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Sediment Removal to Enhance Fisheries*

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1. Introduction

Dredging sands and gravels from river beds and scalping annual sediment deposits from bars are too often considered environmentally harmful to aquatic life and water quality by environmental policy makers, regulators, and the public. One reason for this belief is that natural ecosystems are very complex and highly variable. Adding to this complexity and variability altered weather patterns (precipitation and the entire hydrologic cycle) contribute to changed behaviors by fish within each river system. In the western states resident and anadromous[1] fish in the lower reaches of river system are presented with warmer summer water temperatures, shallower water depths, and slower current velocities than in past decades. This is true for the Nehalem River. These changes in basins such as the Nehalem River, could further stress Pacific salmonids, particularly those listed under the Endangered Species Act (ESA), returning to these rivers to reproduce.

Most conservation and restoration efforts are focused on spawning habitats and passage past barriers to these habitats. Yet fish life cycles require different types of habitats which means that policies and decisions to enhance fish habitats and populations should be based on the entire river network and drainage basin characteristics as well as fish life cycles.

The tight integration of stream/river ecology (the plants and animals living in it) with its geomorphology (the shape and topography of the drainage basin and the pattern of the river network draining it) was first presented in The River Continuum Concept (Vannote et al., 1980) and should be the foundation for aquatic ecosystem policy and regulatory decisions today.

This document presents a detailed description of the Nehalem River basin from an integrated perspective. Based on this description it describes how in-river dredging and bar scalping in the lower reaches of the Nehalem River could contribute to enhanced fish habitats and populations while also benefiting economic and societal interests by reducing winter flooding of cities and farms and by helping to maintain navigation channels in the bay and estuary.

There are 49 species of fresh water fish reported in the Nehalem River system including seven species of anadromous fish (with two runs of chinook salmon and steelhead trout (Table 5.1 on page 21).

Mohler Sand and Gravel's location at River Mile 9.8 allows the company to benefit fish migrations to and from up-river reaches (Figure 2.1 on the next page) while providing small, shaded off-channel refugia for summer out-migrating juveniles. The company's sediment removal from bars (and, potentially, the river channel itself) would also benefit the economic, environmental, and societal environments of the bay and surrounding communities. This document describes the dynamics of this drainage basin and river network and the lower river reach and how control of river morphology, sediment transport, and fish habitat needs can enhance fisheries and benefit people.

Unfortunately, there are comparatively few available data for the hydrology and fisheries of the Nehalem River network; what are available are sufficient for informed decisions.

[1] Fish species which breed and rear in fresh waters and migrate to the ocean to grow to adulthood before returning to their natal streams to reproduce. Anadromous salmon species have only one opportunity per generation to reproduce. Ocean-going steelhead (rainbow) and sea-run cutthroat trout can commute between fresh and marine waters several times per generation.

2. Nehalem River Basin and Network

The Nehalem River basin covers 667 square miles and the river network draining this basin has 932 miles of permanent channels (Figure 2.1).

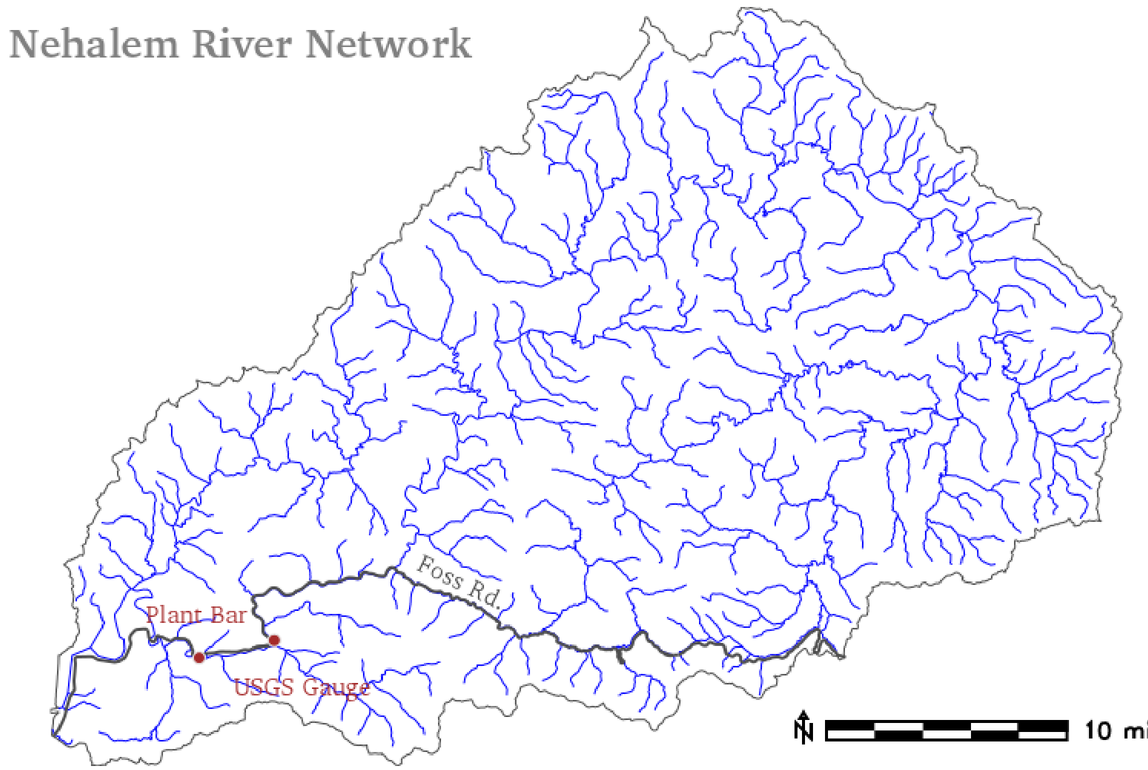

Figure 2.1.: The Nehalem River basin and the river network draining it. The USGS gauge station and the location of Mohler Sand & Gravel's Plant Bar are shown.

Every drainage basin has three zones where topography (the shape of the landscape) and hydrology (how water flows over the surface and through the ground) define sediment transport dynamics. The upper portion of the river network with its lower order streams and tributaries is the sediment production zone. The middle portion of the river network is the sediment transport zone where production and deposition are balanced. The lower portion of the river network is the deposition zone where the flat gradient, wide river channel, and slowly flowing water allows sediments of all sizes to accumulate.

The density of stream channels in the Nehalem River network is sufficiently high that there are no distinct erosion and transport zones but there is a large depositional zone which controls anadromous fish movements.

The average elevation of the basin is 1,094 feet and maximum elevation is 3,703 feet in the south-central portion (Figure 2.2).

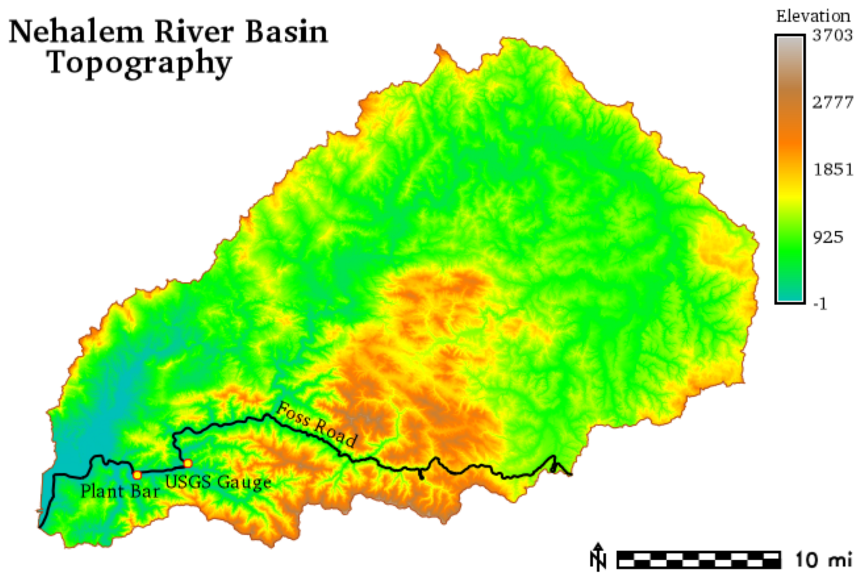

Figure 2.2.: Nehalem River basin topography. The highest elevations are in the south-central and southern edge of the basin.

With the highest elevations near the lower reaches of the river both precipitation runoff and erosion will be greater in this area than in other areas of the basin, and it is likely that the majority of sediments deposited on the Plant and Winslow bars, as well as in-river and the estuary and bay originate here.

