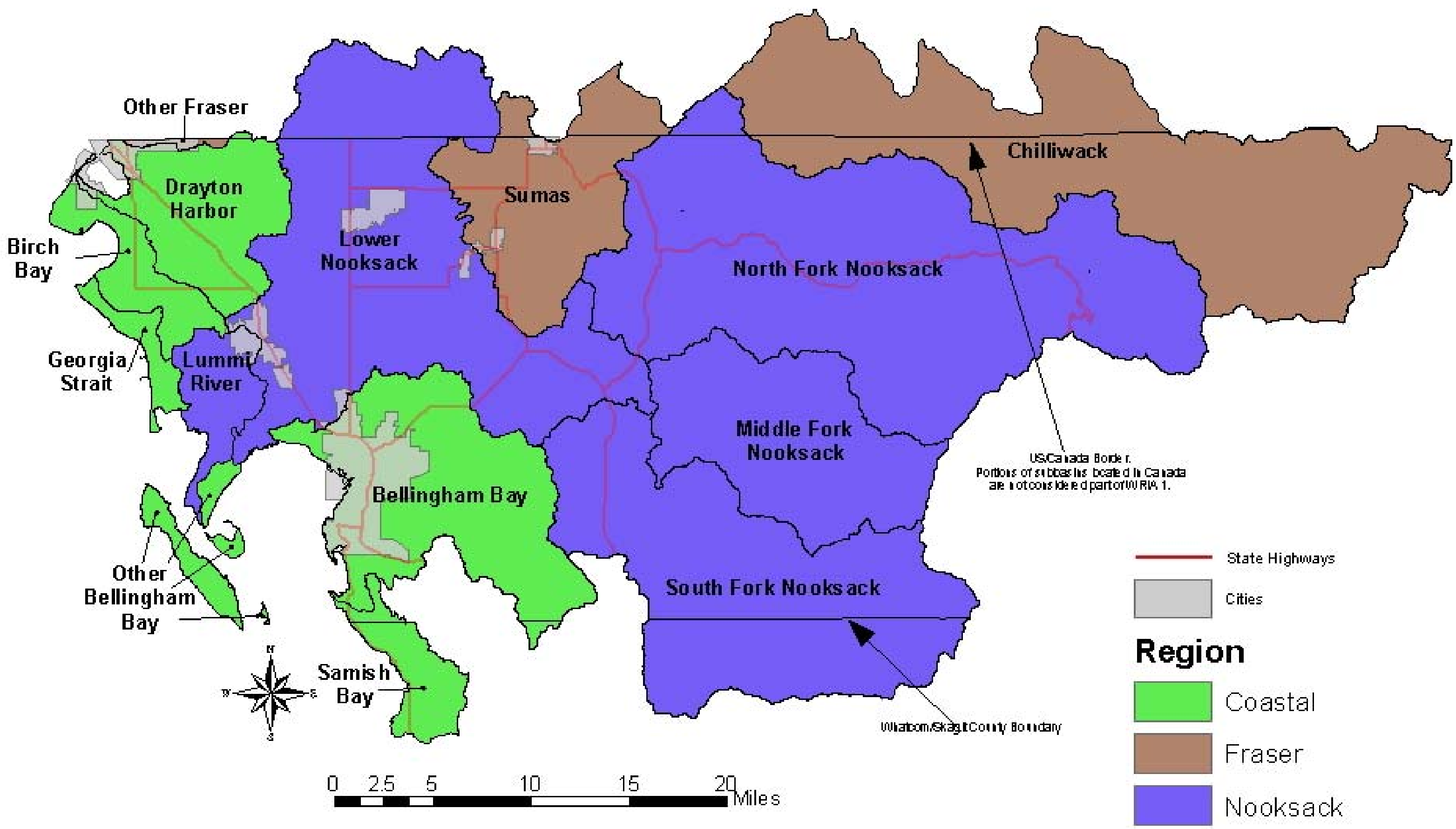
Between 1919 and 1923, Sumas Lake was drained for flood control and to create additional farmland. At low water, the lake covered 3,200 to 4,000 hectares (8,000 to 10,000 acres), but grew to as much as 12,000 hectares (30,000 acres) when the Fraser River was in flood (Carlson et al. 2001). The size and shape of the lake rarely appeared the same on early maps and freshets frequently tripled the size of the lake each year (Carlson et al. 2001). An elaborate system of pumps, dikes and canals drained all the water from the lake, enabling the fertile lake bottom to be farmed. In addition to the loss of the lake, the low elevation of the Sumas Prairie (the bed of the former lake), and potential for flooding of it from the Fraser River or Vedder Canal, have led to a complicated water management system in Canada to prevent flooding (Healey 1997).

The City of Abbotsford B.C. operates this flood control system by a network of dikes, canals and a large pump station at the mouth of the river, with floodgates closing the mouth of the Sumas River in early to mid-May to Sept. 15. During this period the Sumas River waters are pumped through the pump station and over the dike, when the Vedder Canal or Fraser River surface water elevation exceed about 3 meters elevation (Wright, Abbotsford Superintendent of Diking, Drainage, and Irrigation, pers. comm. 2003). In addition to preventing flooding, this permits Sumas River water to be used for agriculture. During years of low snowpack when spring meltoff ends earlier the floodgates still remain closed so more water is available for irrigation (Wright, pers. comm. 2003). Floodgates are reopened Sept. 15, to permit upstream migration of salmon, and left open, unless the Fraser River or Vedder Channel rise 3.5 m above the local datum (Healey 1997). During this lengthy period when floodgates are closed, or during other times of the year when flood risk leads to closing the floodgates, the resident pumphouse operator watches for adult salmon that want to move up the Sumas River milling outside the station pumphouse (Wright, pers. comm. 2003). When adults are observed, the procedure is to open the gates for three to four hours to allow fish to move upstream, and they apparently quickly do so. This has been the standard operating procedure at the pumpstation for many years. The original pump from the 1920's was replaced with a Stork pump in 1983 that operates at only 117 revolutions per minute (Wright, pers comm. 2003). The pump was selected due to its large capacity and environmental friendliness, and there doesn't seem to be much impact on downstream migrating fish as observed juvenile mortality rates are small (Wright, pers. comm. 2003).

The loss of Sumas Lake most likely dramatically impacted salmonids that utilize lakes or wetlands during one or more life history stages including coho, and possibly a former sockeye run. Additionally, during periods when the river is pumped over the dike, upstream migrating adults or foraging sub-adult bull trout cannot access the Sumas River, although if their numbers are substantial they will probably be observed and the floodgates opened to enable their migration with only temporary delays. Adults that migrate between Sept. 15 and mid-May are not delayed, unless the risk of flooding leads to unscheduled closures. This occurred in October 2003, but milling adults were observed and the gates were opened for about six hours, and the fish apparently moved upriver (Wright, pers. comm. 2003).

Another possible impact during periods when the river water is pumped over the dike is to downstream migrating salmon and trout smolts, post spawning adults (steelhead, cutthroat), or to foraging or overwintering bull trout. While observed juvenile mortality rates are low, some level of outmigrant salmon and trout mortality likely still occurs, but presumably less than before the facility improvements occurred in 1983. In recent years Canada has begun to prioritize and correct facilities for fish passage where improvements are needed, and over time any problems with this facility will probably be corrected (Brad Fanos, Department of Fisheries and Oceans, pers. comm. 2003).

Figure C1. Water Resource Inventory Area (WRIA) 1 Subbasin Areas.



Data Sources: WRIA 1 Watershed Management Project delineated subbasins; WADOT Cities (2/2002) and State Highways (6/2003).
Cartography: T. Coe, Nooksack Natural Resources, 10/23/03.

Figure C2. Precipitation and snow accumulation zones in WRIA 1.

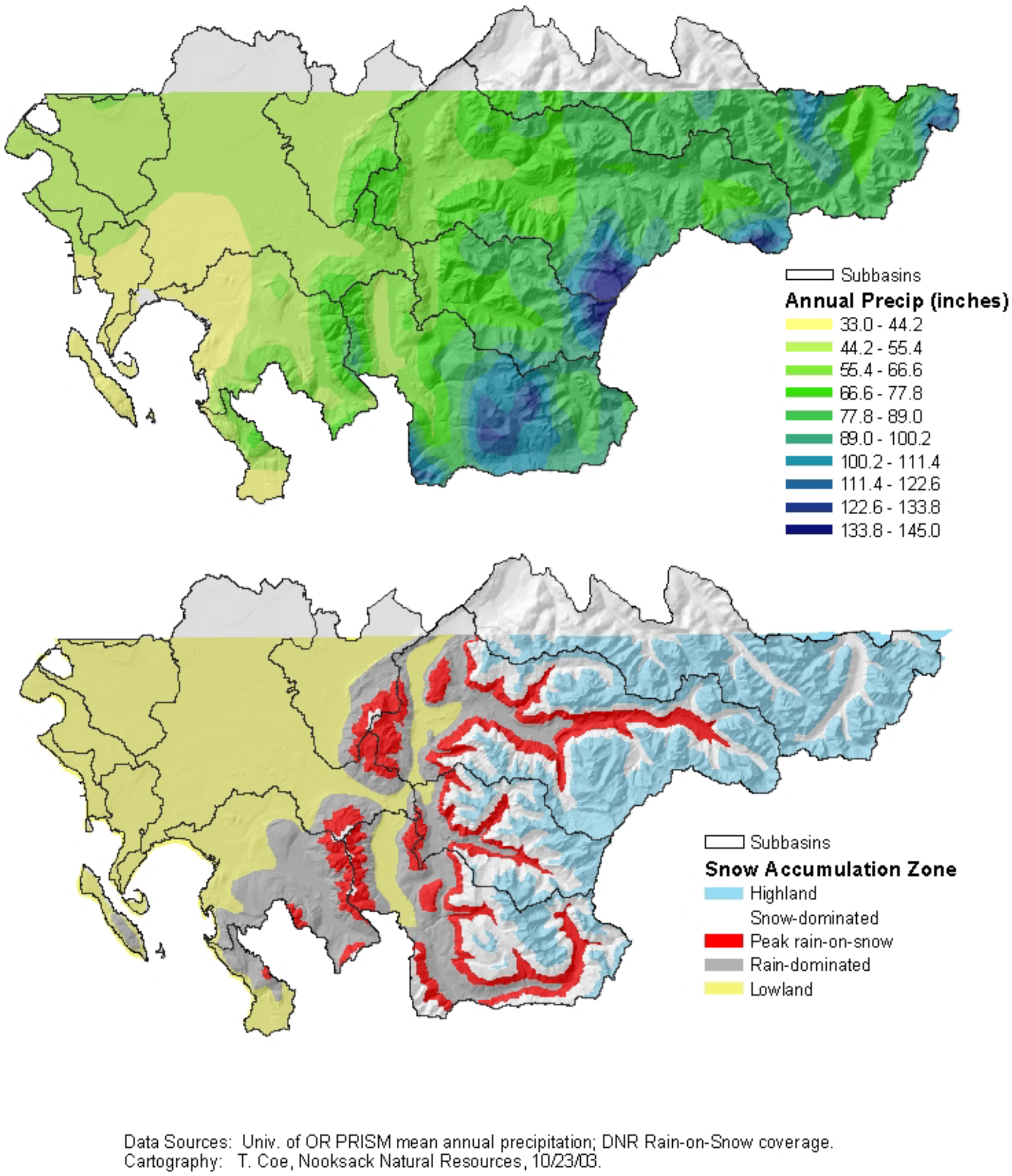
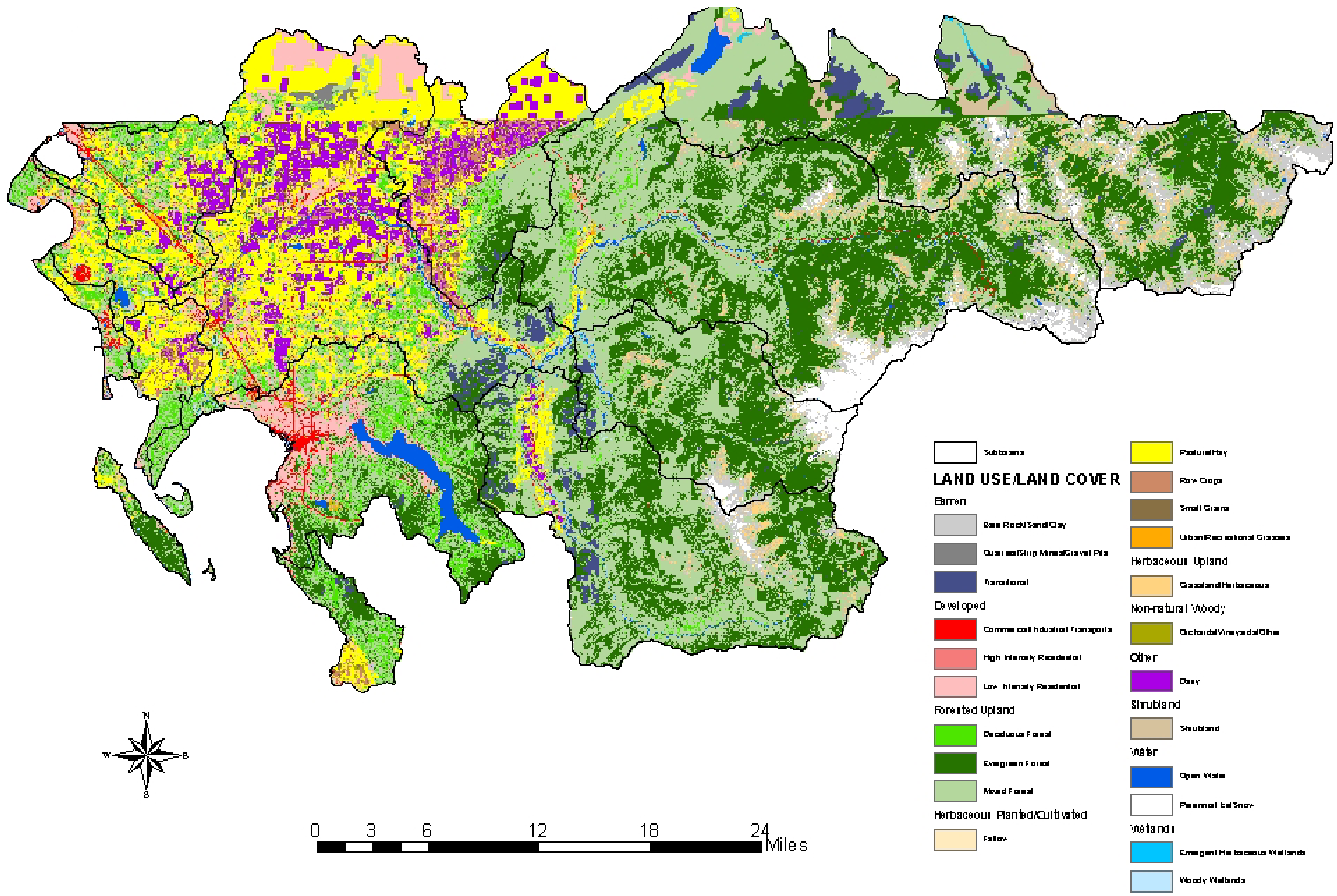


Table C1. General climatic characteristics by WRIA 1 regions and subbasins.

		Mean Annual Precipitation (inches)			Snow Accumulation Zone (% of area)				
	SUBBASIN	**Min**	**Max**	**Mean**	**Lowland**	**Rain-Dominated**	**Peak Rain-on-Snow Zone**	**Snow-Dominated**	**Highland**
Nooksack	North Fork Nooksack[1]	55	145	80	6.1%	13.6%	18.7%	20.6%	41.0%
	Middle Fork Nooksack	55	145	83	1.7%	12.4%	15.2%	34.9%	35.8%
	South Fork Nooksack	49	125	87	8.4%	24.4%	24.2%	29.0%	14.0%
	Lower Nooksack[1]	35	75	49	86.5%	8.1%	5.0%	0.4%	
	Lummi River	35	49	41	100.0%				
	Total Nooksack[1]	35	145	73	27.8%	14.3%	15.8%	19.0%	23.1%
Coastal	Drayton Harbor	43	59	50	100.0%				
	Birch Bay	45	51	48	100.0%				
	Georgia Strait	39	49	45	100.0%				
	Bellingham Bay	37	85	52	39.1%	51.3%	9.0%	0.6%	
	West Bellingham Bay	33	41	36	79.1%	20.9%			
	Samish Bay	33	75	49	56.8%	40.7%	2.5%		
	Total Coastal	33	85	50	66.1%	29.1%	4.5%	0.3%	
Fraser	Chilliwack[1]	61	119	85	0.0%	0.0%	0.0%	17.0%	83.0%
	Sumas[1]	45	79	54	68.5%	21.0%	9.6%	1.0%	
	Other Fraser	45	61	55	100.0%				
	Total Fraser	45	119	76	20.4%	6.0%	2.7%	12.3%	58.6%
	TOTAL WRIA 1[1]	33	145	69	33.7%	15.5%	11.1%	14.2%	25.4%

[1] Excludes Canada.
Sources: University of Oregon PRISM mean annual precipitation; DNR Rain-on-Snow Coverage.

3093 **Figure C3.** WRIA 1 Land Use/Land Cover.



Data Source: LULC_EX2 (WRIA WMP 2003); WRIA 1 Watershed Management Project delineated subbasins.
Cartography: T. Coe, Nooksack Natural Resources, 10/23/03.

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Table C2. Land Use/Land Cover (% of total area) by WRIA 1 regions and subbasins.