Hill slopes in the basin range from flat to 89^o and the average slope is $42 \pm 20°$ (Figure 2.3).

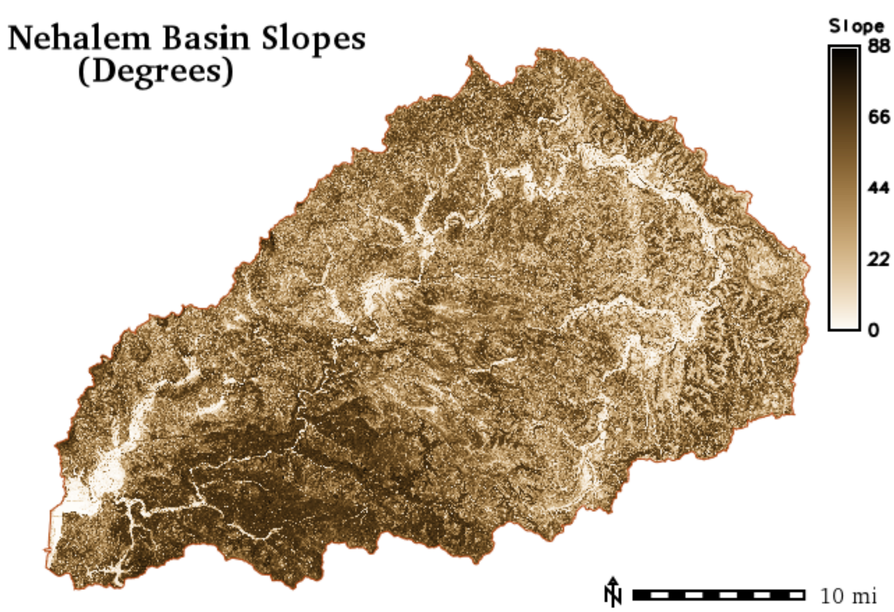

Figure 2.3.: Hillside slopes in the Nehalem River basin. The bay and estuary extends well up into the North Fork of the river.

Runoff will occur quickly when not restrained by ground cover and contribute erosional sediments to the river channel.

While the basin is complex with many hills and valleys the average slope faces southeast (Figure 2.4) which allows afternoon sunlight can warm river waters during the summer.

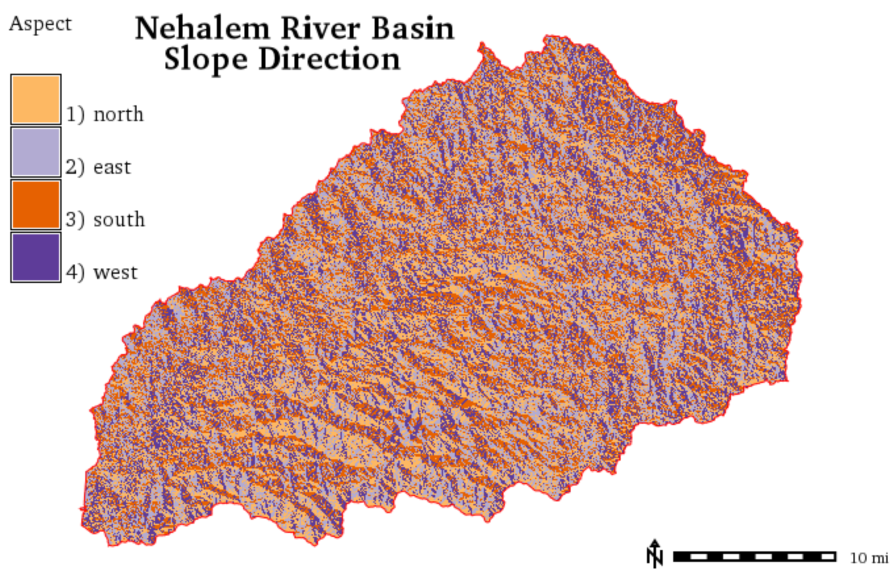

Figure 2.4.: The aspect (compass direction) of hillsides throughout the Nehalem River basin. In the higher elevation areas most slopes face north and south.

The complexity of the river network, topography, and steepness of the slopes all affect the habitats available for use by resident and anadromous fish. Most of the basin does not need work to improve fish travel and habitats but the lower reaches down river from the areas of highest elevations are bottlenecks to travel and population sizes.

3. Current Conditions

The Nehalem River in the vicinity of the Plant and Winslow bars on August 1, 2019 exhibited the low water levels and bank erosion that has been common in recent years. The two bars were being naturally vegetated and the small backwater showed its potential value as a summer warm water refuge for out-migrating salmonid smolts[1].

River beds are not flat from bank-to-bank nor do they have uniform sediment sizes in any direction. As a result flowing water follows the path of least resistance at all scales from headwaters to the mouth. This path of least resistance is called the *thalweg*. As the thalweg wanders from side-to-side it causes the meanders and braids common in river systems. Fast moving water in the thalweg erodes sediments and carries them downstream while slower waters accumulate sediments forming point and mid-channel bard (the former on the inside of bends the latter along banks or in the middle of the river when flows are especially low.)

The water is extremely shallow adjacent to the Plant bar (Figure 3.1)

Figure 3.1.: Looking southeast from the upstream end of the Plant bar. The substrate is almost exposed across the width of the river.

and there are several mid-channel (braid) bars[2] (Figure 3.2)

[1]The juvenile life stage at which anadromous fish begin to travel to the Pacific Ocean.

[2]Common in lower reaches of rivers where low flows result in the water taking the path of least resistance around areas of more tightly packed sediments and eventually eroding the edges of these areas leaving an exposed bar in the channel.

Figure 3.2.: One of many mid-channel bars in the lower Nehalem River left by low flows that move only the lightest loosely-packed sediments.

both up- and downriver from the Plant bar.

The northwest edge of the Plant bar, adjacent to the shaded river bank has a narrow, partially filled channel with potential as an off-channel refuge for fish during the summer and migration (Figures 3.3, 3.4,and 3.5).

Figure 3.3.: The west end of the potential off-channel refuge against the east bank of the river.

Figure 3.4.: The closed end of the potential off-channel refuge.

Figure 3.5.: The mid section of the potential off-channel refuge.

The Winslow bar, close down river from the Plant bar, is an example of point bar development when lower river reaches are not maintained with sufficient depth during the summer low flow period (Figure 3.6).

Figure 3.6.: The Winslow bar is at the left center of this image; the Plant bar is in the center with a few small bars above and below it. Image dated 22 June 2017.

Two years ago the river channel was severely narrowed and started cutting a new channel in private farm land south of the river because the deposited sediments on the bar blocked flows that would normally erode the bar during the rain season.

On 1 August 2019 the bar was larger and the river channel more constricted. One reason is that the size and location of the bar allowed fine organic materials such as twigs to accumulate along with the larger woody debris that could be screened to separate it from the organic river rock (Figure 3.7).

Figure 3.7.: The Winslow bar with vegetation and woody debris. The finer wood pieces cannot be separated from the gravels and are not acceptable for concrete aggregate use.

Because no organic material can be in construction aggregate this bar cannot be scalped without treatment or deposition of the upper layers in stock piles that allow the organics to decay over time. The resulting impacts include deepening of the very narrow channel, decreased clearing of the bar surface by fast flowing waters, increased erosion on the south bank, more sediment deposition further down river and in the estuary and bay, and impaired fish passage for juvenile and adult anadromous salmonid fish.

4. Hydrology

Hydrology is the science of water moving downslope in a drainage basin, creating drainage channels, and flowing into those channels. Hydraulics is the movement of water within channels which transports sediments.

Water years run from October 1st through September 30th of the following year.

The US Geological Survey (USGS) maintains a river gauge for hydrologic unit code 14301000 Nehalem River near Foss (Figure 2.1). Data available at this gauge are presented in Table 4.1. While there are no temperature data, and only three years of precipitation data, there are abundant daily discharge[1] records for about 80 years.

Table 4.1.: Data types, collection date range, and total number of observations for the Nehalem River at the Foss gauge.