		Water		Developed			Barren			Forested Upland			Shrub-land	Non-natural Woody	Herba-ceous Upland	Herbaceous Planted/Cultivated					Dairy	Wetlands	
	SUBBASIN	Open Water	Perennial Ice/Snow	Low Intensity Residential	High Intensity Residential	Commercial/ Industrial/ Transportation	Bare Rock/ Sand/Clay	Quarries/ Strip Mines/ Gravel Pits	Transitional	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrubland	Orchards/ Vineyards/ Other	Grasslands/ Herbaceous	Pasture/ Hay	Row Crops	Small Grains	Fallow	Urban/ Recreational Grasses	Dairy	Woody Wetlands	Emergent Herbaceous Wetlands
Nooksack	North Fork Nooksack	0.74%	5.65%	0.26%	0.00%	0.40%	5.31%	0.03%	0.62%	1.36%	39.49%	38.89%	2.89%	0.01%	2.68%	1.36%	0.05%	0.03%	0.00%	0.06%	0.00%	0.14%	0.02%
	Whatcom	0.76%	5.77%	0.27%	0.00%	0.41%	5.42%	0.03%	0.43%	1.39%	40.32%	38.63%	2.95%	0.01%	2.74%	0.58%	0.05%	0.02%	0.00%	0.06%	0.00%	0.15%	0.02%
	Canada	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.82%	0.00%	0.00%	51.09%	0.01%	0.02%	0.00%	38.76%	0.11%	0.18%	0.00%	0.00%	0.00%	0.00%	0.00%
	Middle Fork Nooksack	0.55%	6.22%	0.01%	0.00%	0.03%	4.69%	0.00%	1.67%	0.62%	43.71%	37.76%	2.30%	0.00%	2.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.12%
	South Fork Nooksack	0.61%	0.59%	0.05%	0.00%	0.16%	2.60%	0.01%	3.44%	1.32%	36.15%	47.35%	1.74%	0.28%	1.81%	2.71%	0.20%	0.03%	0.00%	0.01%	0.74%	0.17%	0.01%
	Whatcom	0.54%	0.89%	0.07%	0.00%	0.23%	3.60%	0.00%	4.58%	1.17%	35.38%	43.16%	1.71%	0.43%	2.42%	4.09%	0.31%	0.04%	0.00%	0.02%	1.11%	0.21%	0.02%
	Skagit	0.76%	0.01%	0.00%	0.00%	0.03%	0.65%	0.03%	1.19%	1.60%	37.67%	55.55%	1.80%	0.00%	0.61%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%	0.00%
	Lower Nooksack	1.39%	0.00%	10.16%	0.04%	1.91%	0.42%	0.88%	2.50%	5.88%	5.02%	14.86%	0.84%	0.71%	0.60%	35.55%	3.04%	1.26%	0.01%	0.10%	14.20%	0.57%	0.06%
	Whatcom	1.68%	0.00%	5.32%	0.05%	2.36%	0.52%	0.02%	3.10%	6.66%	6.04%	16.64%	1.04%	0.88%	0.74%	31.92%	3.71%	1.55%	0.01%	0.12%	16.90%	0.68%	0.07%
	Canada	0.18%	0.00%	30.64%	0.00%	0.00%	0.00%	4.50%	0.00%	2.62%	0.72%	7.30%	0.01%	0.01%	0.00%	50.92%	0.22%	0.02%	0.00%	0.00%	2.77%	0.10%	0.00%
	Lummi River	0.36%	0.00%	6.55%	0.00%	1.87%	0.67%	0.00%	0.31%	10.17%	2.73%	15.15%	1.16%	1.72%	1.69%	37.91%	9.47%	2.08%	0.03%	0.07%	7.06%	0.99%	0.01%
	Total Nooksack	**0.86%**	**2.90%**	**3.07%**	**0.01%**	**0.76%**	**3.17%**	**0.25%**	**1.88%**	**2.75%**	**28.81%**	**33.38%**	**1.96%**	**0.31%**	**1.84%**	**11.87%**	**1.16%**	**0.42%**	**0.00%**	**0.05%**	**4.24%**	**0.28%**	**0.04%**
Coastal	Drayton Harbor	0.47%	0.00%	6.72%	0.03%	3.92%	0.14%	0.00%	0.54%	14.52%	3.81%	18.35%	1.71%	0.45%	0.91%	32.64%	2.42%	1.30%	0.01%	0.51%	10.87%	0.67%	0.01%
	Whatcom	0.47%	0.00%	6.74%	0.03%	3.94%	0.14%	0.00%	0.54%	14.59%	3.82%	18.37%	1.72%	0.46%	0.92%	32.41%	2.43%	1.30%	0.01%	0.52%	10.92%	0.67%	0.01%
	Canada	0.00%	0.00%	3.30%	0.00%	0.00%	0.00%	0.00%	0.00%	3.70%	2.50%	14.89%	1.00%	0.00%	0.00%	69.53%	1.10%	2.10%	0.00%	0.00%	1.90%	0.00%	0.00%
	Birch Bay	3.12%	0.00%	7.68%	1.41%	4.46%	1.05%	0.01%	0.35%	13.75%	4.28%	21.89%	1.12%	0.58%	1.47%	31.13%	1.59%	1.02%	0.00%	0.89%	2.63%	1.54%	0.02%
	Georgia Strait	2.19%	0.00%	7.92%	0.00%	7.36%	0.81%	0.00%	0.29%	17.67%	4.95%	28.00%	3.94%	1.18%	3.16%	18.92%	0.75%	1.09%	0.00%	0.38%	0.28%	1.02%	0.09%
	Bellingham Bay	7.46%	0.00%	15.02%	0.12%	4.99%	0.35%	0.03%	0.74%	14.42%	22.01%	26.89%	1.50%	0.02%	0.68%	4.96%	0.11%	0.09%	0.00%	0.35%	0.09%	0.16%	0.00%
	Whatcom	7.54%	0.00%	15.19%	0.12%	5.04%	0.33%	0.03%	0.75%	14.52%	21.47%	26.95%	1.51%	0.02%	0.69%	5.02%	0.12%	0.09%	0.00%	0.35%	0.09%	0.16%	0.00%
	Skagit	0.00%	0.00%	0.00%	0.00%	0.00%	1.58%	0.00%	0.06%	5.04%	71.91%	21.24%	0.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	West Bellingham Bay	1.79%	0.00%	5.65%	0.00%	0.57%	2.57%	0.00%	0.22%	14.51%	34.08%	30.56%	2.21%	0.03%	0.82%	6.09%	0.11%	0.06%	0.00%	0.00%	0.00%	0.72%	0.01%
	Samish Bay	0.44%	0.00%	2.15%	0.00%	0.37%	0.71%	0.00%	1.92%	20.01%	25.11%	29.52%	0.91%	1.29%	1.39%	11.13%	3.48%	1.21%	0.00%	0.00%	0.00%	0.38%	0.00%
	Whatcom	1.03%	0.00%	2.14%	0.00%	1.02%	0.19%	0.00%	0.17%	20.27%	38.85%	34.95%	0.31%	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.97%	0.00%
	Skagit	0.34%	0.00%	2.15%	0.00%	0.26%	0.79%	0.00%	2.22%	19.96%	22.80%	28.61%	1.01%	1.51%	1.60%	12.99%	4.07%	1.41%	0.00%	0.00%	0.00%	0.28%	0.00%
	Total Coastal	**4.19%**	**0.00%**	**10.32%**	**0.21%**	**4.12%**	**0.55%**	**0.01%**	**0.71%**	**15.01%**	**16.13%**	**24.85%**	**1.60%**	**0.34%**	**0.99%**	**15.40%**	**1.13%**	**0.61%**	**0.00%**	**0.40%**	**2.89%**	**0.51%**	**0.01%**
Fraser	Chilliwack	1.14%	3.08%	0.65%	0.00%	0.00%	10.35%	0.00%	4.96%	0.41%	34.43%	33.01%	6.97%	0.00%	4.30%	0.47%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.21%
	Whatcom	0.31%	4.62%	0.00%	0.00%	0.00%	15.53%	0.00%	1.26%	0.62%	42.10%	22.50%	6.59%	0.00%	6.44%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%
	Canada	2.80%	0.02%	1.94%	0.00%	0.00%	0.05%	0.00%	12.32%	0.00%	19.18%	53.90%	7.72%	0.00%	0.06%	1.39%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.63%
	Sumas	0.02%	0.00%	1.61%	0.00%	1.29%	0.22%	0.01%	0.91%	5.86%	12.28%	23.93%	1.82%	0.99%	0.81%	17.44%	12.22%	2.01%	0.00%	0.00%	18.25%	0.31%	0.00%
	Whatcom	0.02%	0.00%	1.61%	0.00%	1.29%	0.22%	0.01%	0.91%	5.86%	12.28%	23.93%	1.82%	0.99%	0.81%	17.44%	12.22%	2.01%	0.00%	0.00%	18.25%	0.31%	0.00%
	Canada	0.00%	0.00%	4.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.06%	3.24%	0.06%	0.09%	0.00%	75.62%	0.56%	0.07%	0.00%	0.00%	15.98%	0.00%	0.00%
	Other Fraser	0.12%	0.00%	6.78%	0.00%	1.60%	0.00%	0.27%	0.16%	42.10%	5.84%	35.87%	1.15%	0.55%	0.47%	3.92%	0.37%	0.74%	0.00%	0.02%	0.00%	0.06%	0.00%
	Total Fraser	**0.90%**	**2.41%**	**0.89%**	**0.00%**	**0.28%**	**8.15%**	**0.00%**	**4.08%**	**1.80%**	**29.59%**	**31.11%**	**5.85%**	**0.21%**	**3.54%**	**4.07%**	**2.58%**	**0.43%**	**0.00%**	**0.00%**	**3.86%**	**0.07%**	**0.16%**
	TOTAL WRIA 1	**1.44%**	**2.29%**	**3.82%**	**0.04%**	**1.23%**	**3.86%**	**0.15%**	**2.18%**	**4.65%**	**26.79%**	**31.39%**	**2.78%**	**0.29%**	**2.08%**	**10.70%**	**1.48%**	**0.45%**	**0.00%**	**0.10%**	**3.92%**	**0.27%**	**0.06%**

Source: LULC_EX2 (WRIA 1 WMP 2003); WRIA 1 Watershed Management Project delineated subbasins.

Figure C4. Current and potential/historic salmonid-bearing streams in WRIA 1.

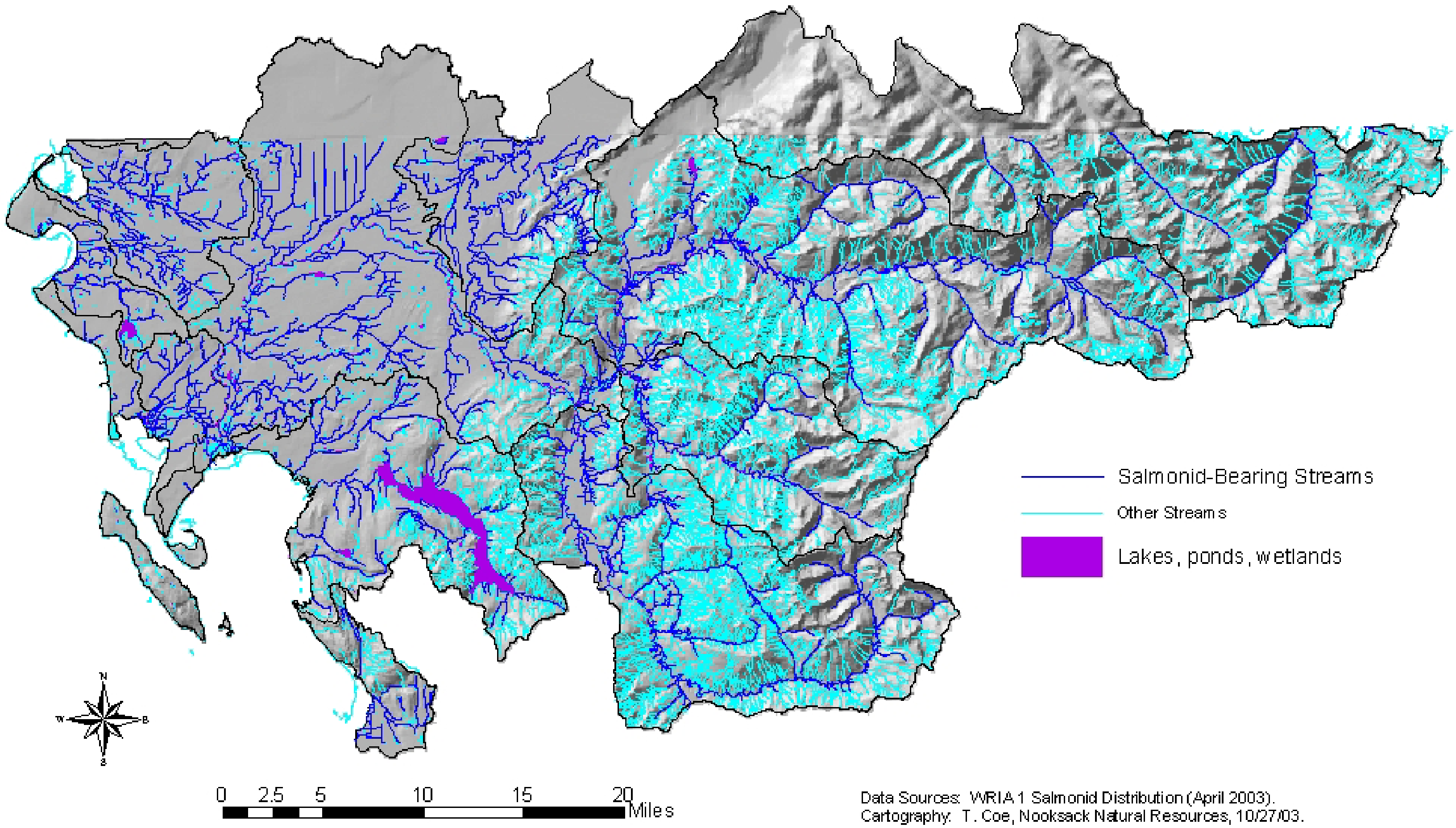
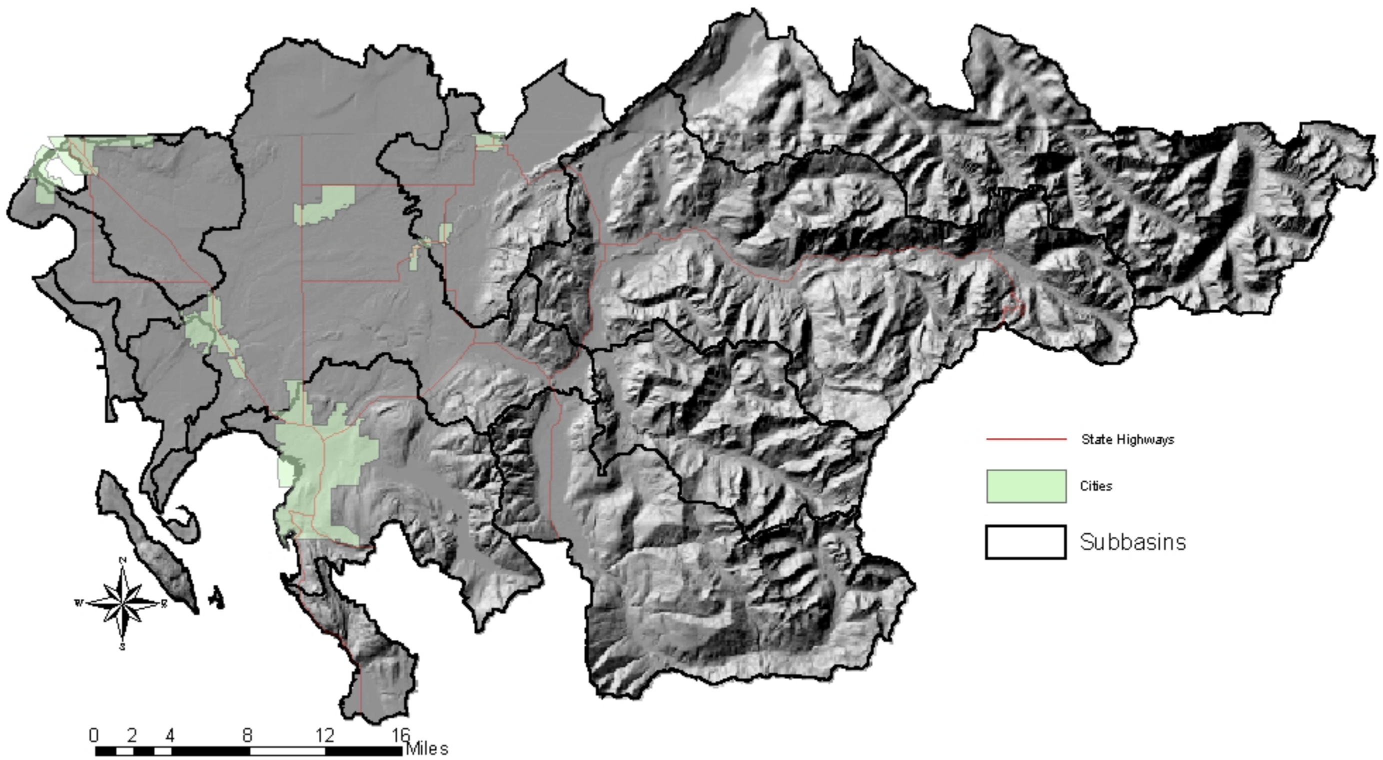


Table C3. Salmonid distribution by WRIA 1 regions and subbasins (lengths in km).