Data Type	Begin Date	End Date	Count
Current & Historical Observations	1986-10-01	2019-08-08	
Daily Data			
Temperature, water (^oC)	1974-12-04	1981–09-29	5449
Precipitation, total, inches	2009-10-01	2012-11-12	1117
Discharge, cubic feet per second	1939-10-01	2019-08-10	29165
Daily Statistics			
Temperature, water (^oC)	1978-10-01	1981-09-29	968
Discharge, cubic feet per second	1939-10-01	2019-04-01	29037
Monthly Statistics			
Temperature, water, degrees Celsius	1979-10	1981-09	
Discharge, cubic feet per second	1939-10	2019-04	
Annual Statistics			
Temperature, water, degrees Celsius	1979	1981	
Discharge, cubic feet per second	1939	2019	
Peak Streamflow	1939-12-16	2017-02-09	78
Field Measurements	1928-02-19	2019-07-18	293
Field/Lab Water Quality Samples	1960-08-30	1993-08-03	245
Water Year Summary	2006	2018	13

4.1. Water temperature

The USGS gauge station recorded daily maximum and minimum water temperatures from December 4, 1974 through September 29, 1981, a total of 2,492 observations. The summary of these observations are in Table 4.2.

[1] The volume of water passing a cross section of a channel. The current velocity multiplied by the cross-sectional area is the discharge.

Table 4.2.: Daily maximum and minimum water temperatures at the USGS Foss Road gauge. The first number is in ^oC, the second in ^oF.

	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	No Data
High	0.10/32.18	7.60/45.68	11.40/53.52	12.21/53.98	17.20/62.96	24.30/75.74	249
Low	0.00/32.00	6.60/43.88	10.80/51.44	10.88/51.58	15.40/59.72	22.70/72.86	253

The daily maximum and minimum water temperatures are in Figure 4.1.

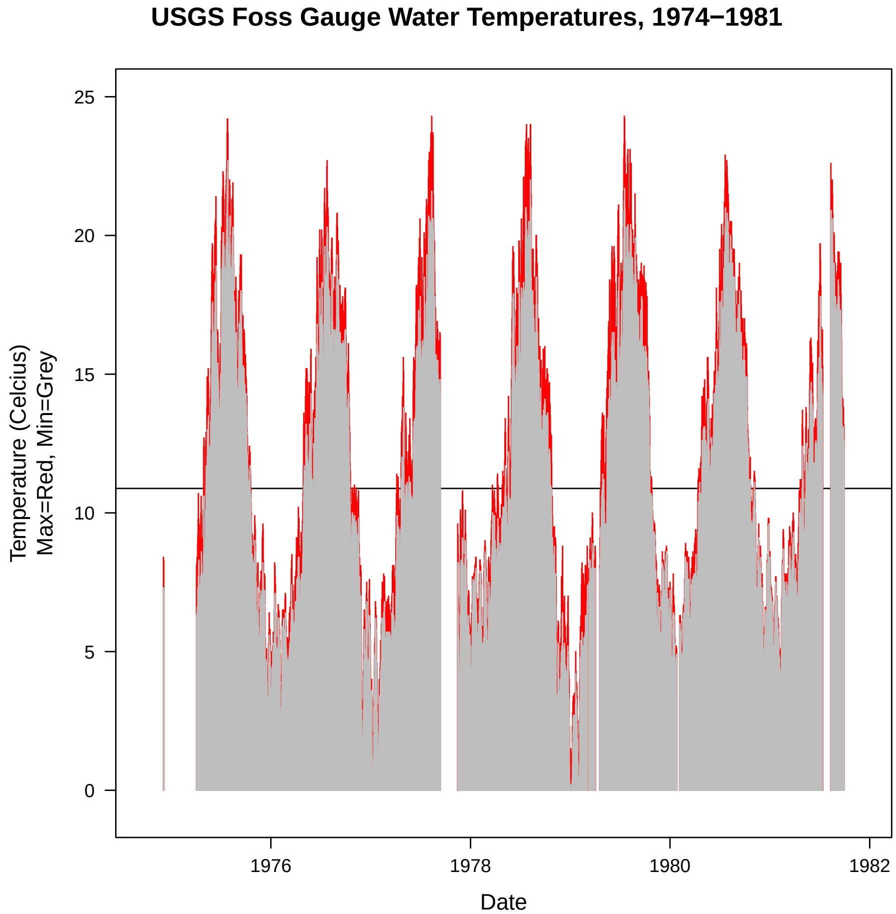

Figure 4.1.: Daily maximum and minimum water temperatures at the USGS Foss Road gauge. The horizontal line is the median daily temperature (51.6 ^oF).

During the summer months with low precipitation and water levels 25% of the days the maximum water temperature is between 11–17 °C (52–63 °F) and the minimum water temperature is between 11–15 °C (52–59 °F). These are within the estimated optimal temperatures for common anadromous salmon summer habitat use of 10–17 °C (50–63 °F) Poole et al. (2001).

Cold(er) water refuges benefit the fish traveling through the lower reaches of the main step Nehalem River and the potential for one such refuge along the northeast side of the Plant Bar should be developed [reference here].

4.2. Precipitation

The three years of daily total precipitation at the gauge are seen in Figure 4.2.

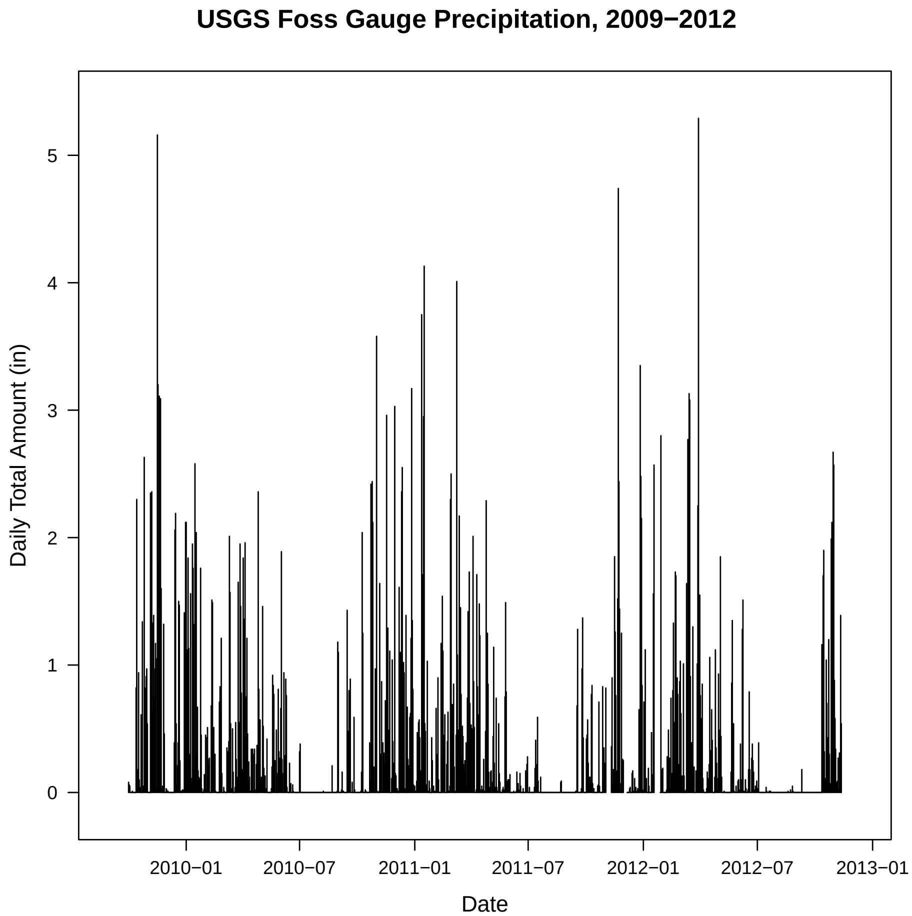

Figure 4.2.: Total daily precipitation at the USGS gauge during 2009-2012.

While there are a few storms with peak accumulation of more than 4 inches there are frequent storms throughout the year other than late summer; a pattern typical for the Oregon coast which might change as the climate warms and weather patterns. A summary of the precipitation records is in Table 4.2 on the preceding page.

Table 4.3.: Descriptive statistics of the three years of precipitation records at the USGS Foss Road gauge. Numbers are total inches per day. See text for explanation.

Minimum	!st Quartile	Median	3rd Quartile	Maximum	No Data
0.00	0.00	0.03	0.38	0.45	22

The first quartile represents 25% of all measurements, the median represents the value that has the same number of lower and higher values (50%), and the third quartile represents the value greater than 75% of all measurements.

If these rain events dropped greater amounts higher in the drainage basin then there would be high enough flow rates to move sediments down the river, particularly smaller sands and gravels which quickly drop out of suspension when current velocity slows.

While we lack more extensive precipitation data for other portions of the basin, the Foss Road gauge is a good summary of how much precipitation runoff throughout the drainage basin reaches the lower reach of the river.

4.3. Discharge and stage height

4.3.1. Discharge

The basin-wide rainfall is reflected in the discharge recorded at the USGS gauge (Figure 4.3).

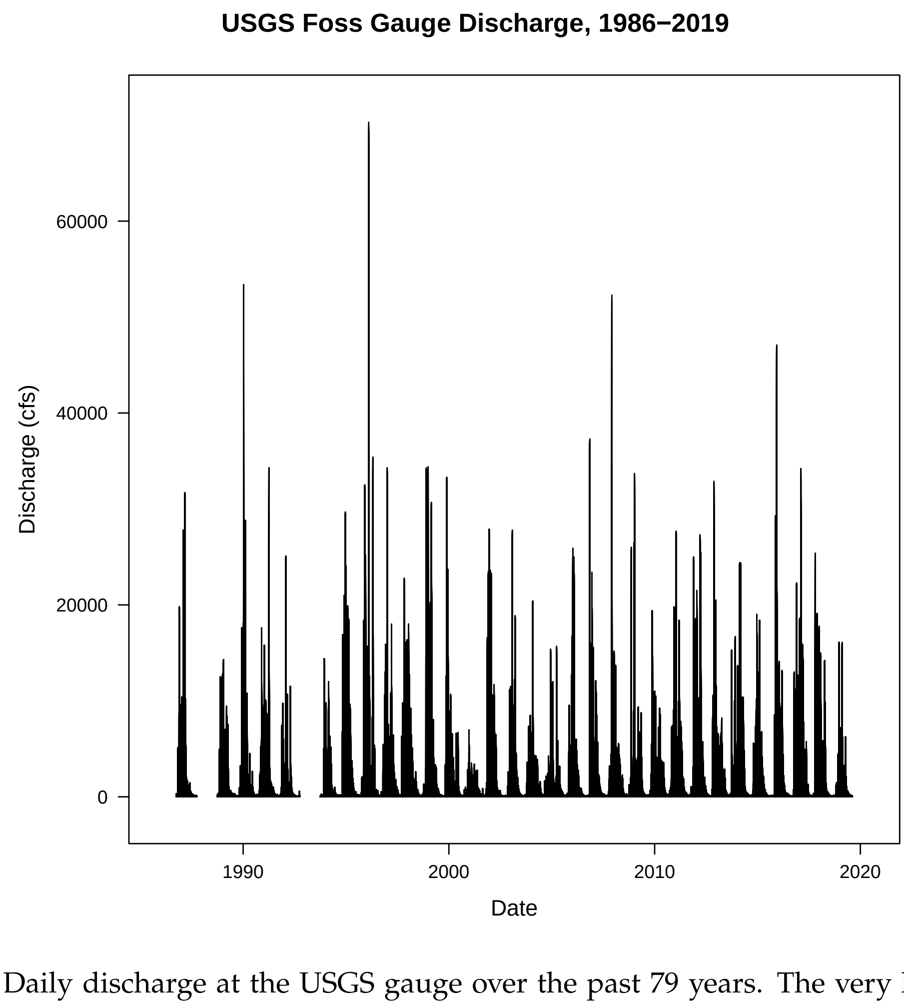

Figure 4.3.: Daily discharge at the USGS gauge over the past 79 years. The very high value was probably recorded winter 1996 when many Oregon rivers flooded.

Measurements were collected every half-hour from October 1, 1986 through August 12, 2019 when the data set were downloaded from the agency's web site.

A summary of the discharge is in Table 4.4.

Table 4.4.: Descriptive statistics of the half-hourly measures of discharge at the USGS Foss Road gauge. Values are in cubic feet per second.

Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
42	234	1220	2684	3400	70300

Over the period of record the most common discharge value has been 1,220 cfs (the median value) while the four observations of discharge greater than 40,000 cfs influences the mean value at 2,685 cfs, more than twice the median value. It is also important to note that 25% of all measurements were no greater than 234 cfs, a very slow flow of water this far down the river system.

4.3.2. Stage height

Stage height is the elevation of the river's water surface above the riverbed at the USGS Foss Road gauge. Measurements at 15 minute intervals from October 1, 2007 at 1:00 am through August 12, 2019 at 1:15 pm (when the data were downloaded from the agency's web site) provide a data set of 363,062 values (Figure 4.4).

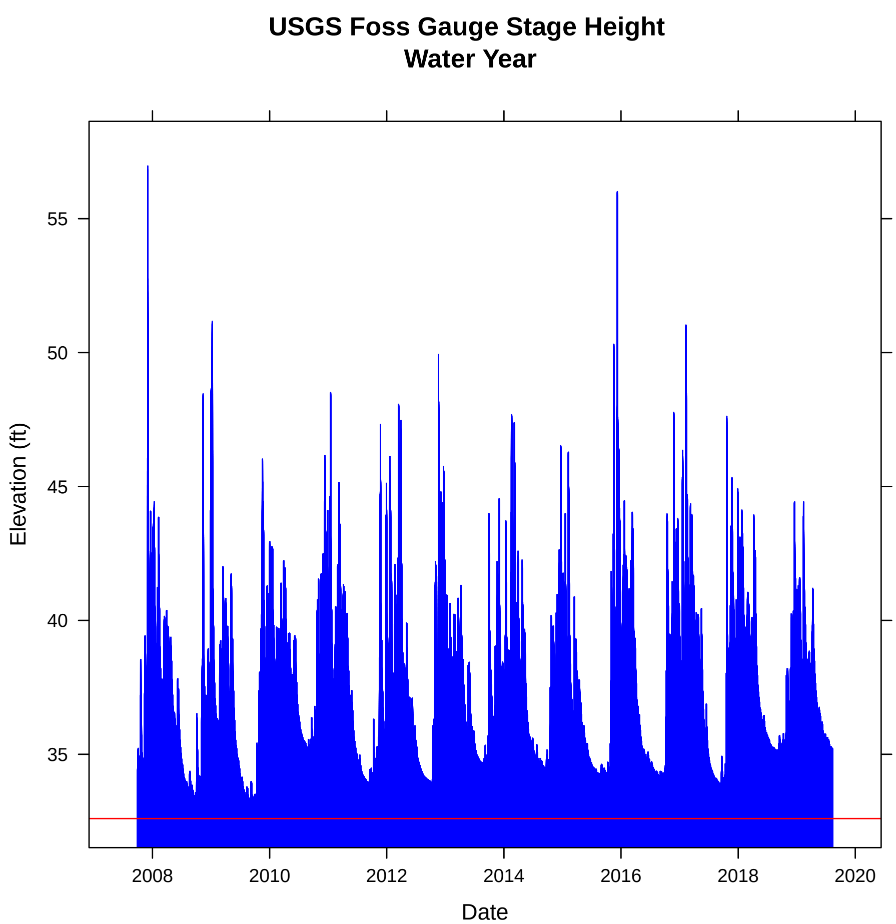

Figure 4.4.: Water depth (stage height) at the USGS Foss Road gauge. The red horizontal line is the elevation of the riverbed at the gauge.

Descriptive summaries for the water depth are in Table 4.5.

Table 4.5.: Stage heights (water depth) at the USGS Foss Road gauge. Both the elevation and the depth of the water surface above the river bed are shown.

	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Elevation	33.18	35.16	37.30	37.50	39.30	56.97
Depth	0.580	2.560	4.700	4.895	6.700	24.370

These data show the need for increased water depths during the low flow season. The minimum depth measured over the dozen water years is slightly more than 1/2 foot, and 25% of all water depths are between 7–25 inches. Such shallow water depths in the lowest reaches of an extensive river system result in warmer water temperatures, lower dissolved oxygen levels, increased sediment deposition in the middle of the channel as well as along the banks, and loss of habitats to resident and migratory fish.

5. Fish populations

The Pacific States Marine Fisheries Commission maintains a fisheries database called StreamNet for the entire Columbia River basin (`https://www.streamnet.org`). Federal, tribal, and state resource agencies and other participants contribute information on fish populations and redd (breeding nests) counts. The database also has information on dams and other barriers to fish passage and hatcheries.

There are five Pacific salmon species: Chinook, Chum, Coho, Pink, and Sockeye. The terms "run" and "stock" are human population management terms without biological meaning.

The Nehalem River and its tributaries provide habitats for 49 species of fish, both resident fresh water and anadromous life histories (Table 5.1).

Table 5.1.: Common and scientific names of fish recorded in the Nehalem River and its tributaries.