	SUBBASIN	Total Salmonid-Bearing Length (km)	Chinook Salmon		Native Char[1]		Coho Salmon		Chum Salmon		Pink Salmon		Sockeye Salmon		Steelhead		Cutthroat Trout	
			Current	Potential or Historic	Current	Potential or Historic	Current	Potential or Historic	Current	Potential or Historic	Current	Potential or Historic	Current	Potential or Historic	Current	Potential or Historic	Current	Potential or Historic
Nooksack	North Fork Nooksack	393	97	2.7	181	51	142	185	72	57	97	22	73		392	451	219	140
	Middle Fork Nooksack	121	30	22	84	14	38	87	20	9.7	29	39	23		120	178	81	31
	South Fork Nooksack	346	66	13	175	51	131	184	49	61	52	39	62		346	435	229	104
	Lower Nooksack	526	185	41	356	157	356	516	198	284	85	133	98		526	800	309	201
	Lummi River	89	17		47	38	48	86	13	73	0	0	0		88	174	20	69
	Total Nooksack	1474	396	78	843	310	714	1058	352	484	263	233	256		1473	2037	857	545
Coastal	Drayton Harbor	196	35	6.2	91	103	92	196	37	144	0	0.14	0		196	365	77	113
	Birch Bay	61	0	1	16	45	16	61	0	59	0	0	0		61	88	15	24
	Georgia Strait	9.5	0	0	2.8	6.4	2.8	9.5	0	5.2	0	0	0		9.5	18	0	8.5
	Bellingham Bay	220	18	0	51	46	51	97	30	48	5.1	0.077	4.2		221	281	179	37
	Other Bellingham Bay	1.1	0	0	0	1.07	0	1.07	0	1.1	0	0	0		1.1	1.1	0	0
	Samish Bay	48	3.4	0	18	17	21	38	5.4	12	0	0	0		49	68	29	1.8
	Total Coastal	538	56	7.3	179	219	182	401	73	269	5.1	0.21	4.2		537	821	300	184
Fraser	Chilliwack	64			62		20	20					14		64	64	43	0.47
	Sumas	238	34	55	139	82	139	221	38	22			9		239	408	127	104
	Other Fraser	0																
	Total Fraser	303	34	55	201	82	158	241	38	22			22		303	472	170	104
	TOTAL WRIA 1	2313	486	140	1223	611	1055	1700	462	776	268	233	282		2313	3329	1327	833

[1] Includes bull trout and Dolly varden. Bull trout predominate in WRIA 1 (see text for details).
Sources: WRIA 1 Chinook salmon distribution (10/27/03), Native Char distribution (10/27/03), Salmonid Distribution (04/24/03).

Figure C5. WRIA 1 Shaded Relief Map.



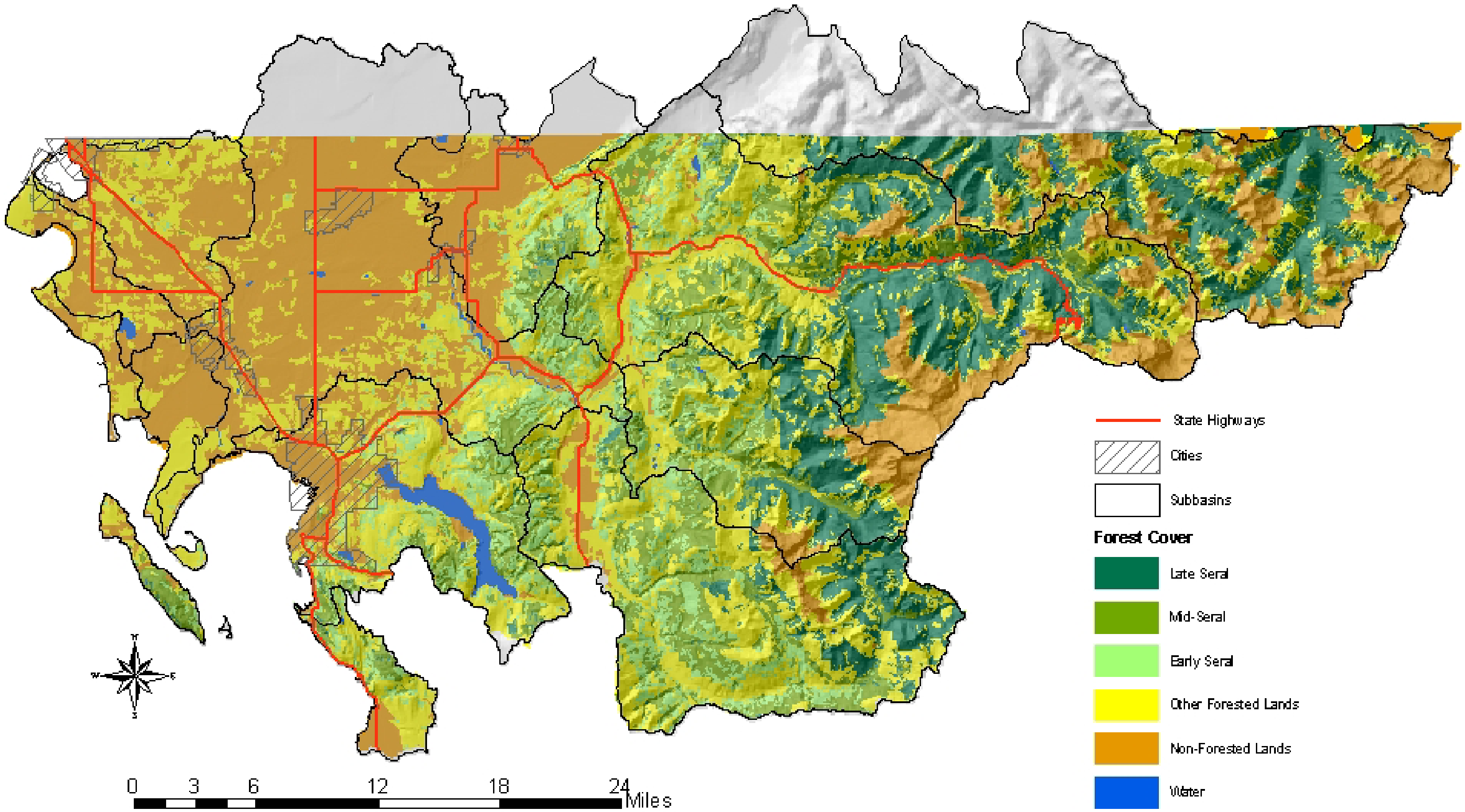
Data Sources: 10m DEM (US), 30m DEM (Canada); WRIA 1 Watershed Management Project delineated subbasins; WADOT Cities (2/2002) and State Highways (6/2003).
Cartography: T. Coe, Nooksack Natural Resources,10/23/03.

Table C4. General watershed characteristics by WRIA 1 regions and subbasins.

Region	SUBBASIN	Total Subbasin Area (km²)	Elevation (m) Min	Elevation (m) Max	Elevation (m) Mean	Landscape Slope Class (% of area) <30%	30-65%	>65%
Nooksack	North Fork Nooksack	769	87	3283	963	34%	44%	22%
	Whatcom	753	87	3283	977	33%	45%	23%
	Canada	16	171	772	311	82%	17%	1.0%
	Middle Fork Nooksack	260	87	3283	990	28%	50%	23%
	South Fork Nooksack	475	66	2137	697	41%	48%	11%
	Whatcom	315	66	2137	671	43%	44%	14%
	Skagit	161	129	1595	748	37%	56%	6.8%
	Lower Nooksack	588	0	940	88	95%	4.7%	0.47%
	Whatcom	476	0	940	91	94%	5.8%	0.58%
	Canada	112	36	120	76	100%	0.11%	
	Lummi River	61	0	110	24	100%	0.12%	
	Total Nooksack	**2154**	**0**	**3283**	**642**	**53%**	**34%**	**13%**
Coastal	Drayton Harbor	147	0	165	35	100%	0.26%	
	Whatcom	146	0	165	35	100%	0.26%	
	Canada	1	60	82	68	100%	0.28%	
	Birch Bay	65	0	117	44	100%	0.35%	0.03%
	Georgia Strait	26	0	86	39	98%	2%	0.4%
	Bellingham Bay	294	0	1029	220	75%	21%	4.1%
	Whatcom	291	0	934	216	76%	20%	4.1%
	Skagit	3	167	1029	577	54%	44%	2.4%
	West Bellingham Bay	36	0	507	93	73%	20%	7.5%
	Samish Bay	55	0	702	192	67%	27%	6.0%
	Whatcom	8	0	593	296	47%	43%	10%
	Skagit	47	0	702	175	70%	25%	5.3%
	Total Coastal	**623**	**0**	**1029**	**141**	**84%**	**13%**	**2.9%**
Fraser	Chilliwack	644	36	2739	1226	20%	46%	35%
	Whatcom	428	616	2739	1406	13%	44%	43%
	Canada	216	36	2226	868	34%	48%	18%
	Sumas	212	3	1040	122	85%	12%	2.7%
	Whatcom	174	6	1040	144	82%	15%	3.2%
	Canada	39	3	516	26	98%	1.4%	0.49%
	Other Fraser	5	21	163	107	100%		
	Total Fraser	**861**	**3**	**2739**	**948**	**36%**	**37%**	**27%**
	TOTAL	**3638**	**0**	**3283**	**629**			
TOTAL WRIA 1 (US only)		**3255**				**54%**	**31%**	**15%**

Sources: 10m DEM (US), 30m DEM (Canada); WRIA 1 Watershed Management Project delineated subbasins.

3108 **Figure C6.** WRIA 1 Forest Cover.



Data Sources: EPA Forest-Cover Data, from Landsat 5 TM data, 1988-1993 (Lunetta 1997); WADOT Cities (2/2002) and STate Highways (6/2003); 10m DEM (US); 30m DEM (Canada); WRIA 1 Watershed Management Project delineated subbasins.
Cartography: T. Coe, Nooksack Natural Resources, 10/23/03.

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Table C5. Forest cover (% of total forested land area) by WRIA 1 regions and subbasins[1].

		Forested Land			
	SUBBASIN	**Late Seral Stage**	**Mid-Seral Stage**	**Early Seral Stage**	**Other Forested Lands[3]**
Nooksack	North Fork Nooksack[2]	35%	19%	8.0%	38%
	Middle Fork Nooksack	32%	20%	10.5%	38%
	South Fork Nooksack	15%	23%	18.3%	44%
	Lower Nooksack[2]	0%	11%	21.5%	68%
	Lummi River	0%	0%	0.7%	99%
	Total Nooksack[1]	24%	19%	12.7%	44%
Coastal	Drayton Harbor	0%	1%	1.5%	98%
	Birch Bay	0%	1%	0.3%	99%
	Georgia Strait	0%	0%	0.0%	100%
	Bellingham Bay	1%	18%	24.5%	56%
	West Bellingham Bay	2%	32%	8.3%	58%
	Samish Bay	1%	17%	20.7%	61%
	Total Coastal	1%	15%	16.6%	68%
Fraser	Chilliwack[2]	60%	6%	0.0%	34%
	Sumas[2]	4%	23%	25.4%	48%
	Other Fraser	0%	0%	0.0%	100%
	Total Fraser	49%	9%	4.9%	37%
	TOTAL WRIA 1[1]	25%	17%	12.0%	47%

[1] See *Forest Cover Types* in Glossary.
[2] Excludes Canada.
[3] Less than 10% coniferous crown cover (can contain hardwood tree/shrub cover, cleared forest land, etc.)
Sources: EPA Forest-Cover data from Landsat 5 TM data, 1988-1993 (Lunetta 1997); WRIA 1 Watershed Management Project delineated subbasins.

Figure C7. WRIA 1 Streams by Habitat Type.

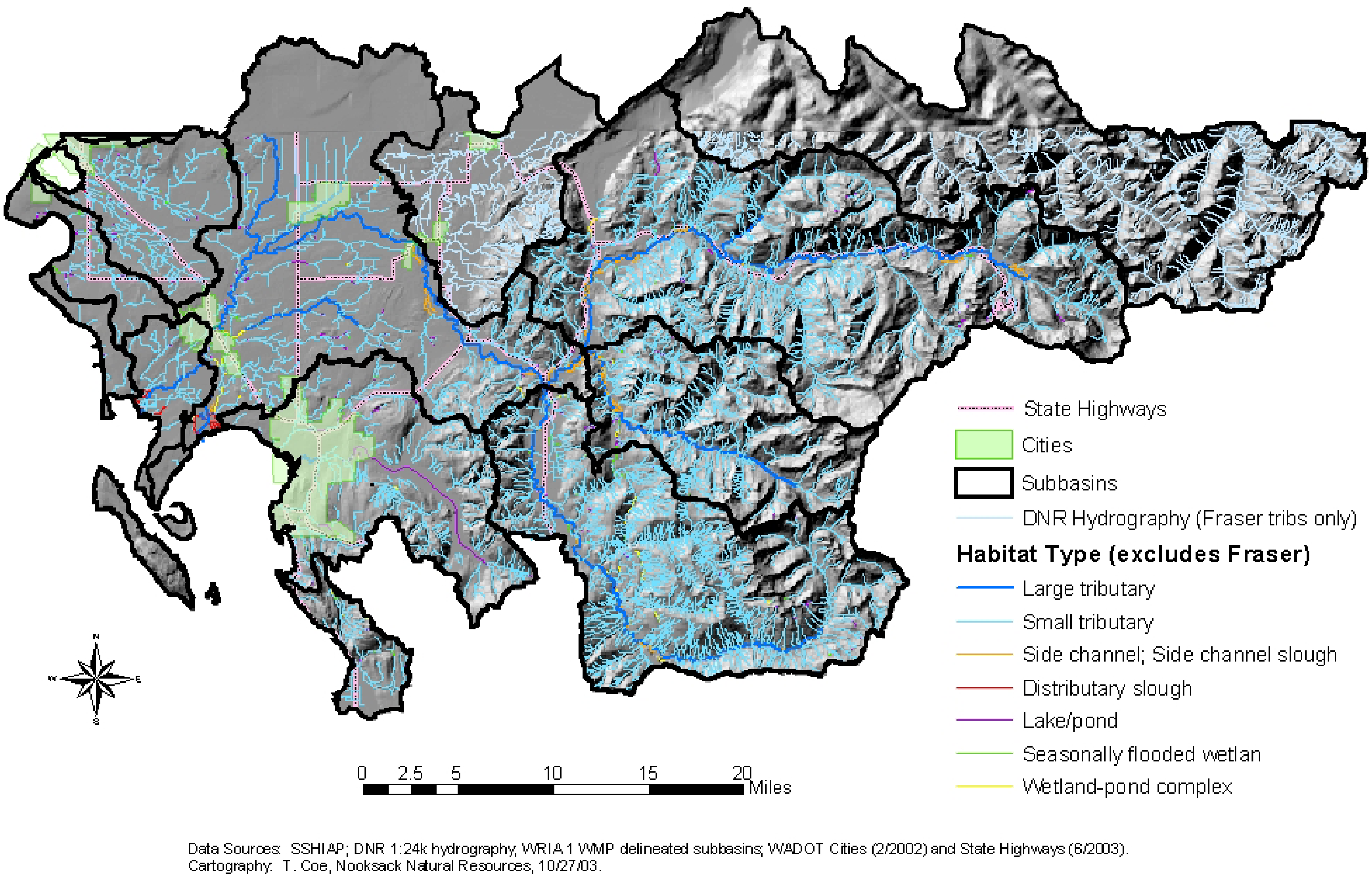
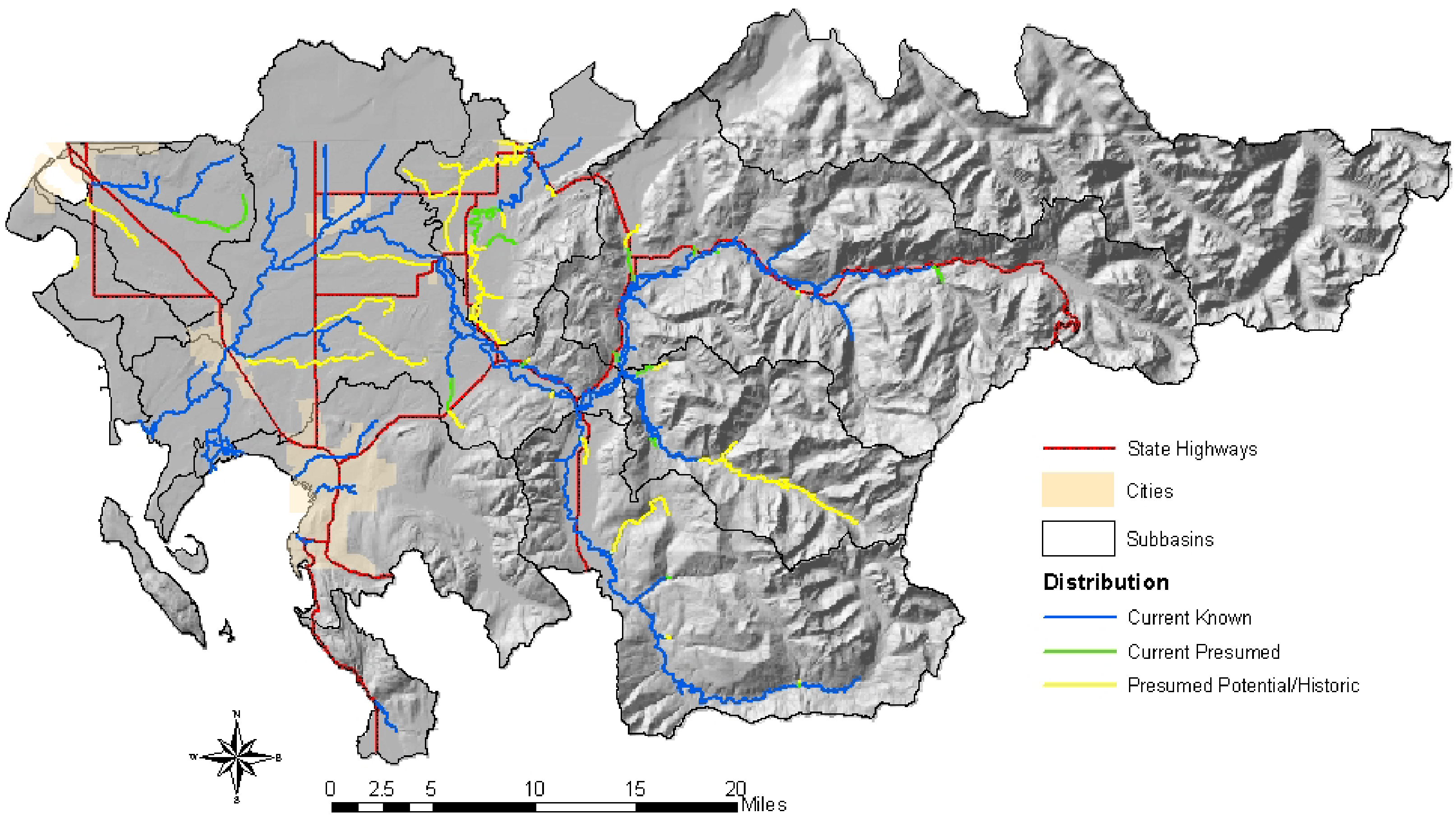


Table C6. Gradient, confinement and habitat type of WRIA 1 streams by region and subbasin (lengths in miles).