Common Name	Scientific Name
Black crappie	Pomoxis nigromaculatus
Bluegill	Lepomis macrochirus
Brook trout	Salvelinus fontinalis
Brown bullhead	Ameiurus nebulosus
Brown trout	Salmo trutta
Bull trout	Salvelinus confluentus
Chinook salmon	Oncorhynchus tshawytscha
Chiselmouth	Acrocheilus alutaceus
Chum salmon	Oncorhynchus keta
Coastal cutthroat trout	Oncorhynchus clarkii clarkii
Coho salmon	Oncorhynchus kisutch
Common carp	Cyprinus carpio
Cutthroat trout	Oncorhynchus clarkii
Fathead minnow	Pimephales promelas
Goldfish	Carassius auratus
Grass carp	Ctenopharyngodon idella
Green sturgeon	Acipenser medirostris
Lampreys	Petromyzontidae
Largemouth bass	Micropterus salmoides
Largescale sucker	Catostomus macrocheilus
Longnose dace	Rhinichthys cataractae
Mountain sucker	Catostomus platyrhynchus
Mountain whitefish	Prosopium williamsoni
Northern pikeminnow	Ptychocheilus oregonensis
Oregon chub	Oregonichthys crameri
Pacific lamprey	Entosphenus tridentatus
Pink salmon	Oncorhynchus gorbuscha
Prickly sculpin	Cottus asper

Table 5.1.: Common and scientific names of fish recorded in the Nehalem River and its tributaries.

Common Name	Scientific Name
Pumpkinseed	Lepomis gibbosus
Rainbow trout X Cutthroat trout hybrid	Oncorhynchus mykiss X Oncorhynchus clarkii
Rainbow/Steelhead/Redband trout	Oncorhynchus mykiss
Rainbow/Redband/Steelhead trout	Oncorhynchus mykiss gairdnerii
Redside shiner	Richardsonius balteatus
Reticulate sculpin	Cottus perplexus
Sculpins	Cottus spp.
Smallmouth bass	Micropterus dolomieu
Sockeye salmon/Kokanee	Oncorhynchus nerka
Speckled dace	Rhinichthys osculus
Threespine stickleback	Gasterosteus aculeatus
Torrent sculpin	Cottus rhotheus
Warmouth	Lepomis gulosus
Western brook lamprey	Lampetra richardsoni
Western mosquitofish	Gambusia affinis
Westslope cutthroat trout	Oncorhynchus clarkii lewisi
White crappie	Pomoxis annularis
White sturgeon	Acipenser transmontanus
Yellow bullhead	Ameiurus natalis
Yellow perch	Perca flavescens

Distribution maps for the species and runs in the Nehalem River network are in Appendix A.

The Nehalem River network includes 53 tributaries[1] in which resident and/or anadromous fish populations were identified by the Oregon Department of Fish & Wildlife (ODFW). The number of species per tributary range from 4 to 150 (Table 5.2).

Table 5.2.: Nehalem River tributaries and the number of fish species found in each when ODFW surveyed it.

Tributary Name	Species Count
Anderson Creek	4
Battle Creek	4
Beaver Creek	4
Beneke Creek	40
Big Rackheap Creek	4
Buchanan Creek	50
Buster Creek	14
Clear Creek	16
Coal Creek	24
Cook Creek	78

[1]Some tributaries might be entered twice with slightly different names because the database does not enforce a consistent naming system.

Table 5.2.: Nehalem River tributaries and the number of fish species found in each when ODFW surveyed it.

Tributary Name	Species Count
Cow Creek	52
Cronin Creek	132
Crooked Creek	25
Deep Creek JabRef-2.9.2-noarch-1_SBo	16
Deer Creek	8
East Fork Nehalem River	9
Fall Creek	10
Fall Creek	10
Fishhawk Creek	48
Foley Creek	44
George Creek	4
Gods Valley Creek (previously temp2)	13
Gravel Creek JabRef-2.9.2-noarch-1_SBo	6
Henderson Creek	4
Humbug Creek	141
Jim George Creek	4
Kenusky Creek	4
Little North Fork Nehalem River	58
Lost Creek	6
Lost Creek	5
Lousignont Creek	16
Lundgren Creek (Historical)	12
Necanicum River	8
Neskowin Creek	11
Salmon River	8
Moores Creek	4
Nehalem Bay	5
Nehalem River	31
Nehalem River & Tribs	11
North Fork Nehalem River	87
Northrup Creek	12
Oak Ranch Creek	150
Pebble Creek	24
Rock Creek	38
Salmonberry River	92
Squaw Creek	12
Step Creek	4
Sweet Home Creek	16
Unnamed Stream [1230895458400]	8
Unnamed stream [1233078460150]	8
Unnamed stream [1237470458119]	6
Wolf Creek	4

The effects of precipitation, runoff, and the complex dendritic form of the river network in a basin with a lot of small drainages (Figures 2.1 on page 6 and 2.2 on page 7) is seen in the distribution patterns of chinook salmon. The fall run of chinook salmon occurs during wet months and use smaller tributaries (Figure A.1 on page 29) than does the spring run which returns to spawn during the warmer, less wet months and is restricted to the mainstems of the North Fork and main fork of the river system (Figure A.2 on page 30).

Distribution of west coast sturgeons (green and white; Figures A.7 on page 35 and A.8 on page 36) are found in the estuary where suitable spawning habitats are a limiting factor to their populations. While sediments deposited in the estuary and bay are transported from the entire drainage basin, the majority come from the main river because the North Fork is comparatively flat (Figure 2.2 on page 7).

Chum salmon are highly dependent on suitable spawning and rearing habitats in the North Fork and lowest reach of the main stem (Figure A.4 on page 32) while coho salmon make use of much more of the river network (Figure A.3 on page 31).

The importance of suitable habitats for all cold-water fish is seen in the distribution of the pacific lamprey in the larger reaches of the river (Figure A.6 on page 34) while winter steelhead trout use both main stem and many tributaries (Figure A.9 on page 37) and the smaller resident cutthroat trout will occupy any perenial stream and river reach within the network (Figure A.5 on page 33). This is why maintaining greater depths in the lower reaches during low flow months is important to all fish in the basin.

6. Sediments

Sediments are transported through river networks by suspension and bedload transport. Current velocity determines the particle sizes that are suspended in the water column and rolled (or pushed) along the bottom. The smaller the particle size (silts, clays, sands, fine organic materials) the further it will be carried downriver.

Sediment particle type, size, and stability play a major role in fish distribution and population size. For example, gravels of a certain range of sizes with ample space between individual rocks are used as redds (nests) for salmonid eggs. Fine sediments that fill in the interstitial spaces can smother the eggs or make it difficult for the female fish to sweep them away to build the redd. Current velocities and temperatures in the redds need to allow sufficient levels of dissolved oxygen for the fish eggs to develop.

After the eggs hatch and the fry leave the redd they need a different habitat that provides them with the macroinvertebrate food resources they need while keeping the fish out of swift currents which consume too much energy to maintain position.

At all life stages and all seasons fish need abundant macroinvertebrate foods because all fish are carnivores. Sediment particle size distribution and current velocity determine which macroinvertebrates, and how many of them, are present. These macroinvertebrates reproduce abundantly and their life cycles are such that almost always the fish find sufficient foods. But, the types and sizes of sediments affects the species and abundances of macroinvertebrates along the river network and, therefore, how fish respond.

The Coast Range was pushed up from sedimentary and volcanic rocks in the immediate offshore areas millions of years ago. Sandstone and siltstone predominate and, being relatively soft rocks, are erodible by the steep drainage basins on the west side and readily transported down river.

Mohler Sand & Gravel has readily-available records of the volume of gravels collected from the Plant Bar 2011-2018 (Table 6.1) and the last time from the Winslow Bar in 2011 (4,743 cubic yards)[1].

Table 6.1.: Volumes and weights of gravel removed from the Plant Bar 2011–2018.

Year	Volume (yd^3)	Weight (tons)
2011	6,194	8,207
2012	7,300	9,672
2013	7,454	9,877
2014	7,880	10,441
2015	2,800	3,710
2016	6,150	6,149
2017	7,500	9,938
2018	5,300	7,022

[1] All river rock is considered to have the same weight per cubic yard: 1.325 tons (2,650 pounds).

These numbers summarize sediments collected from the river network upriver from the Plant Bar and suggest the variability from year to year.

7. Recommended Improvements

In the introduction I wrote that policies and decisions to enhance fish habitats and populations should be based on the entire river network and drainage basin characteristics as well as fish life cycles. This focus on the entire drainage basin provides a technically sound and legally defensible basis for making policy and regulatory decisions from among several future condition alternatives (Fullerton et al. 2009, McHugh and Budy 2004).Note, though, that while it is easy to relate salmon conservation efforts with economic growth the results are dependent on many factors not always considered (Lackey, 2005).

Figure 2.1 shows the basin has a pear shape and is oriented northeast-to-southwest with an extensive and complex river network that is not linear and with the majority of stream miles in the mainstem (the North Fork is comparatively small.)

Topographically, the North Fork drainage is comparatively flat (Figure 2.2) while the larger mainstem drainage has very high topographic diversity (changes in elevation in the southern half immediately upriver from the lower reaches feeding water and sediments to the bars in the vicinity and downriver from the Plant bar.

The entire basin has many small basins with a range of slopes (Figure 2.3) that contribute to the physical and hydrologic complexity of this basin.

Biologically and ecologically the basin is very rich in supporting all Northwest anadromous fish species with diverse habitats as can be seen in the extensive range of distributions in Appendix A. The combination of biological and physical comlexity makes the Nehalem River system important to Oregon's ecological, economic, and societal ecosystems. All of this depends on the condition of the lower river below the USGS gauge station.

The focus of efforts to benefit salmon populations and habitats in the lower Nehalem River is on the major limiting factor: travel through the lower reaches for out-migrating smolts and in-migraging adults such as summer steelhead trout (a cool, deep channel that offers protection from bird predation, rearing habitats for juvenile salmonid smolts, and off-channel refugia from high flows.) The likelihood of achieving a desired environmental future condition increases when the focus is on limiting factors (Booth et al., 2016) and the spatial and temporal needs of the species and runs of concern (Coronado and Hilborn, 1998).

In addition to benefitting anadromous and native fish these improvements will reduce bank erosion and the amounts of sediments deposited in the estuary and bay (benefitting the sturgeon populatoins that use this area for breeding.)

Planting trees on the south and west banks of the river will stabilize the ground and reduce erosion (and the sediment load that results) but will not completely shade the width of the river. The most benefits will result from creating a deeper channel and cool patches within the warm river (Ebersole et al., 2003 and Torgersen et al. 2012). River bank erosion reduction will not eliminate replenishment of bank-side bars such as the Plant and Winslow while it will eliminate in mid-channel and brand bars. Directing water flow through the main channel will keep it relatively free of deposited sediments and prevent (or greatly reduce) bank erosion on both sides.

Considering the role of the channel depth and management in the lower reaches of the Nehalem River on ESA-listed salmonids offers many opportunities for environmental, economic, and societal benefits but all factors must be carefully evaluated in designing and implementing specific alternatives. Doing this means setting aside one-size-fits-all environmental criteria and considering this ecosystem as unique and highly valuable.

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A. Nehalem River Fish Distributions

A.1. Chinook Salmon

A.1.1. Fall Run

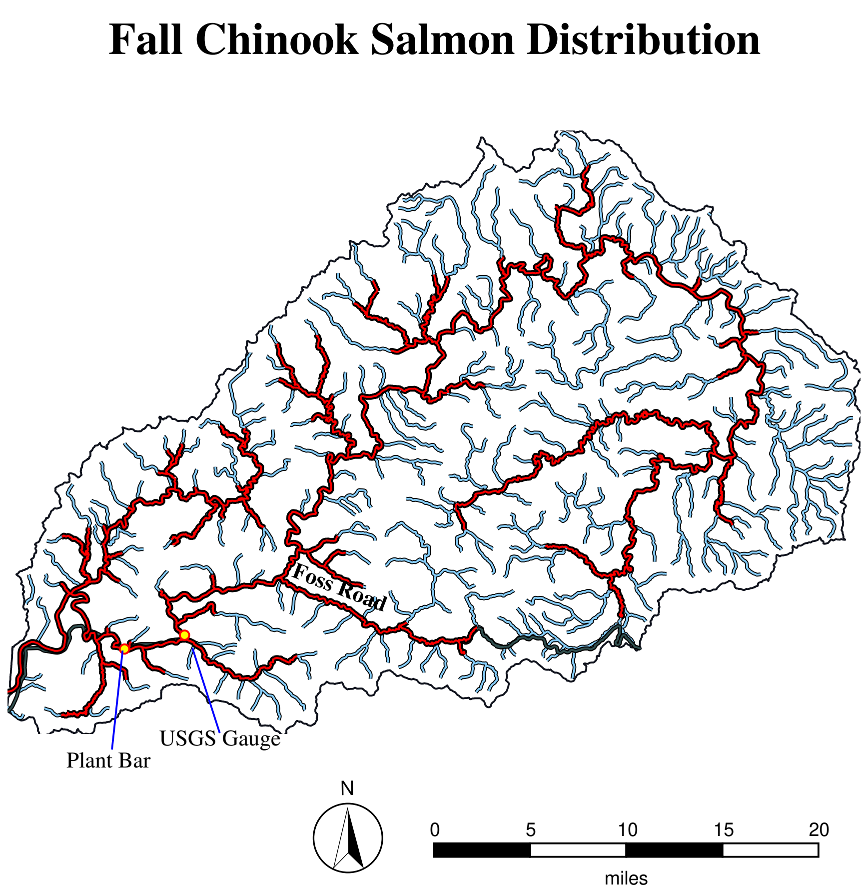

Figure A.1.: Fall chinook salmon distribution in the Nehalem River.

A.1.2. Spring Run

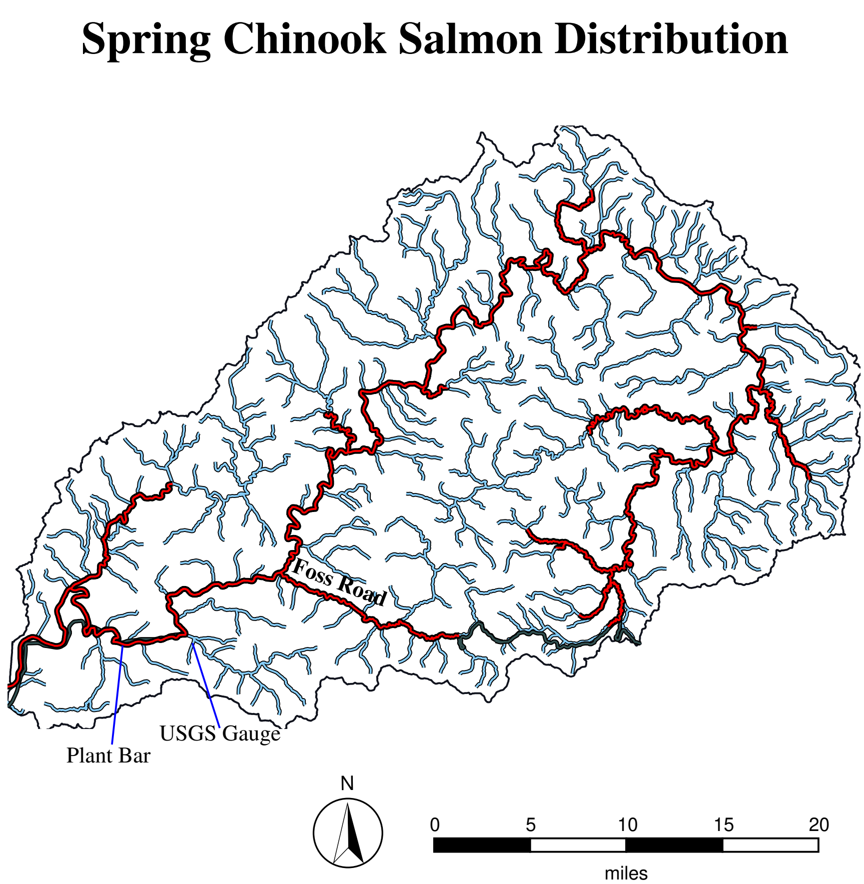

Figure A.2.: Spring chinook salmon distribution in the Nehalem River.