Region	SUBBASIN	Water-course Length[1]	SSHIAP Length	Channel Gradient (%) and Confinement (U,M,C) by Habitat Type2														
				Size	<1% U	<1% M	<1% C	1-2% U	1-2% M	1-2% C	2-4% U	2-4% M	2-4% C	4-8% U	4-8% M	4-8% C	8-20% C	>20% C
Nooksack	North Fork Nooksack	929	705	Large Tributary	23		0.28	3.7	3.3	3.7		0.28	0.87			2.9	1.1	
				Small Tributary	11	0.43		8.9	3.6		7.0	12	16	2.9	16	27	116	429
	Middle Fork Nooksack	408	298	Large Tributary	1.7			3.4		3.5		1.1	4.5		1.2	1.8		
				Small Tributary	0.17			2.6	0.49		0.60	4.0	3.4	1.3	2.6	16	49	193
	South Fork Nooksack	904	708	Large Tributary	19	2.4	1.4	1.3	5.8			1.5	0.91		0.52	0	0	
				Small Tributary	24			5.6	6.9	2.9	4.7	8.6	7.0	3.3	14	21	97	476
	Lower Nooksack	406	361	Large Tributary	49	12			4.1									0
				Small Tributary	135	30	0.68	6.3	6.0	0.49	6.0	10	10	1.7	2.3	4.2	12	53
	Lummi River	60	55	Large Tributary	5.2													
				Small Tributary	34	1.6		5.9			1.5	0.36	0.61	0.81	0.96			
	Total Nooksack	2707	2127	Large Tributary	97	15	1.6	8.3	13	7.2		2.8	6.3		1.7	5.2	1.3	
				Small Tributary	204	32	0.68	29	17	3.4	20	35	37	10	36	68	273	1152
Coastal	Drayton Harbor	124	118	Small Tributary	76	6.3	3.7	9.0	4.2	2.3	3.2	1.9	0.67	1.3	7.0	0.22	1.5	0.41
	Birch Bay	40	32	Small Tributary	23	0.64		2.2	1.7	1.2	3.6							
	Georgia Strait	7.3	6.1	Small Tributary	1.11			1.3			2.2			0.33	0.66		0.17	0.14
	Bellingham Bay	348	202	Large Tributary		1.3												
				Small Tributary	21	4.7	1.8	16	5.8	4.8	5.9	6.7	6.8	2.9	8.8	9.5	27	79
	West Bellingham Bay	3.2	0.67	Small Tributary				0.7										
	Samish Bay	51	44	Small Tributary	12		0.32	0.61	0.60	1.7	0.68	0.80	4.7		0.43	6.2	2.4	14
	Total Coastal	573	404	Large Tributary		1.3												
				Small Tributary	133	12	5.8	30	12	10	16	9.41	12	4.58	17	16	31	94
	Total Fraser	535																
	TOTAL WRIA 1	3814																

[1] Source: WADNR Hydrography. Watercourses include streams, rivers, lakes, ponds, and wetlands.
[2] Source: Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP). U=unconfined, M=moderately confined, C=confined)

Figure C8. Chinook distribution in WRIA 1.



Data Sources: WRIA 1 Chinook Distribution (10/27/2003); WADOT Cities (2/2002) and State Highways (6/2003).
Cartography: T. Coe, Nooksack Natural Resources, 10/27/03.

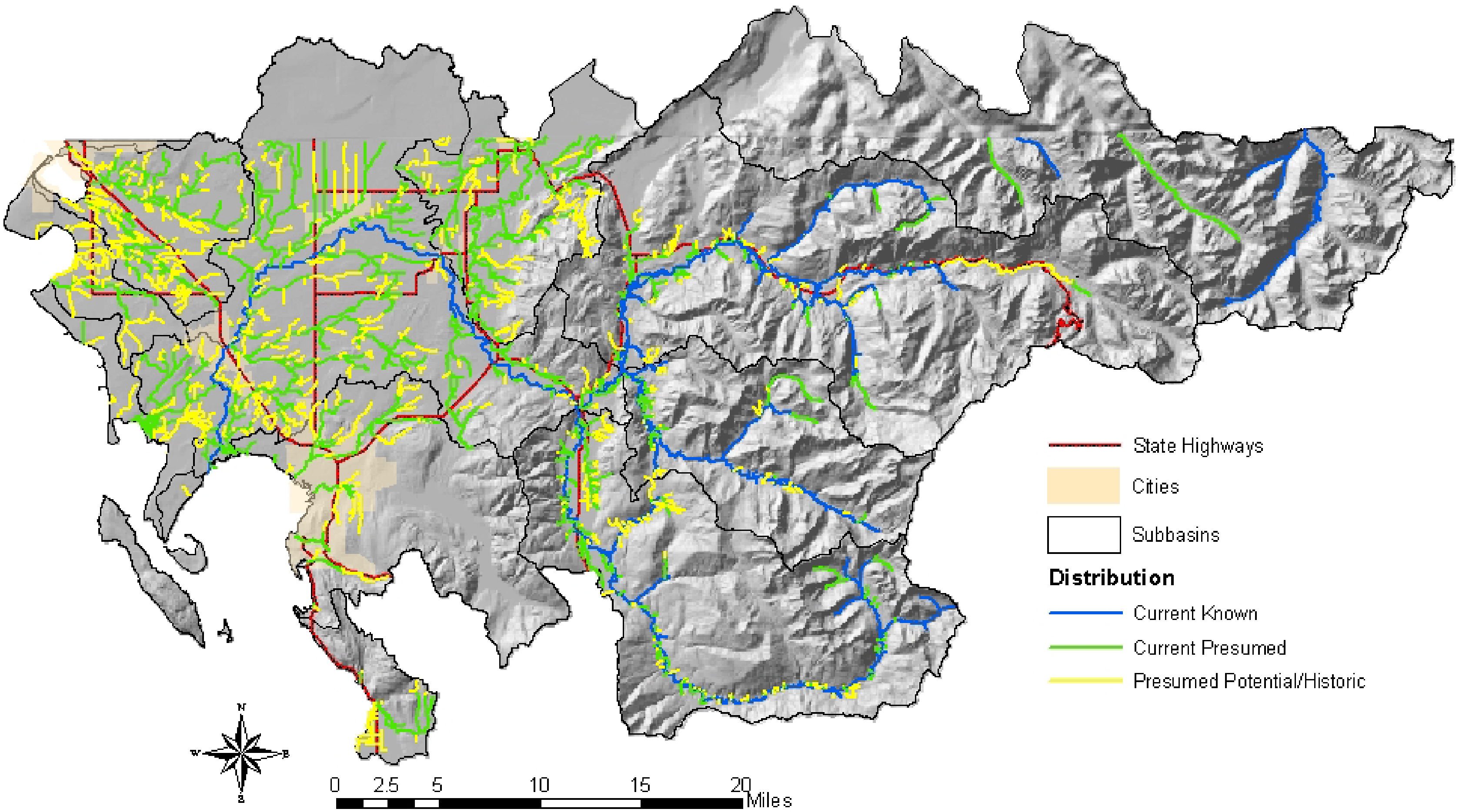
Table C7. Escapements from 1993-2002 for Nooksack early chinook populations

Year	North/Middle Fork Early Chinook		South Fork Early Chinook	
	Natural Origin	Kendall Hatchery Origin	South Fork Escapement	Hatchery Strays (not included as part of escapement)
1993	335	91	235	
1994	8	37	118	
1995	175	55	290	
1996	210	328	203	
1997	121	496	180	
1998	39	331	157	
1999	91	820	164	126
2000	160	1082*	283	89
2001	240	1945[1]*	267	153
2002	221	3466[2]*	282	338

[1]Number from June 18 paper and consistent with A&P table and SASSI (total esc. of 2,185)
[2]NOR of 221 confirmed by Curt Kraemer 1/29/03, and 3466 is from A&P with the source being Bruce Sanford in April 2003. Total co-manager esc. for 2002 then is 3687.

Additional Notes:
2000: Additional to the total volitional spawners shown (which when combining natural origin and Kendall hatchery equal the co-manager N/M Fk stock escapement estimates) there were 61 females, 785 males, and 40 jacks "turned/put back" into the North or Middle Fork (total of 886) from the Kendall Hatchery to spawn in the wild
2001: Additional to the total volitional spawners shown, there were 924 females, 3401 males, and 439 jacks (total 4,764) "turned/put back" to spawn in the wild.
2002 : Additional to the total volitional spawners shown, there were 1835 females, 1896 males, and 29 jacks "turned/put back" to spawn in the wild (source of all three years of turnback data is Ted Thygussen)

Figure C9. Native char (bull trout/Dolly varden) distribution in WRIA 1.



Data Sources: WRIA 1 Native Char Distribution (10/27/2003); WADOT Cities (2/2002) and State Highways (6/2003).
Cartography: T. Coe, Nooksack Natural Resources, 10/27/03.

3142 **Figure C10.** Coho salmon distribution in WRIA 1.

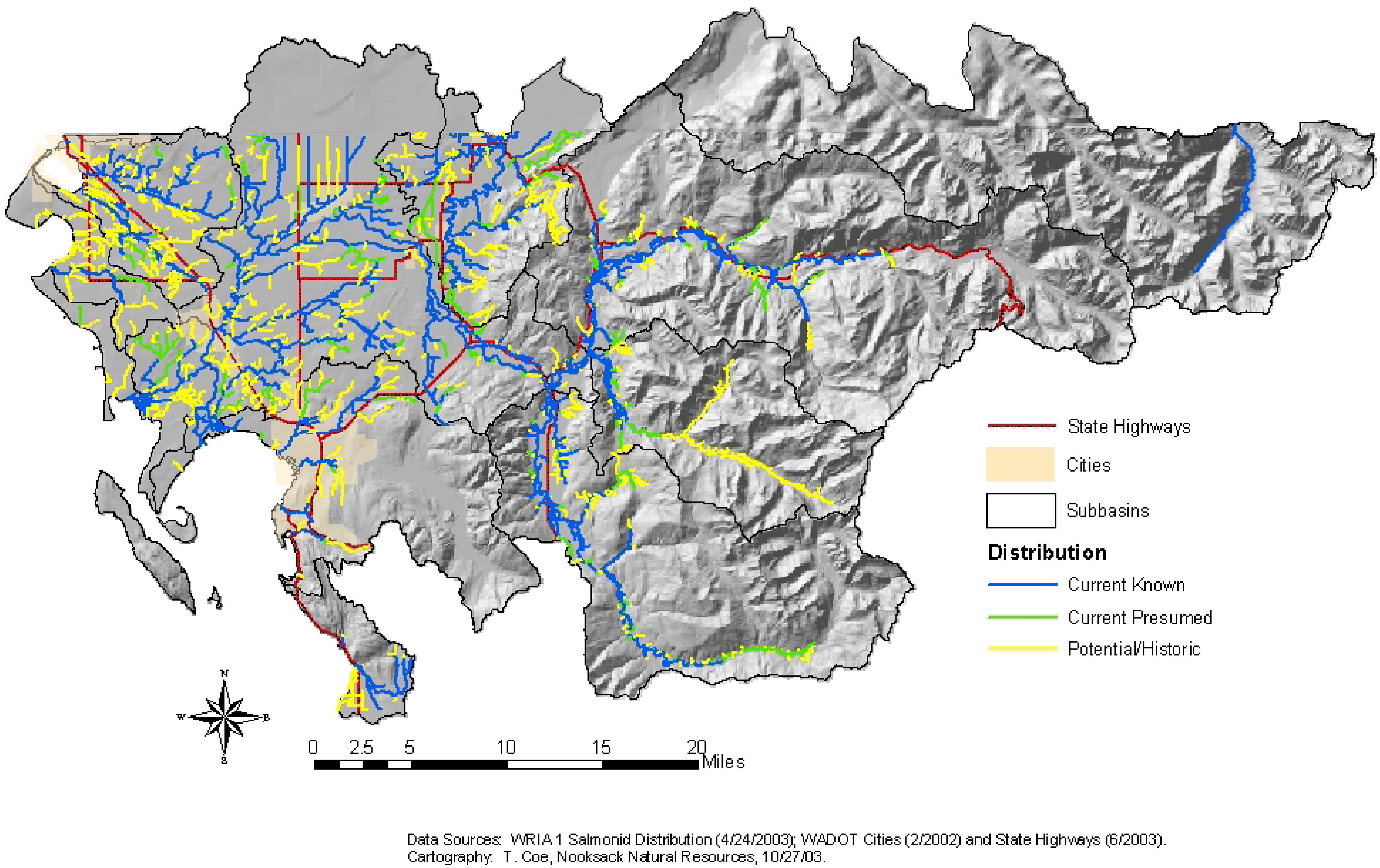


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Figure C11. Chum salmon distribution in WRIA 1.

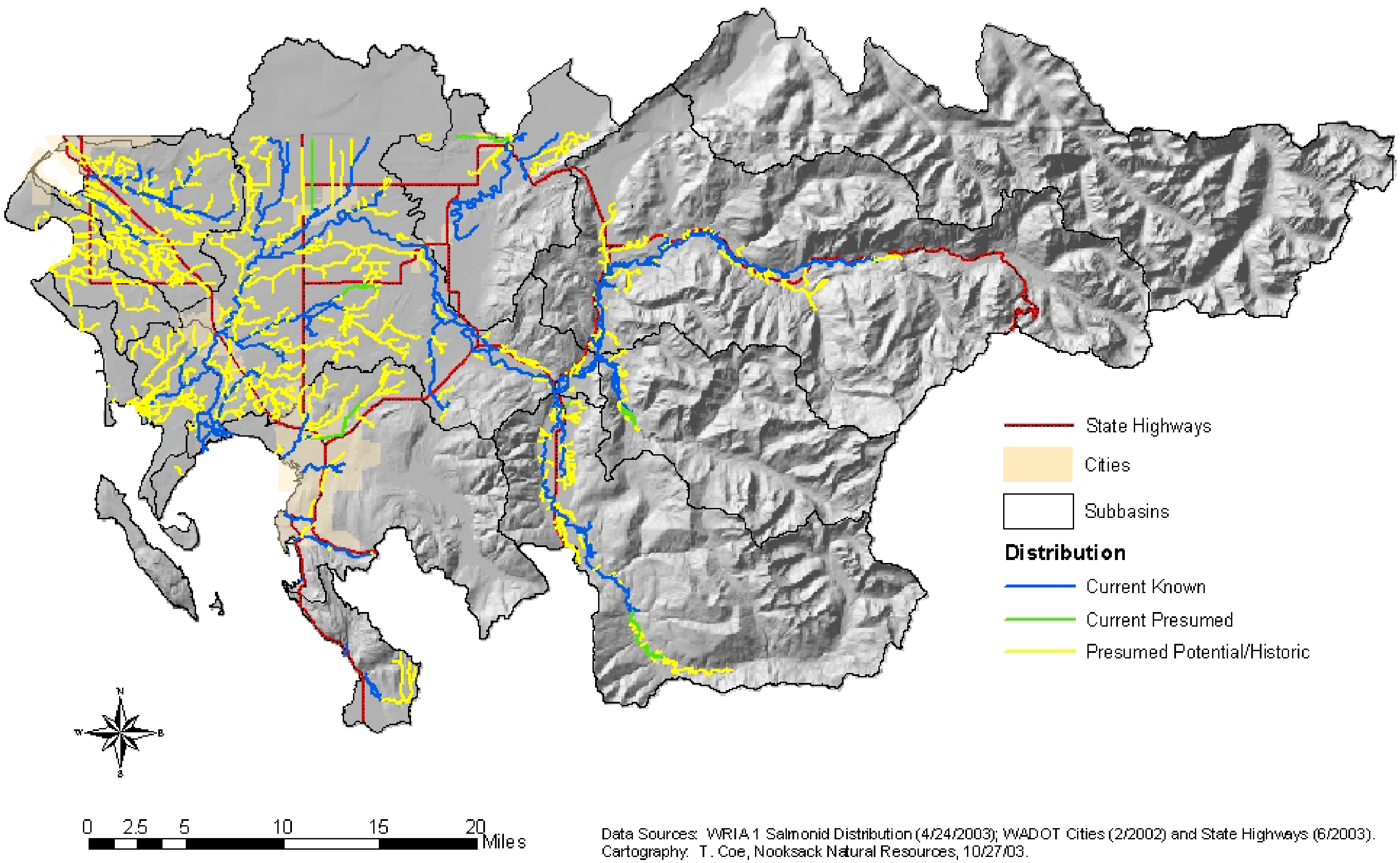

Figure C12. Pink salmon distribution in WRIA 1.