A.2. Coho Salmon

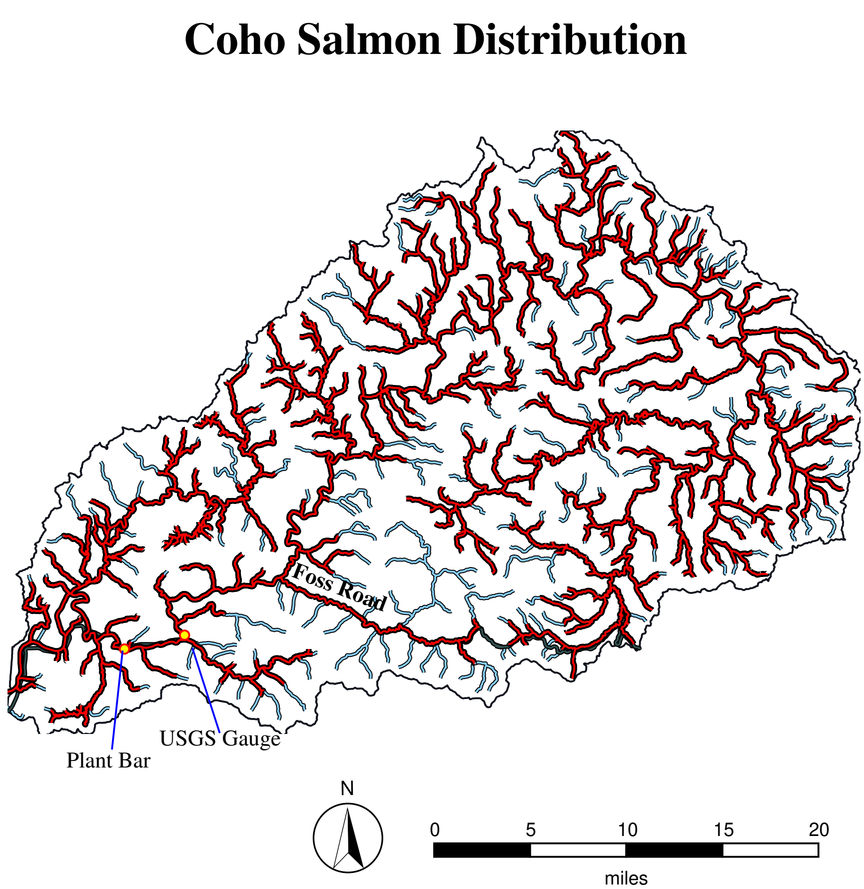

Figure A.3.: Coho salmon distribution in the Nehalem River.

A.3. Chum Salmon

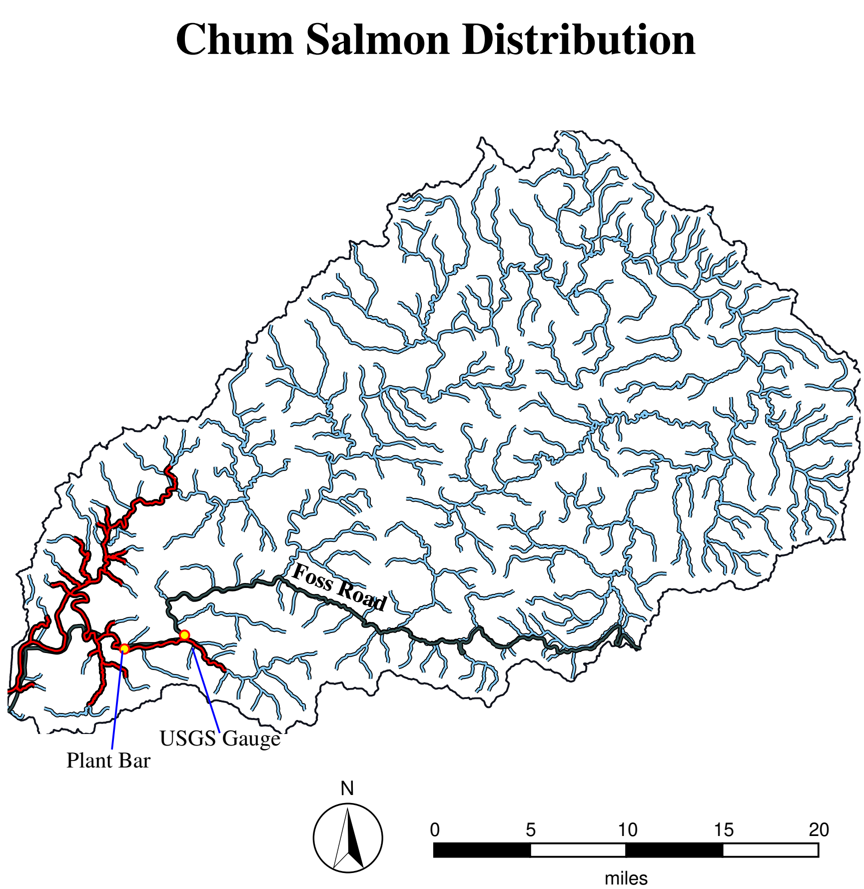

Figure A.4.: Chum salmon distribution in the Nehalem River.

A.4. Cutthroat Trout

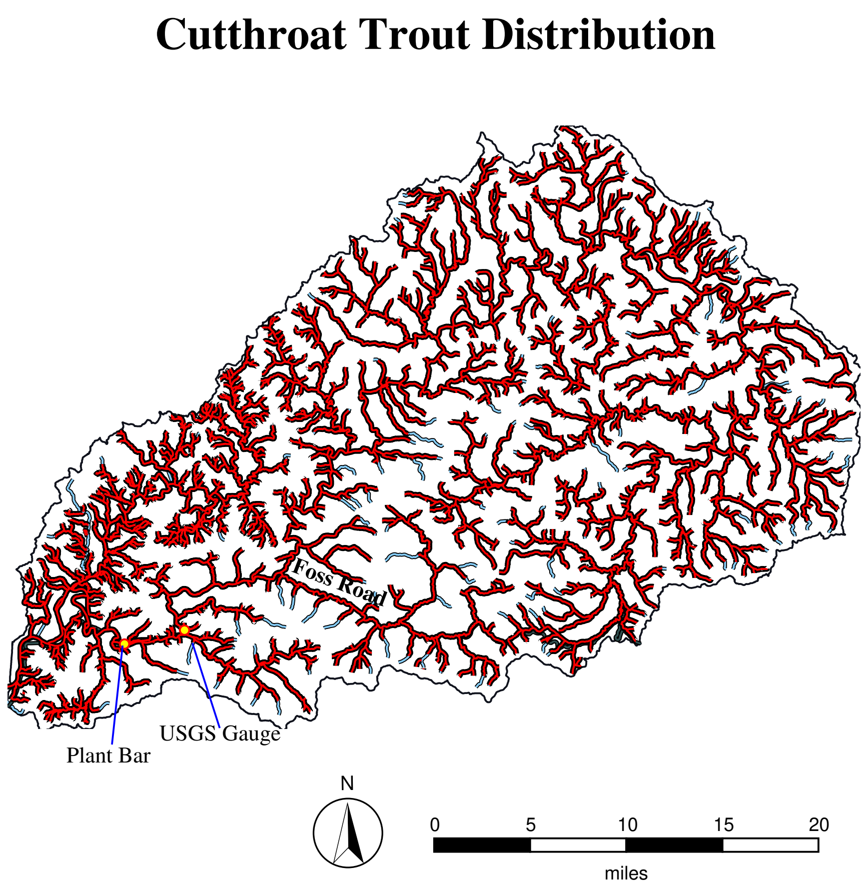

Figure A.5.: Cutthroat trout distribution in the Nehalem River.

A.5. Pacific Lamprey

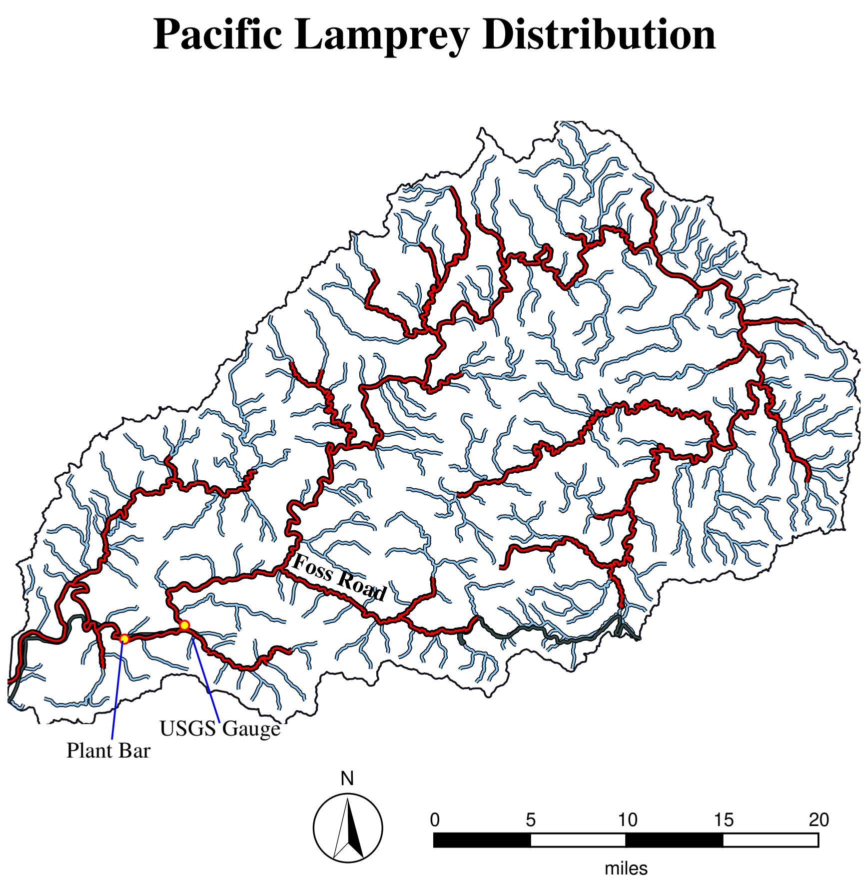

Figure A.6.: Pacific lamprey distribution in the Nehalem River.