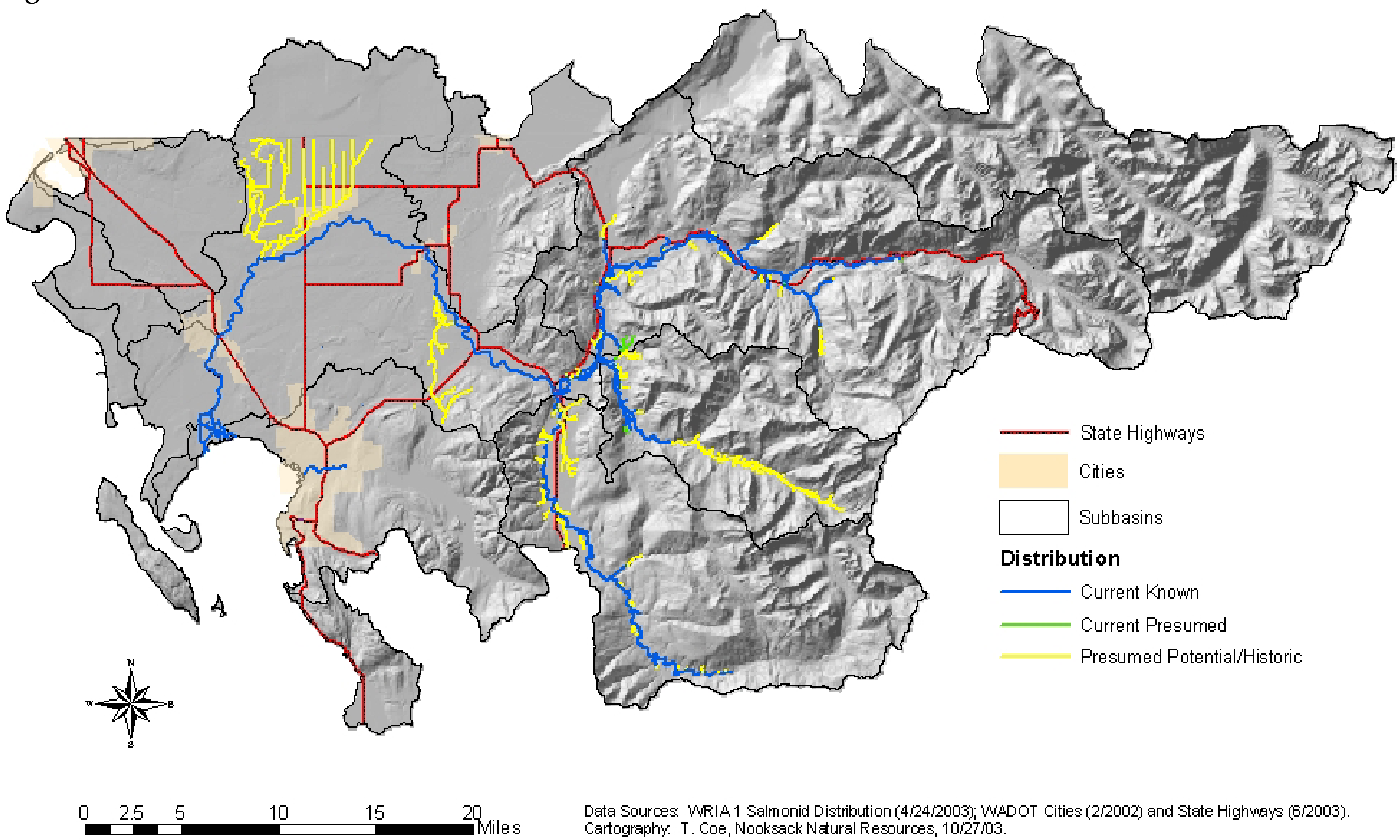

Figure C13. Sockeye salmon distribution in WRIA 1.

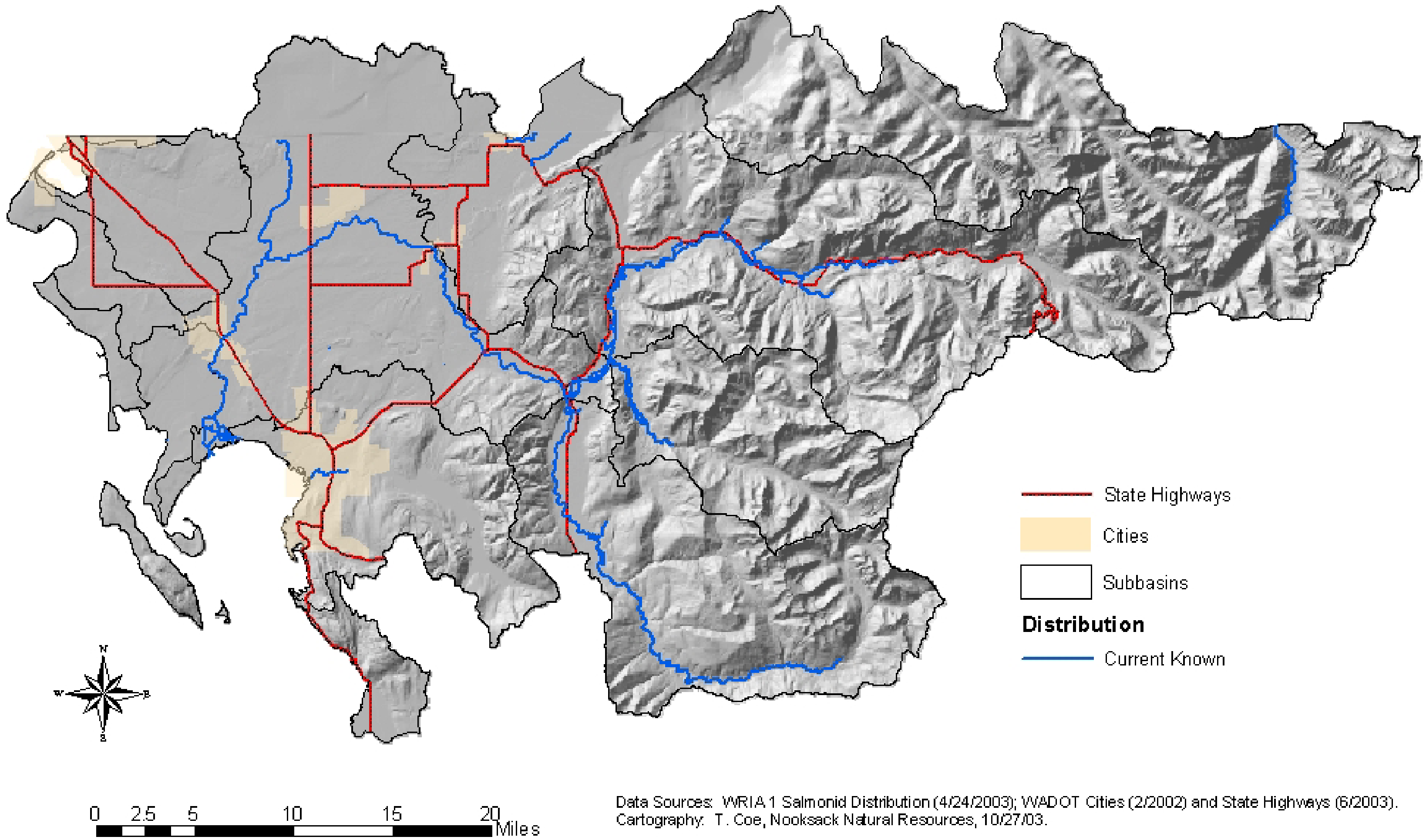

Figure C14. Steelhead distribution in WRIA 1.

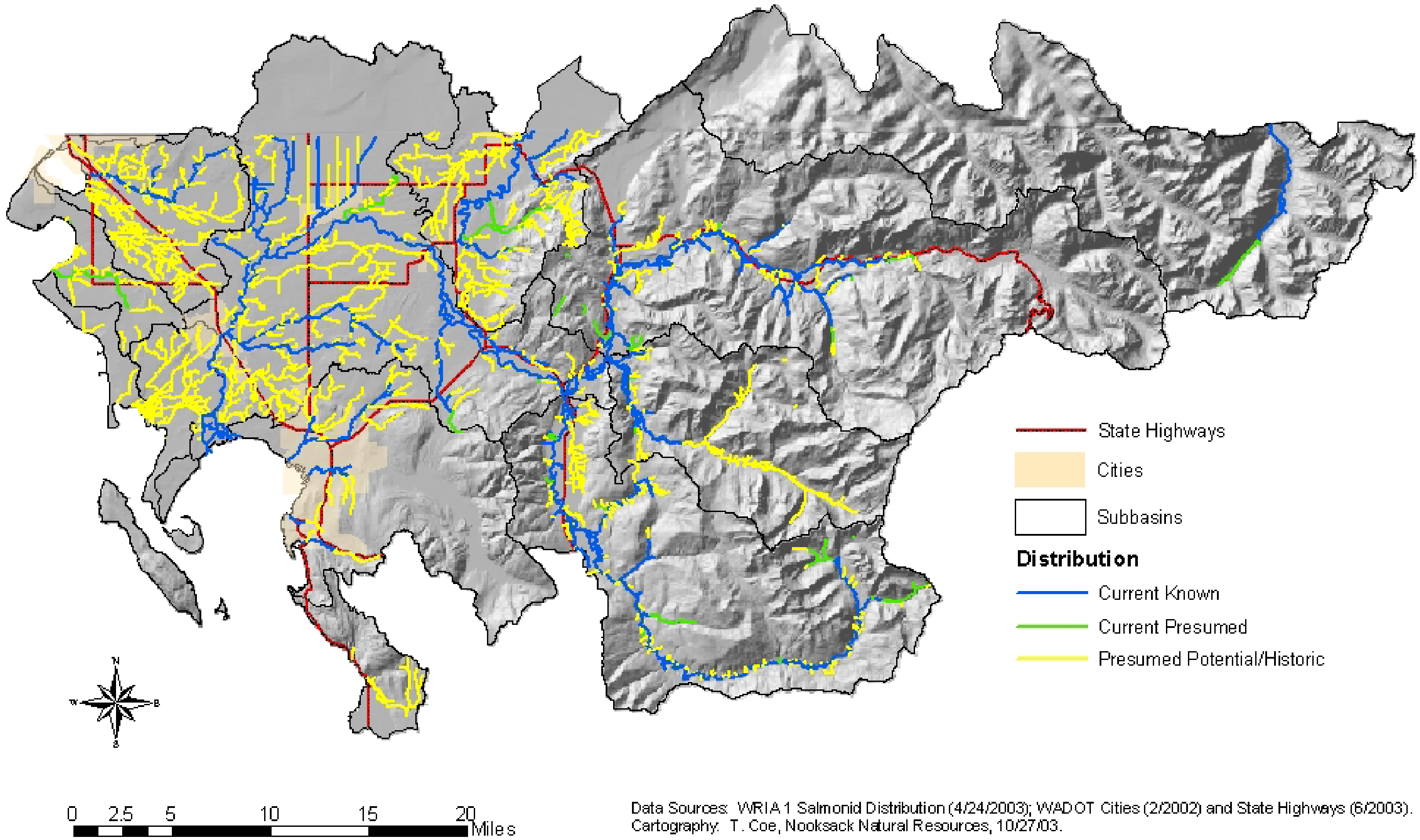

Figure C15. Rainbow trout distribution in WRIA 1.

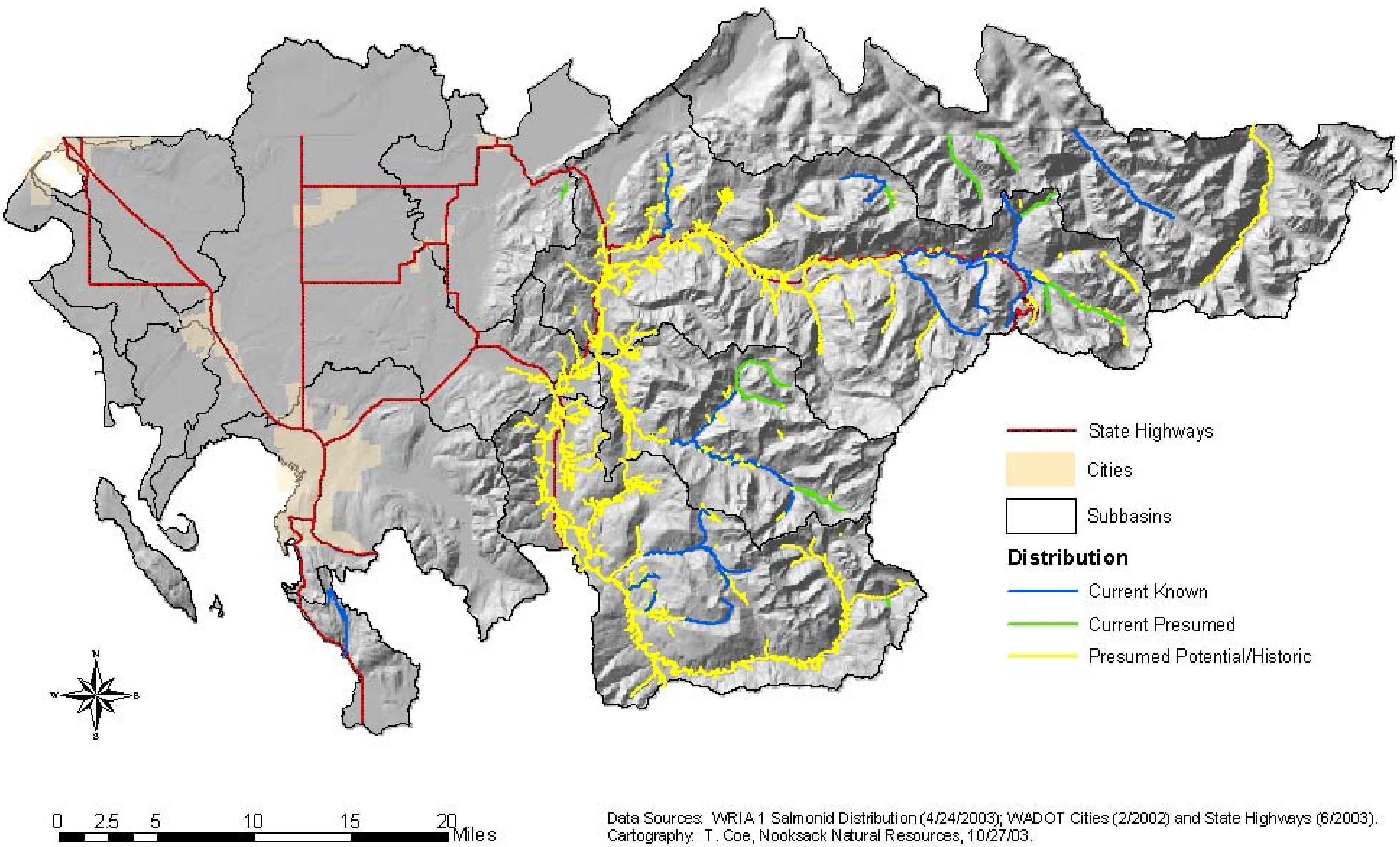

Figure C16. Cutthroat trout distribution in WRIA 1.

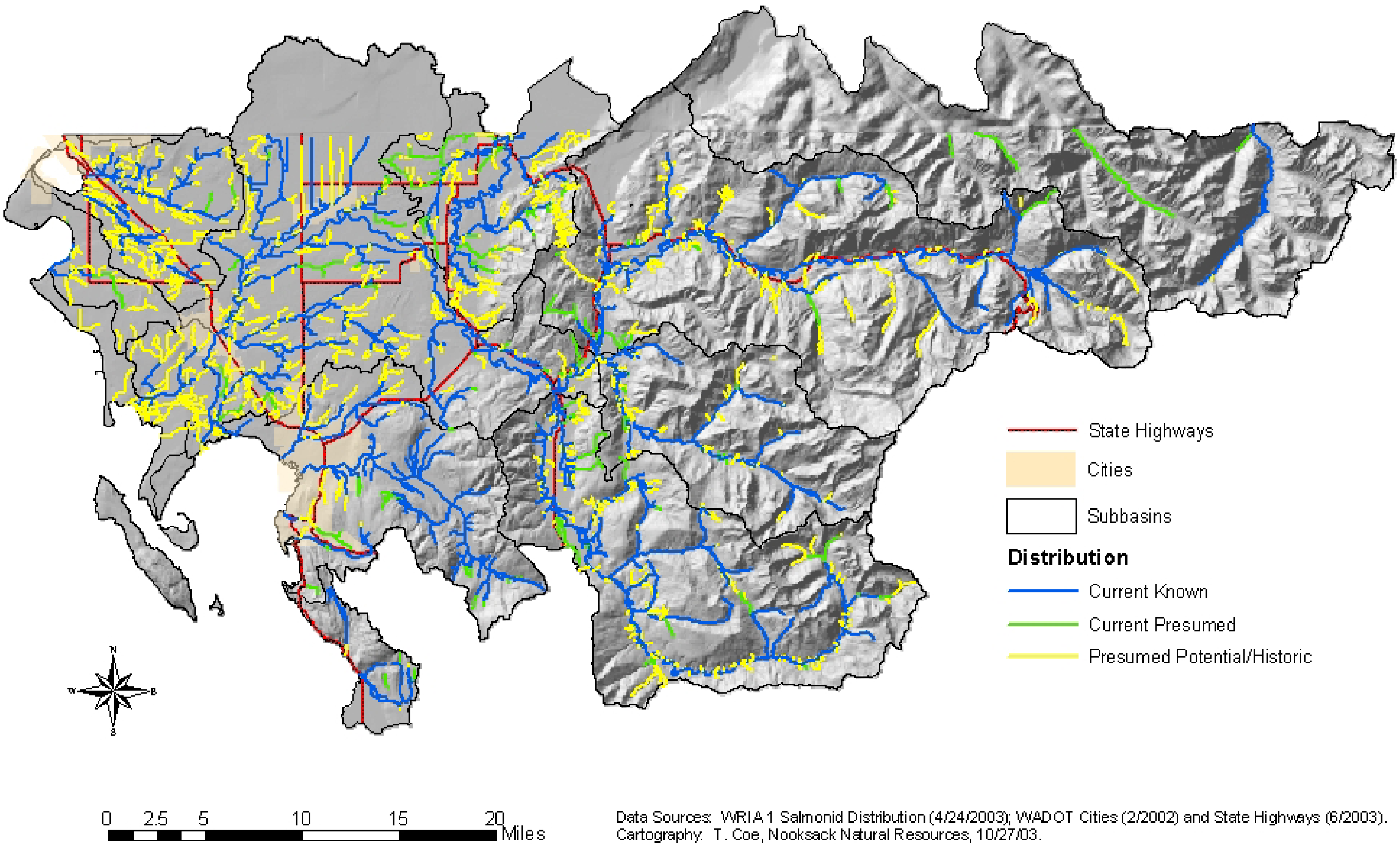

Figure C17. Inventoried potential fish passage barriers in WRIA 1.

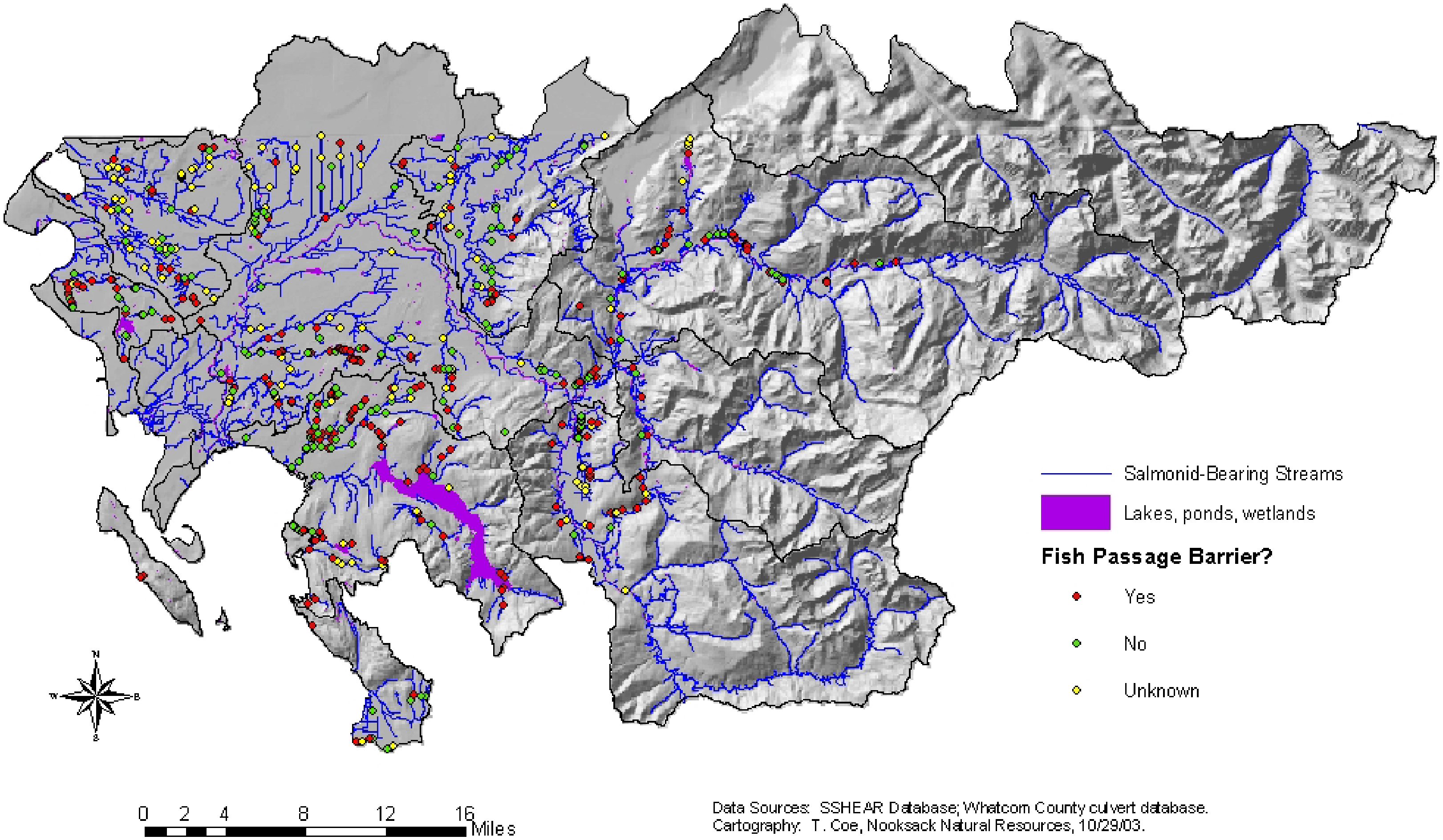

Table C8. Fish passage barriers in WRIA 1 streams by region and subbasin.

		Total Inventoried			Known or Suspected Fish Use			Unknown Fish Use			Fish Passage Barriers[1] where Affected Species Identified									
	SUBBASIN	Culvert	Fishway	Dams	Barrier[1]	Pass-able	Un-assess-ed[2]	Barrier[1]	Pass-able	Un-assess-ed[2]	Total	Chinook Salmon	Bull trout/ Dolly varden	Coho Salmon	Chum Salmon	Pink Salmon	Sockeye Salmon	Steel-head	Cut-throat Trout	Resi-dent Trout
Nooksack	North Fork Nooksack	173	3	1	31	20	6	2	0	6	14	5	9	12	5	3	0	13	14	3
	Middle Fork Nooksack	34	2	0	5	2	0	1	0	10	1	0	0	1	0	1	0	0	0	0
	South Fork Nooksack	103	1	0	25	11	12	1	1	26	5	0	0	5	2	0	0	3	5	3
	Lower Nooksack	541	13	5	63	50	43	14	5	144	32	0	19	32	24	2	18	28	28	27
	Lummi River	2	0	0	0	0	0	0	0	2	0									
	Total Nooksack	**853**	**19**	**6**	**124**	**83**	**61**	**18**	**6**	**188**	**52**	**5**	**28**	**50**	**31**	**6**	**18**	**44**	**47**	**33**
Coastal	Drayton Harbor	393	0	0	20	12	34	7	3	69										
	Birch Bay	44	0	20	24	16		9	1	1	33		0	27	27	0	0	27	27	33
	Georgia Strait	2	0	0	0	0	0	0	0	0										
	Bellingham Bay	654	13	12	96	68	18	10	7	114	74		0	66	42	0	2	57	64	71
	Other Bellingham Bay	2	0	3	2	0	0	0	0	0										
	Samish Bay	17	4	0	7	8	6	0	0	0	7		0	6	5	0	0	1	0	1
	Total Coastal	**1112**	**17**	**35**	**149**	**104**	**58**	**26**	**11**	**184**	**114**	**0**	**0**	**99**	**74**	**0**	**2**	**85**	**91**	**105**
Fraser	Chilliwack	0						0	0	0										
	Sumas	247	1	0	17	26	18	3	2	15	1	0	0	1	0	0	0	0	0	0
	Other Fraser	0						0	0	0										
	Total Fraser	**247**	**1**	**0**	**17**	**26**	**18**	**3**	**2**	**15**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
	TOTAL WRIA 1	**2212**	**37**	**41**	**290**	**213**	**137**	**47**	**19**	**387**	**167**	**10**	**56**	**299**	**210**	**12**	**40**	**258**	**276**	**276**

Sources: WDFW SSHEAR Database, Whatcom Co. Culverts database (1/2003).
[1] Includes both partial and complete barriers to fish passage.
[2] Includes those requiring Level B analysis.

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Figure C18a. GIS mapping of the lower Nooksack valley, interpreted from archival sources, for approximately 1880. FP: floodplain; EEW: estuarine emergent wetland; ESW: estuarine scrub-shrub wetland; RTS: riverine-tidal scrub-shrub wetland; PSW: palustrine scrub-shrub wetland; PFW: palustrine forested wetland. (Source: Collins & Sheikh 2004).

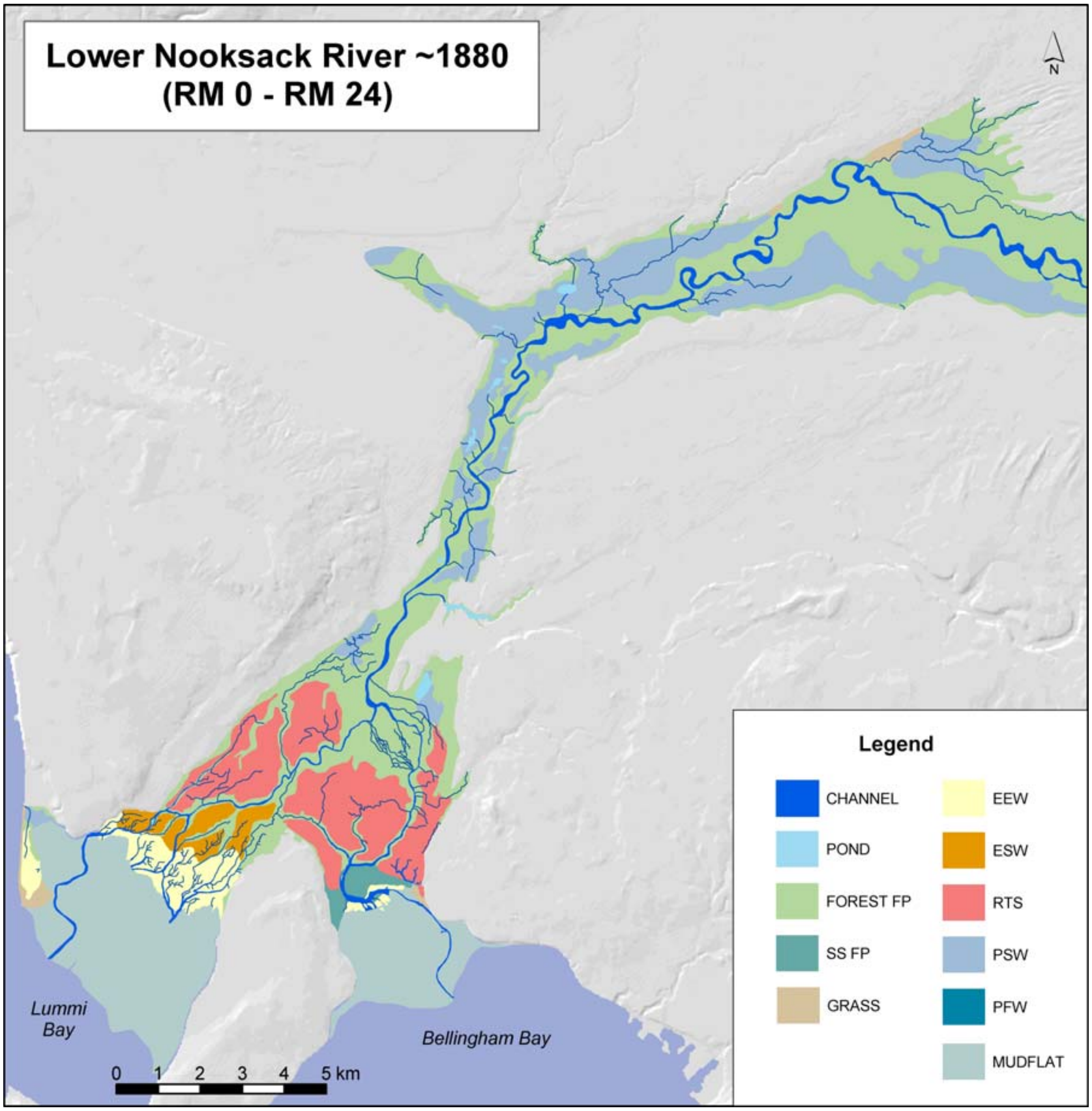


Figure C18b. GIS mapping of the upper Nooksack valley, interpreted from archival sources, for approximately 1880.
Source: Collins & Sheikh 2004.

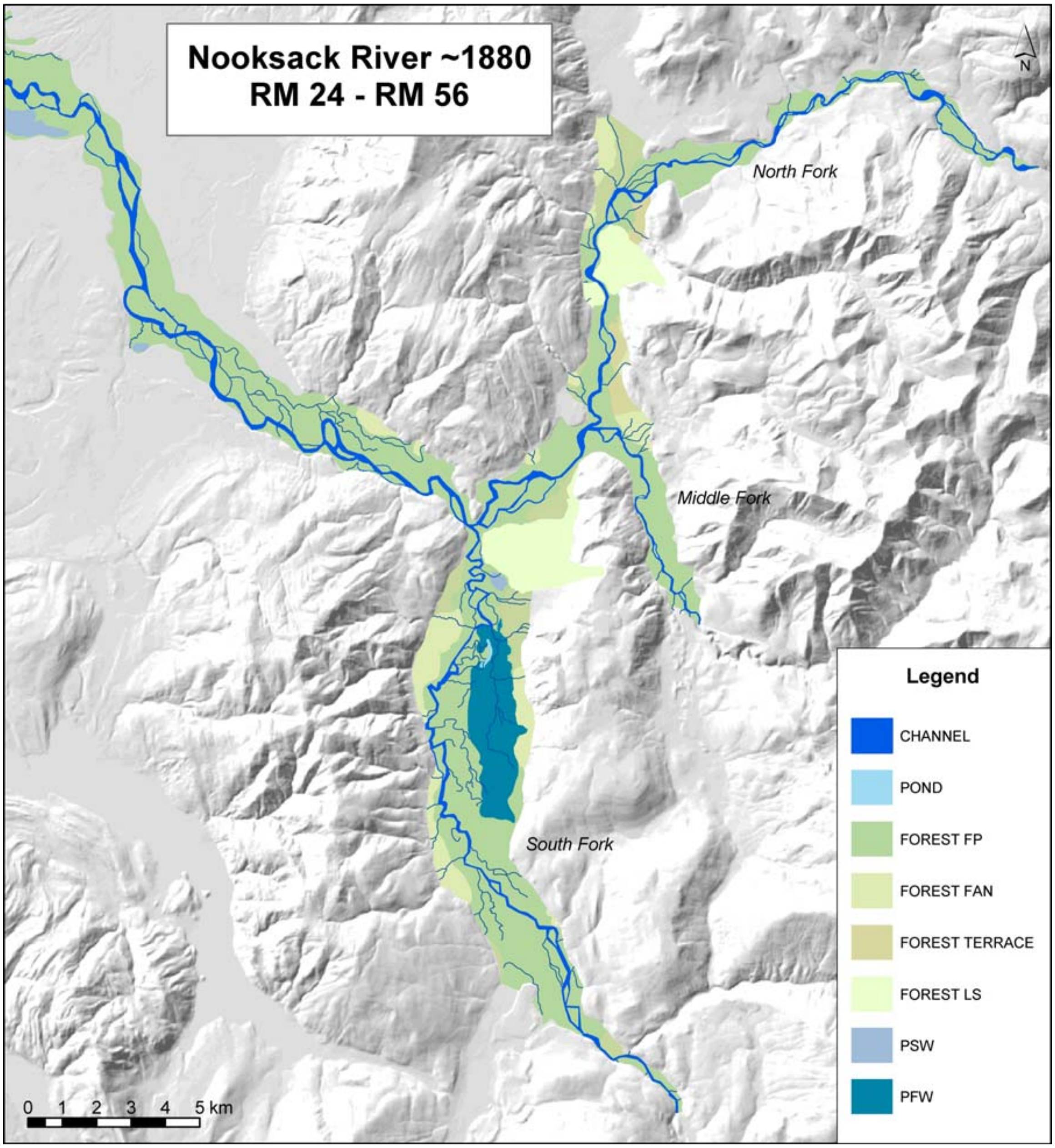


Figure C19a. GIS mapping of the lower Nooksack valley, interpreted primarily from 1998 aerial photos.
Note: Extent of tideflats is from NOAA Bellingham Bay 1989.
Source: Collins & Sheikh 2004.

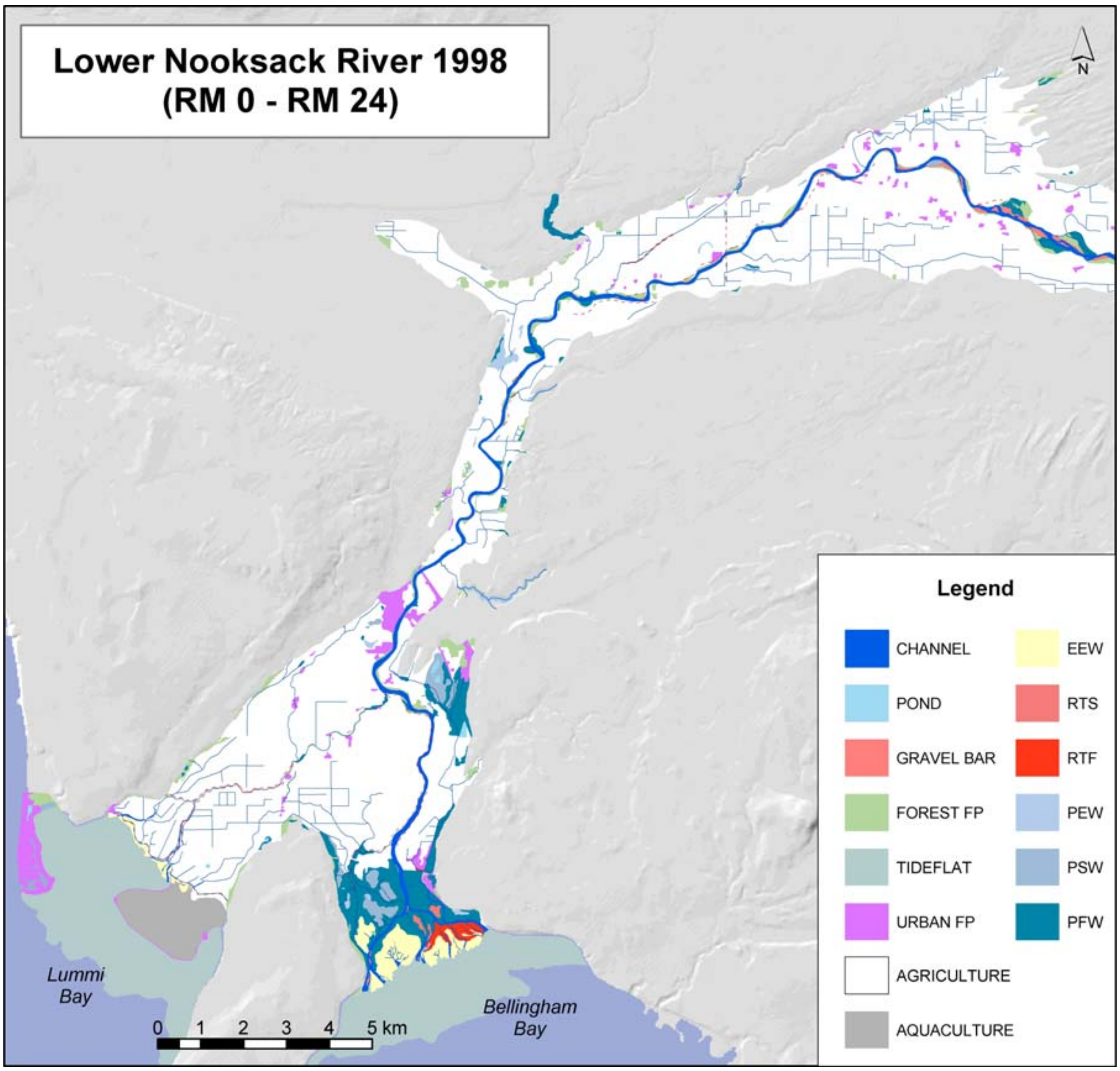


Figure C19b. GIS mapping of the upper Nooksack valley, interpreted primarily from 1998 aerial photos.
Source: Collins & Sheikh 2004.