A.6. Sturgeon

A.6.1. Green

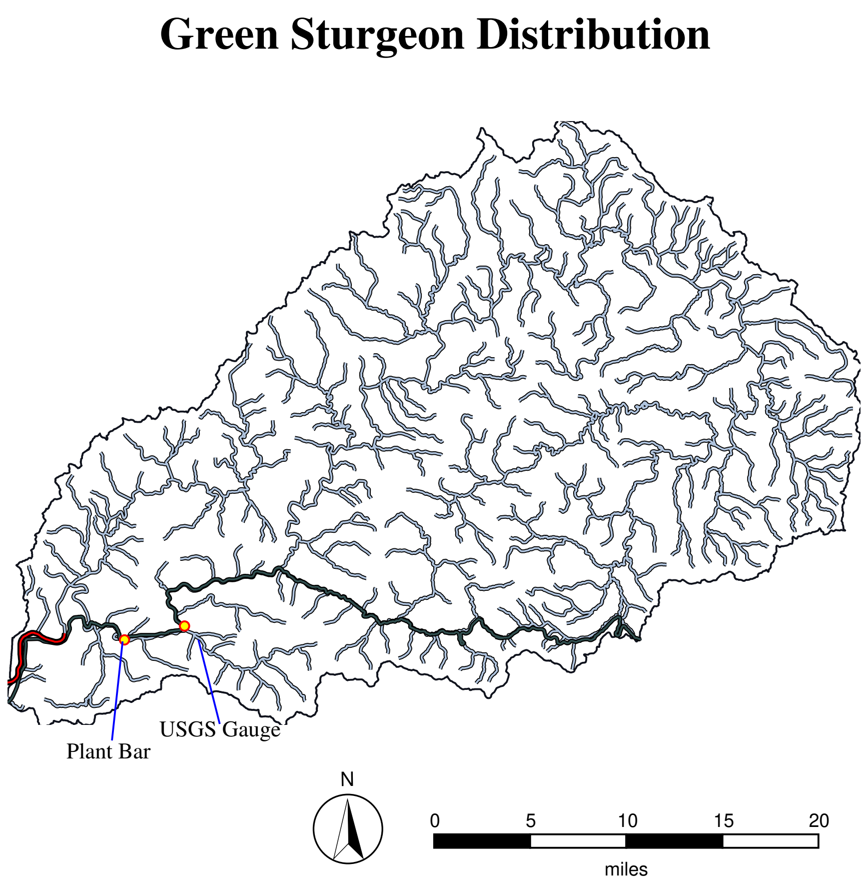

Figure A.7.: Green sturgeon distribution in the Nehalem River.

A.6.2. White

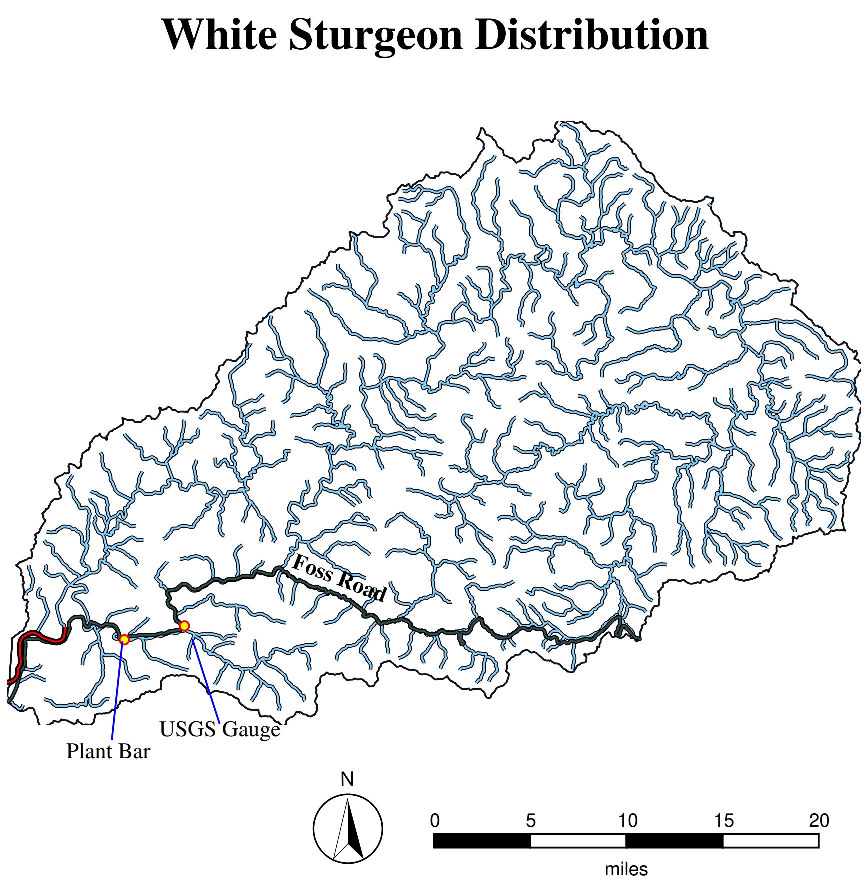

Figure A.8.: White sturgeon distribution in the Nehalem River.

A.7. Winter Steelhead Trout

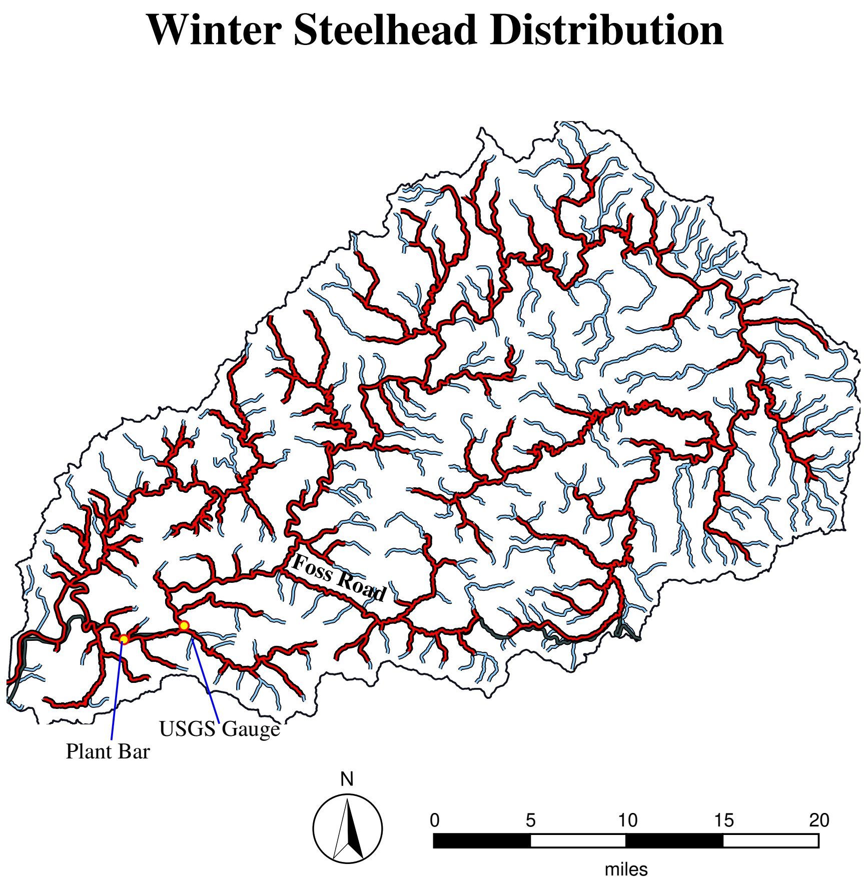

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Figure A.9.: Winter steelhead trout distribution in the Nehalem River.