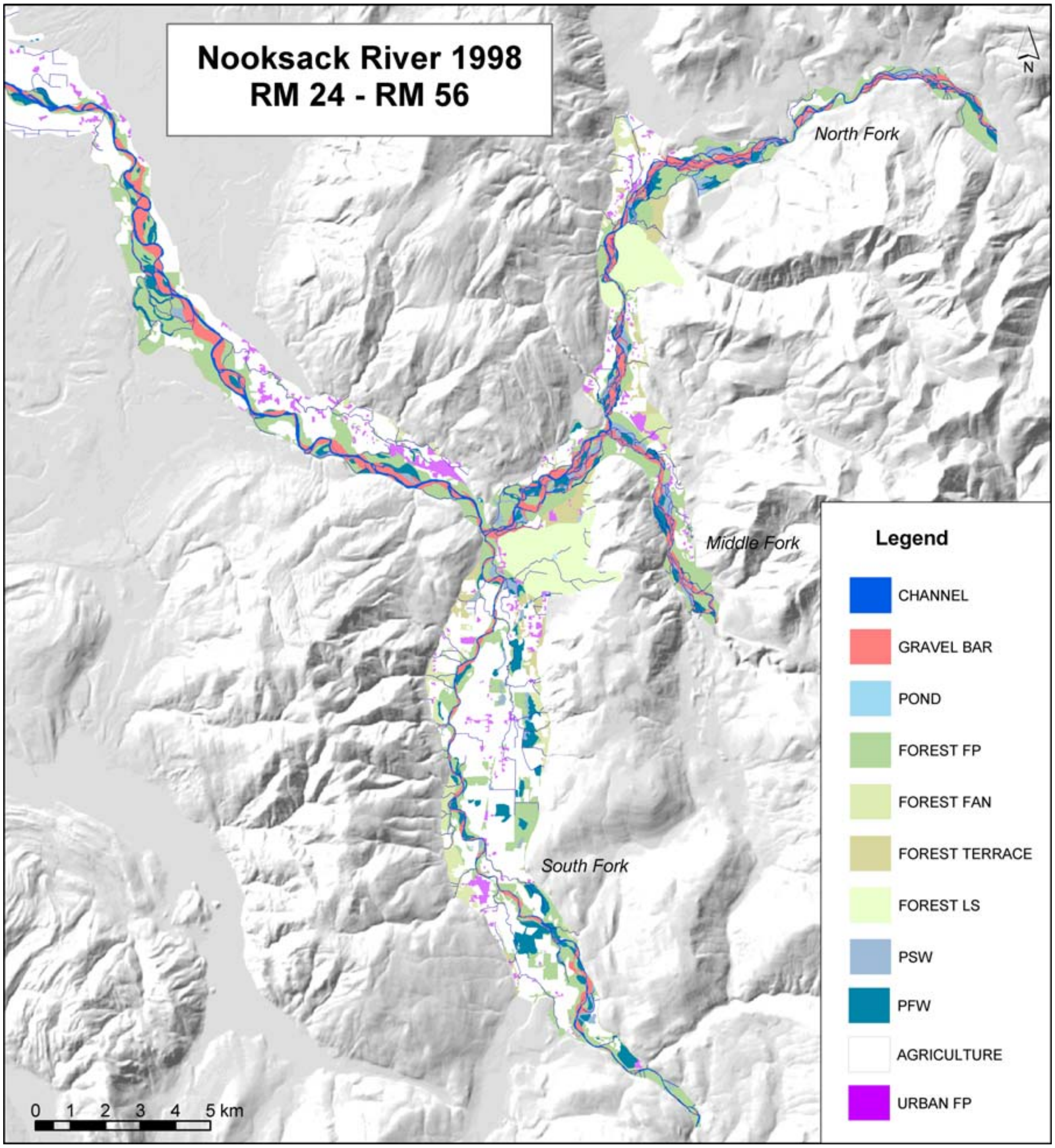


Figure C20. Change in mapped wetland area between 1880 and 1998. Note that the methods used to delineate wetlands are not comparable between the two eras—the criteria used to map total wetland areas for 1998 are more inclusive than for 1880 conditions (Source: Collins & Sheikh 2004).

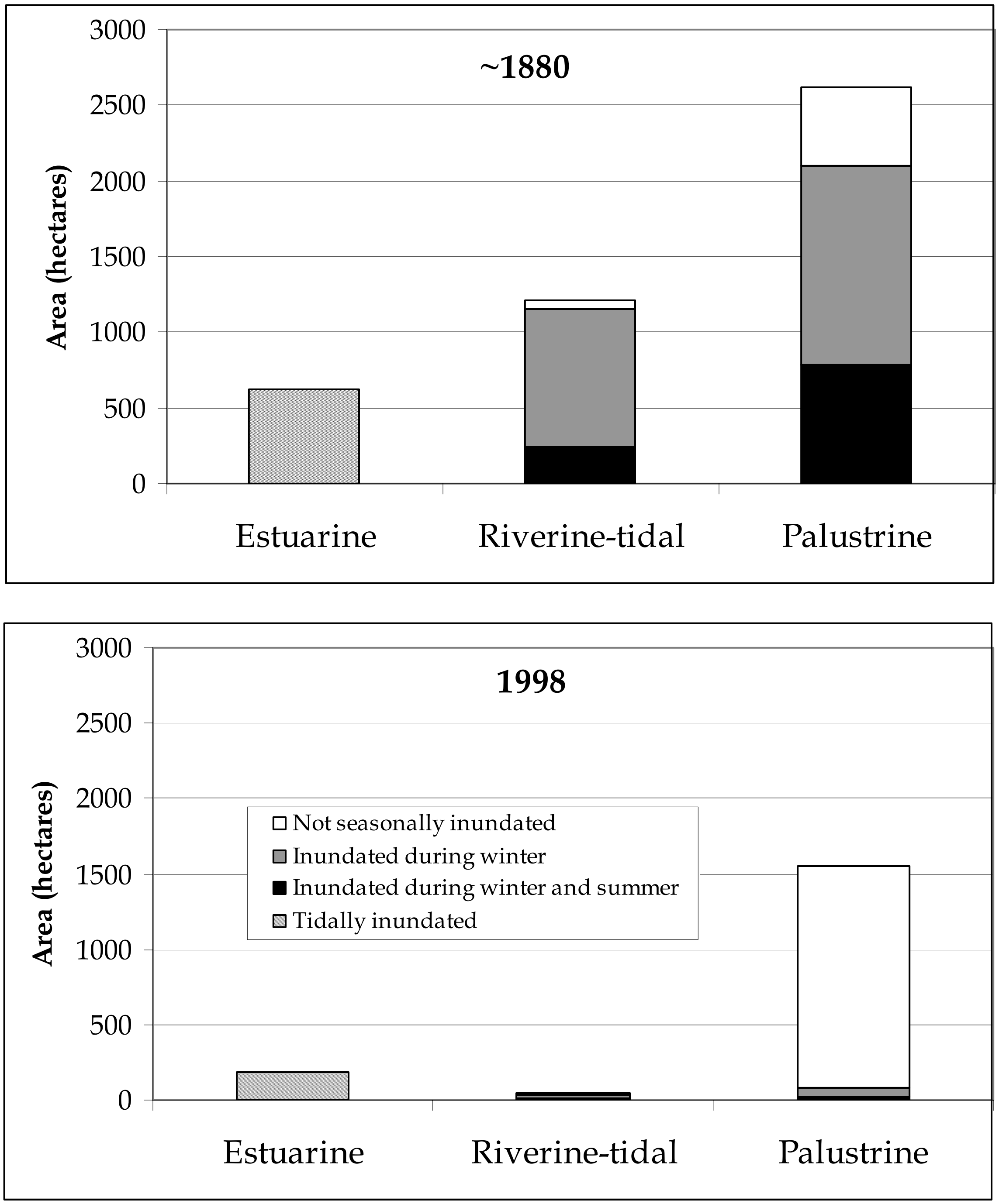


Figure C21a. Channel migration constraints in Nooksack River unconfined reaches.

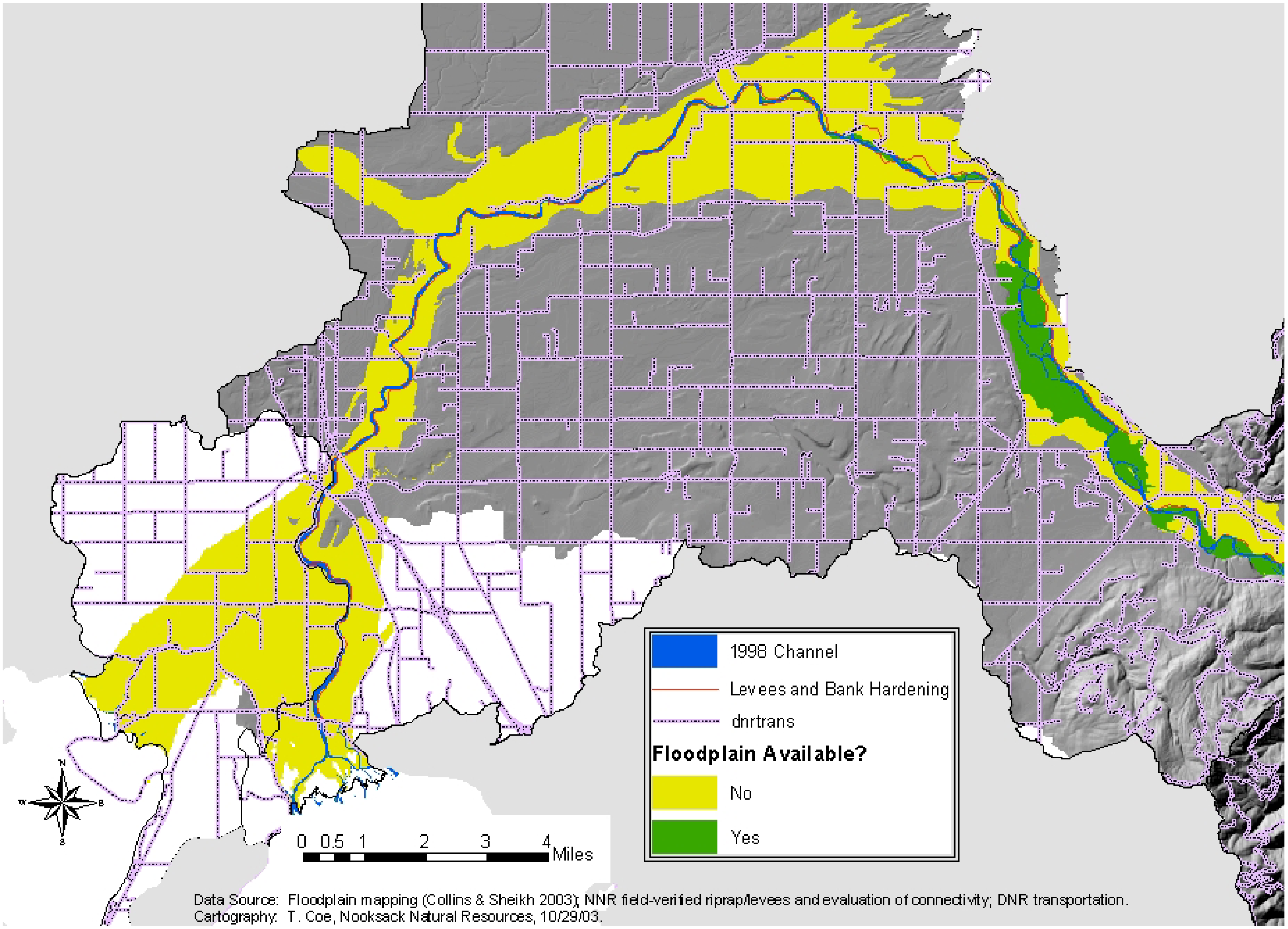


Figure C21b. Channel migration constraints in upper Nooksack River and Forks.

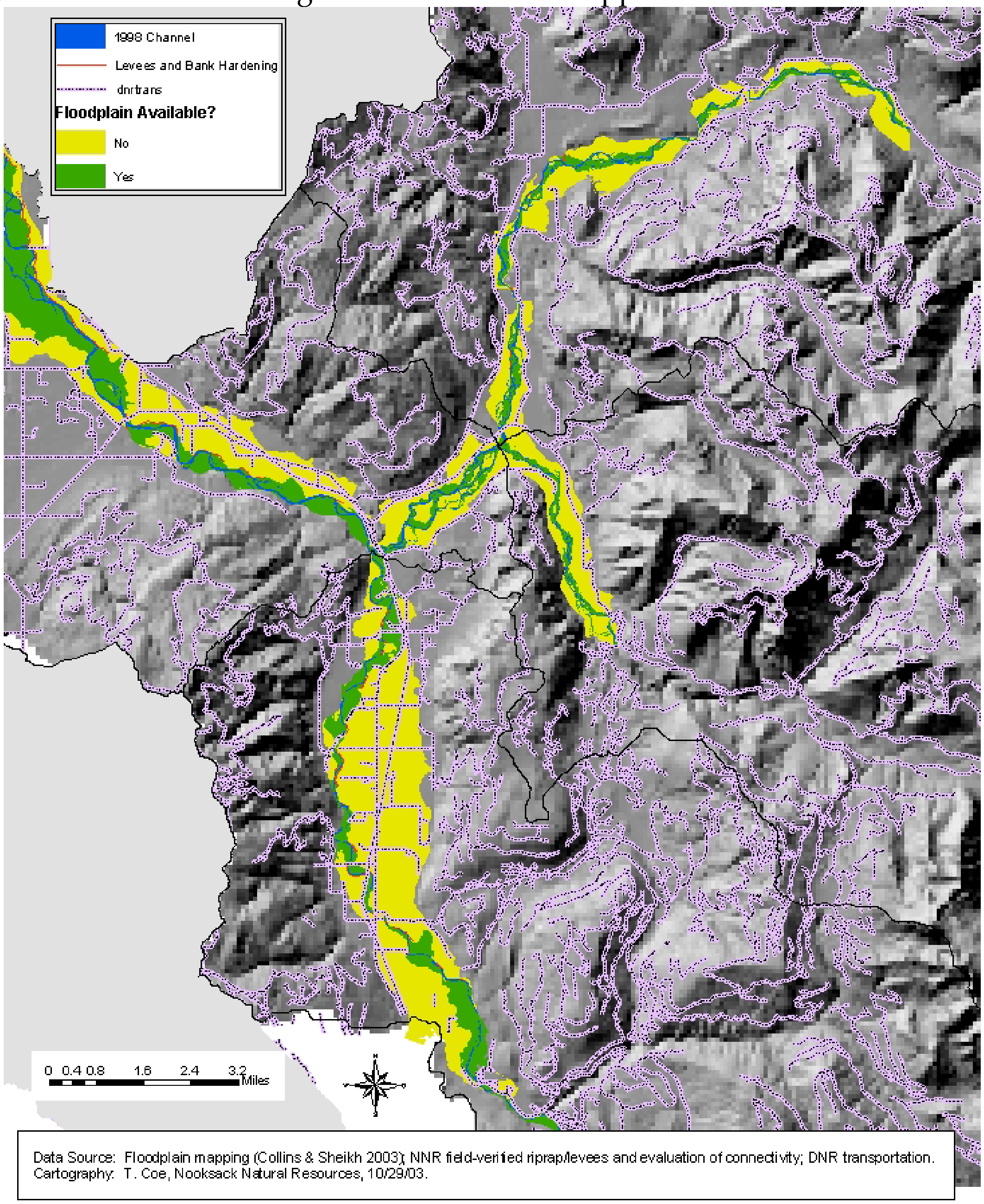


Figure C22. Nooksack River watershed riparian function: Near-term LWD recruitment potential.

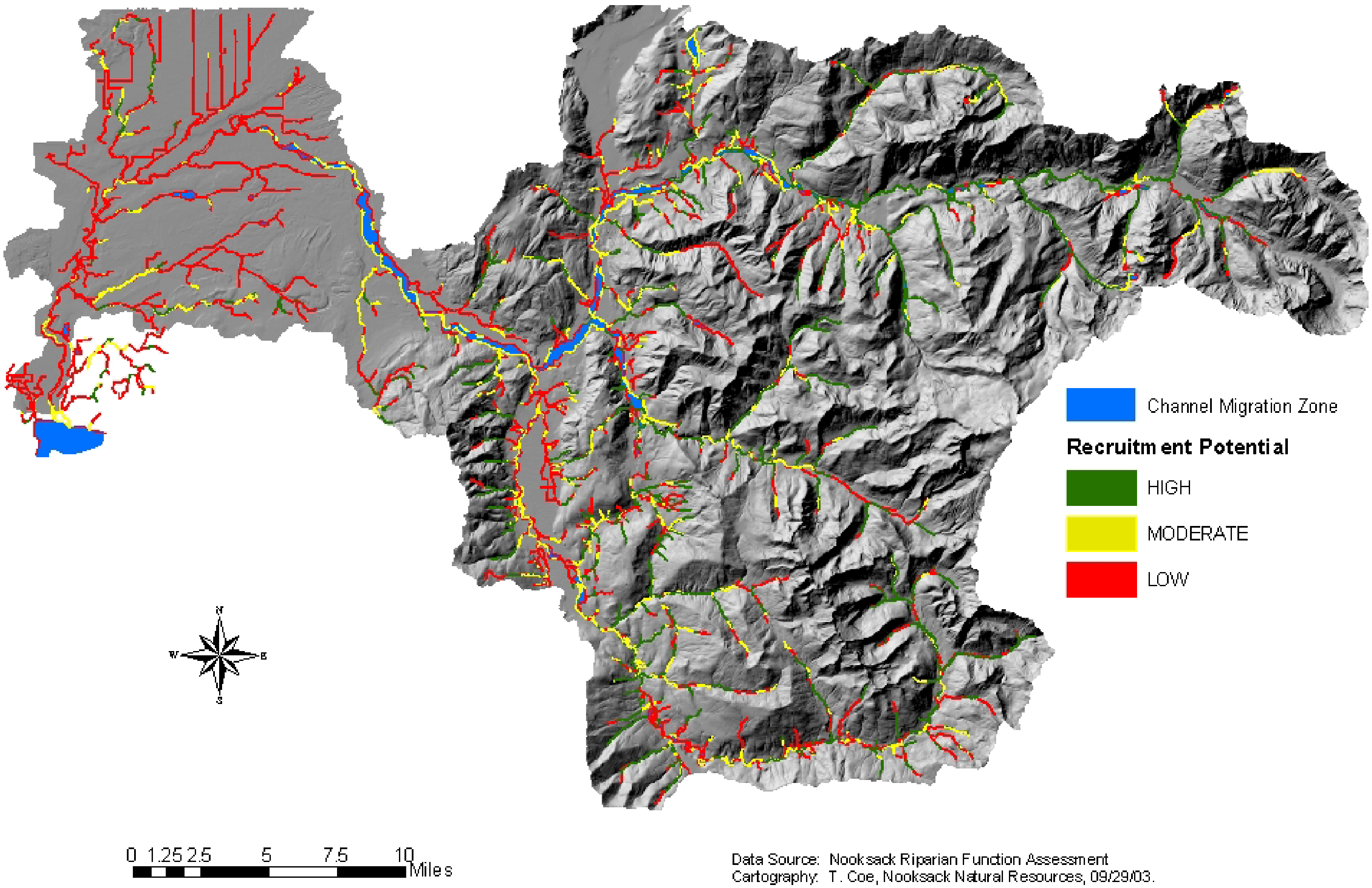


Table C9. Nooksack River watershed riparian function.

Subbasin	Location	Total Riparian Acres[1]	Near-Term LWD Recruitment Potential			Stream Shading Hazard[2]			
			High	Moderate	Low	High (>40% below target)	Mod (10-40% below target)	Low (within 10% of target)	Above Target (>10%)
Lower Nooksack	Mainstem	909		31%	69%				
	Tribs	5107	10%	12%	77%	77%	18%	1.9%	3.0%
	Total	6017	8.7%	15%	76%				
North Fork	Mainstem	982	51%	26%	23%				
	Tribs	4092	43%	23%	34%	11%	31%	19%	39%
	Total	5075	44%	24%	32%				
Middle Fork	Mainstem	468	36%	30%	34%				
	Tribs	1168	51%	14%	35%	16%	31%	18%	35%
	Total	1635	47%	19%	34%				
South Fork	Mainstem	1025	28%	32%	40%				
	Tribs	4173	42%	18%	41%	12%	38%	18%	32%
	Total	5197	39%	20%	41%				
Total	Mainstem	3383	28%	30%	42%				
	Tribs	14539	32%	17%	51%	35%	28%	13%	24%
	Total	17922	31%	19%	50%				

Source: Nooksack River Watershed Riparian Function Assessment (Coe 2001).
[1] 100 feet buffers on either side of stream or channel migration zone were delineated as riparian areas (see Coe 2001).
[2] Target shade levels are based on elevation levels as specified in WADNR Watershed Analysis Manual.

Figure C23. Nooksack River watershed riparian functions: Stream shading.

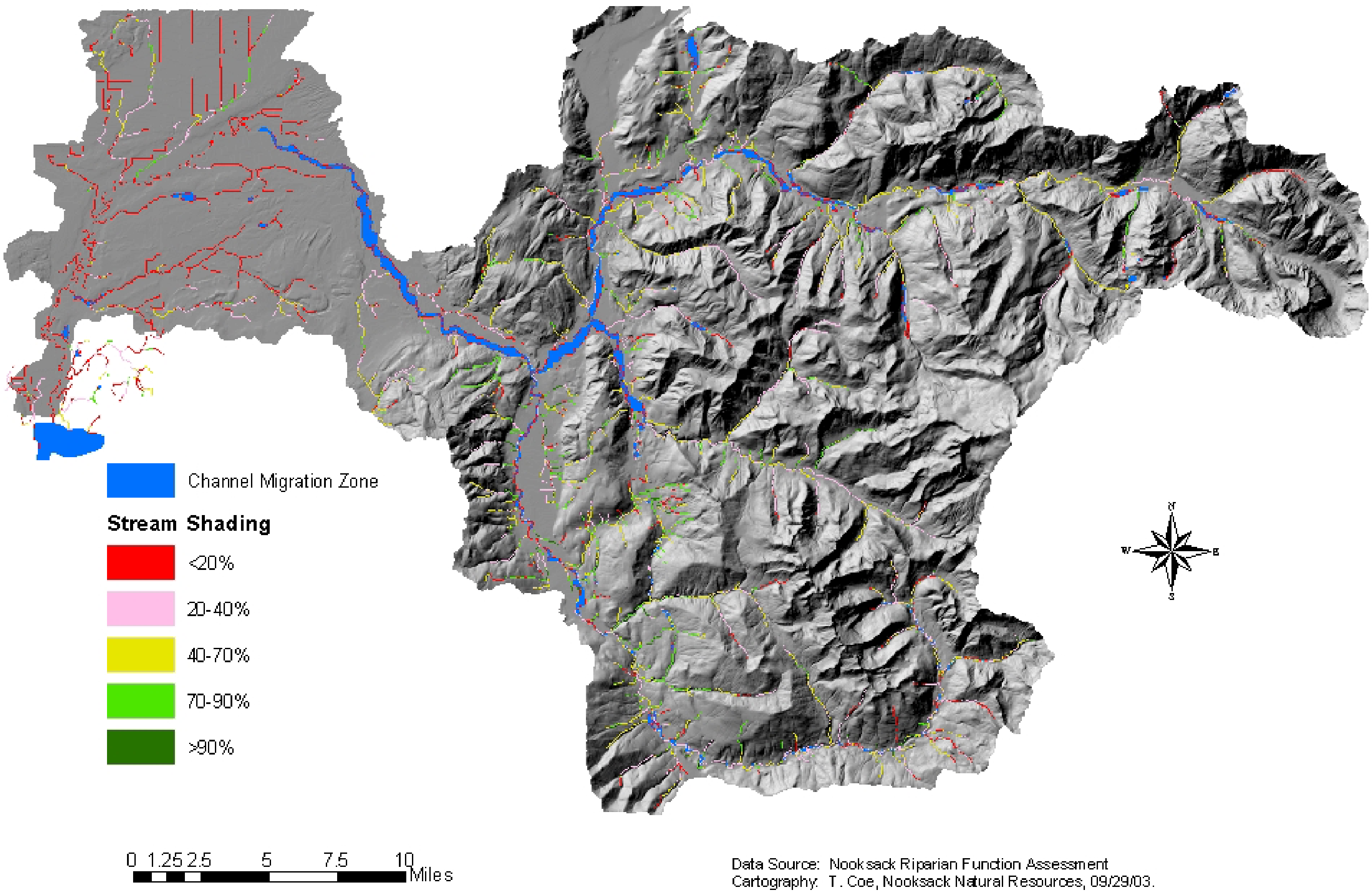
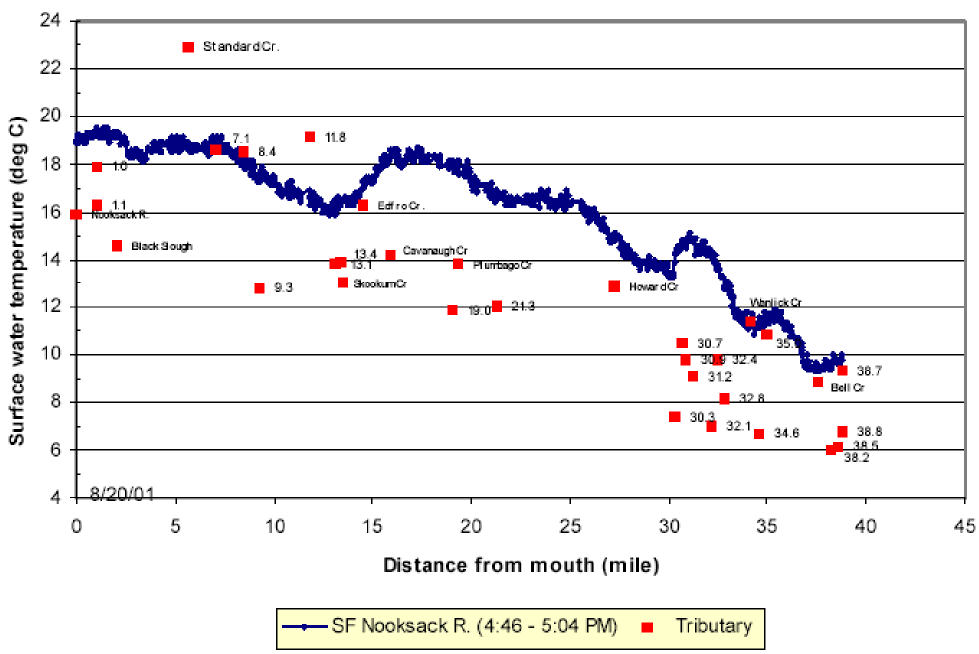


Figure C25. Median channel temperature (8/20/01) versus river mile for: (a) the Nooksack River and tributaries downstream of the South Fork confluence; and (b) The South Fork Nooksack River and tributaries.

NOTE: RM differs from those derived from either USGS maps or the WRIA 1 Stream Catalog. Source: *Aerial Remote Sensing Surveys in the Nooksack River Basin: Thermal Infrared and Color Videography*. Final Report to Nooksack Indian Tribe, Natural Resources Dept., Deming, WA. Report by Watershed Sciences, LLC, Corvallis, OR. December 12, 2002.



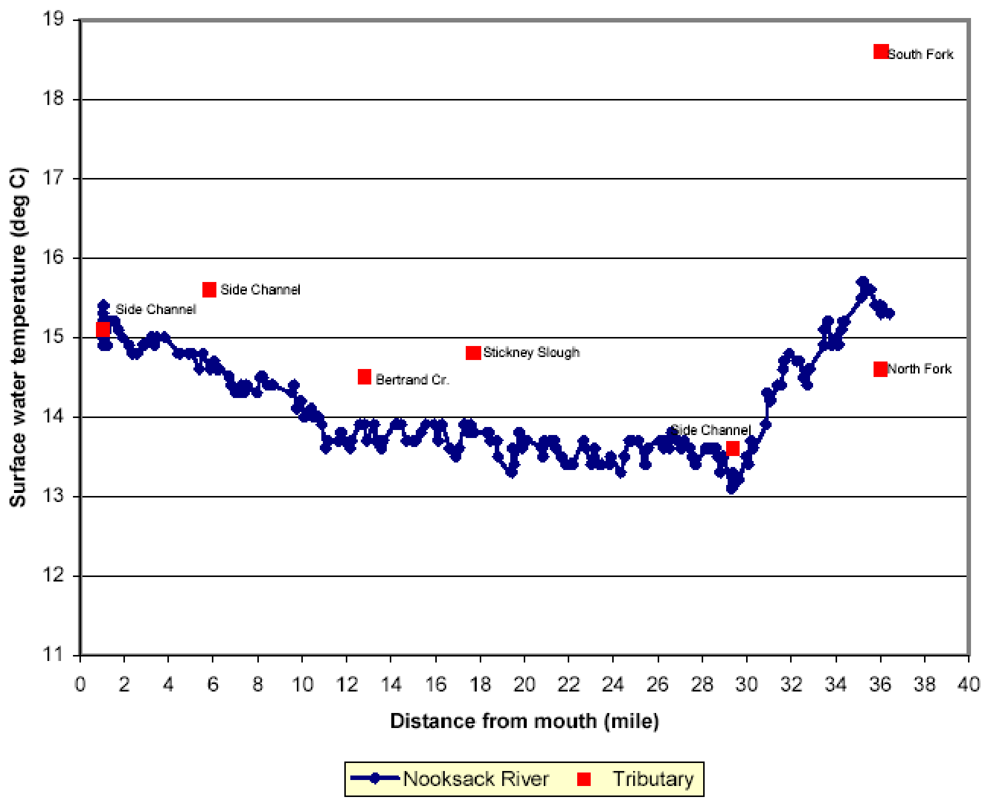


Figure C27. Post Season FRAM estimates of % harvest for Nooksack early Chinook stocks. (Source: 'FRAM validation set - May 2003' , A. Rankis, NWIFC pers. comm. Dec. 2003).

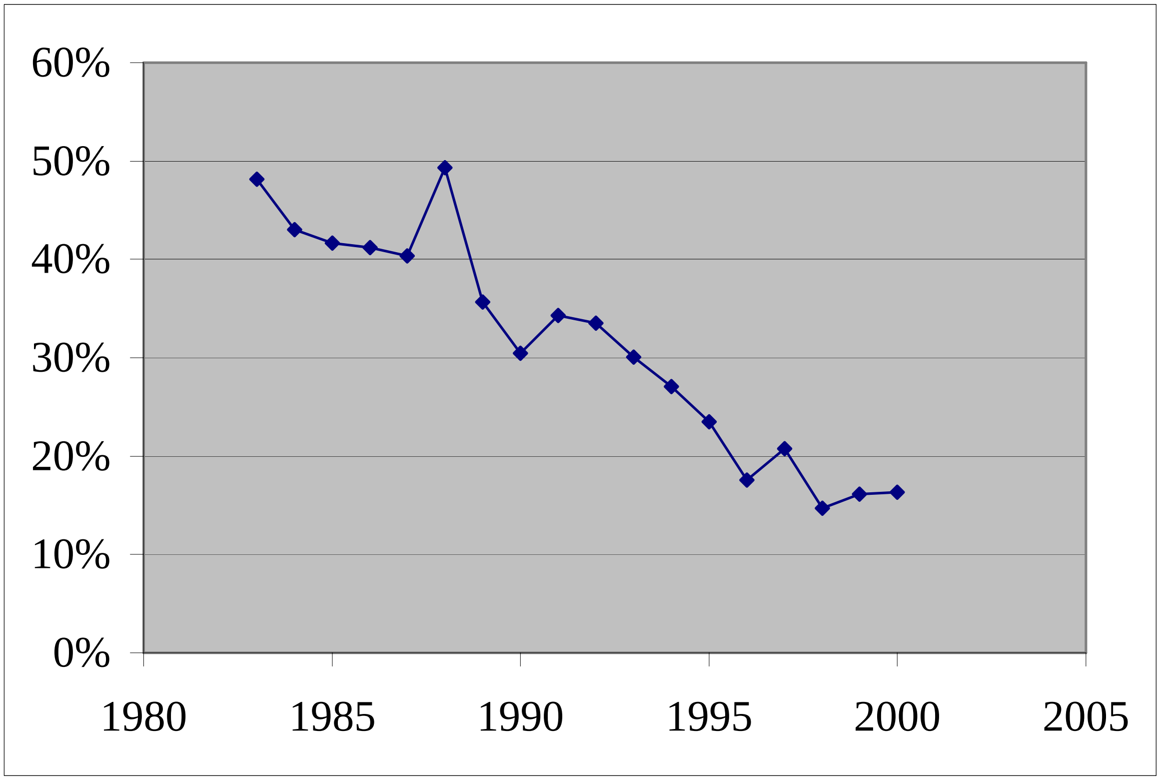


Table C12. Distribution of harvest for Puget Sound chinook indicator stocks, expressed as an average (1996-2000) proportion of total, annual, adult equivalent fishing exploitation rate (TCChinook 02-3 2002)

	Alaska	**B.C.**	**Washington troll**	**Puget Sound Net**	**Washington Sport**
Samish Fall	2.3%	43.0%	1.8%	40.2%	12.7%
Stillaguamish Sum	17.8%	50.3%	0.3%	2.6%	29.1%
South Puget Snd Fall	2.0%	29.6%	6.0%	21.7%	40.7%
Nisqually Fall	0.5%	14.5%	2.6%	44.9%	37.6%
Skokomish Fall	1.7%	37.4%	9.0%	7.2%	44.7%
Hoko Fall	74.2%	25.3%	0.0%	0.6%	0.0%
Nooksack Spring	1.6%	75.7%	1.5%	3.0%	18.3%
Skagit Spring	1.0%	51.4%	1.2%	7.1%	39.2%
White River Spring	0.0%	4.5%	0.6%	3.5%	91.4%

Table C13. Commercial net fishery harvest of pink salmon from the Nooksack, Skagit, and Snohomish river systems, 1991 – 2001.

2001 data are preliminary. (TFT database).

	Bellingham Bay & Nooksack River	Skagit Bay & Skagit River	Possession Sound & Port Gardner
1991	17,447	133,672	46,039
1993	1,335	143,880	9,648
1995	7,339	524,810	48,006
1997	1,196	46,169	34,537
1999	2,484	32,339	13,055
2001	12,280	198,534	86,097

Table C14. Landed coho harvest for Puget Sound net fisheries, 1998 - 2002.

Regional totals include freshwater catch (TFT database).

	Strait of Juan de Fuca	Georgia & Rosario Strait	Nooksack Samish	Skagit	Stillaguamish Snohomish	So Puget Sound	Hood Canal	Total
1998	8,083	1,980	22,892	10,359	24,743	65,617	21,974	155,648
1999	5,586	1	50,175	7,411	18,439	21,189	4,845	107,646
2000	4,338	1,501	67,587	11,151	86,328	186,397	20,860	378,162
2001	15,521	721	76,232	15,948	60,863	137,327	8,512	315,124
2002	9,458	3,638	50,863	7,688	48,578	107,236	7,547	235,008