CHAPTER 5. WATER USE

Under Oregon law, all water is publicly owned. Consequently, withdrawal of water from surface and some groundwater sources requires a permit, with a few exceptions. The Oregon Water Resources Department administers state water law through a permitting process that issues water rights to many private and public users (Bastasch 1998). In Oregon, water rights are issued as a 'first in time; first in right' permit, which means that older water rights have priority over newer rights. Water rights and water use were examined for each of the water availability watersheds (watersheds defined by the Oregon Water Resources Department for the assessment of flow modification).

Water that is withdrawn from the stream has the potential to affect in-stream habitats by dewatering that stream. Dewatering a stream refers to the permanent removal of water from the stream channel, thus lowering the natural in-stream flows. For example, a percentage of the water that is removed from the channel for irrigation is permanently lost from that watershed as a result of plant transpiration and evaporation. In-stream habitats can be altered as a result of this dewatering. Possible effects of stream dewatering include increased stream temperatures and the creation of fish passage barriers.

Water availability basins are areas of land defined by the Oregon Water Resources Department (OWRD) that aid in the administration of state water rights. OWRD defines water availability as the amount of water that can be appropriated from a given point on a given stream for new out-of-stream consumptive uses. The location at which water is removed from a stream is called a Point of Diversion (POD). Because it may be impractical to calculate water availability for every POD within a watershed, water availability basins allow many PODs to be grouped within a defined watershed boundary. Within Oregon, OWRD has delineated 18 larger river basins that contain thousands of smaller water availability basins. The number and delineation of water availability basins depends on the location of gages and in-stream water rights and the physiography of affected streams.

Water is appropriated at a rate of withdrawal that is usually measured in cubic feet per second (cfs). For example, a water right for 2 cfs of irrigation allows a farmer to withdraw water from the stream at a rate of 2 cfs. Typically, there are further restrictions put on these water rights, including a maximum withdrawal amount allowed and the months that the water right can be exercised. Identifying all of these limits is a time-consuming and difficult task, which is beyond the scope of this assessment. However, for subwatersheds identified as high priority basins, this might be the next step if water use is judged to pose a substantial problem.

The Oregon Water Resources Board (1975) rated watersheds throughout the Coastal Zone in terms of their water availability risk. Based on climatic and water use data, streamflows expected to occur 1 out of 2 years and 8 out of 10 years were estimated for coastal rivers. The Necanicum River was placed in the Extreme Risk category, which reflected demand in excess of average September (the most critical month) monthly flow during 1 out of every 2 years.

5.1 In-stream Water Rights

In-stream water rights were established by the Oregon Water Resources Department for the protection of fisheries, aquatic life, and pollution abatement. Four of the subwatersheds in the Necanicum River watershed currently have in-stream water rights (Table 5.1). The Necanicum River, North Fork Necanicum River, Klootchy Creek, and Bergsvik Creek all have in-stream water rights established in 1990 or 1991 by ODFW for the protection of anadromous and resident fish rearing. In addition, the Necanicum River has an in-stream water right established in 1973 for the protection of aquatic life. However, these water rights are junior to almost all of the other water rights in the watershed. Developing in-stream water rights that are more senior than current in-stream water rights would aid in the protection of in-stream flows in the Necanicum River watershed. This could be accomplished through water right trading and leasing through the Oregon Water Resources Department.

Table 5.1. In-stream water rights in the Necanicum River watershed. Data were obtained from the Oregon Water Resources Department.

Water Availability Watershed	Priority	Purpose
Necanicum River @ mouth	5/9/73 11/30/90	Supporting Aquatic Life Anadromous and Resident Fish Rearing
NF Necanicum River @ mouth	11/30/90	Anadromous and Resident Fish Rearing
SF Necanicum River @ mouth	10/11/91	Anadromous and Resident Fish Rearing
Klootchy Creek @ mouth	3/28/90	Anadromous and Resident Fish Habitat
Bergsvik Creek @ mouth	3/28/90	Anadromous and Resident Fish Habitat

5.2 Consumptive Water Use

5.2.1 Irrigation

Most of the sites for agricultural water withdrawal are located in the Seaside (6 sites) and Upper Necanicum (4 sites) subwatersheds (Figure 5.1). We are not aware of any of this agricultural water being used at the present time.

5.2.2 Municipal and Domestic Water Supply

The largest amount of water appropriated in the Necanicum River watershed is for municipal and domestic use by the City of Seaside (17.65 cfs; Table 5.2). Domestic points of diversion are scattered throughout the watershed, but most occur in the three lower subwatersheds (Figure 5.1). Municipal and domestic water supplies can have a large impact on in-stream flows, especially during low flow months. The City of Seaside, which resides adjacent to the Necanicum River estuary, draws its domestic water primarily from the South Fork Necanicum River and secondarily from the mainstem Necanicum River. During dry seasons, domestic water use combined with irrigation withdrawals may have deleterious effects on in-stream habitats by seriously reducing in-stream flows.

Table 5.2. Water use in the Necanicum River watershed. Data were obtained from the Oregon Water Resources Department

Water Availability Basin	Irrigation\ Agriculture (cfs)	Municipal / Domestic (cfs)	Fish/ Wildlife (cfs)	Industrial (cfs)	Livestock (cfs)	Total (cfs)
Bergsvik Creek @ mouth	-	0.01	0.50	-	-	0.51
NF Necanicum River @ mouth	-	0.02	-	-	-	0.02
SF Necanicum River @ mouth	-	8.00	-	-	-	8.00
Necanicum River @ mouth	3.24	1.42	1.61	0.02	0.02	6.31
Brandice Creek	-	0.60	-	-	-	0.60
Necanicum River @ Peterson Point	-	7.00	-	-	-	7.00
Unnamed Creek	-	0.60	-	-	-	0.60
TOTAL	3.24	17.65	2.11	0.02	0.02	23.04

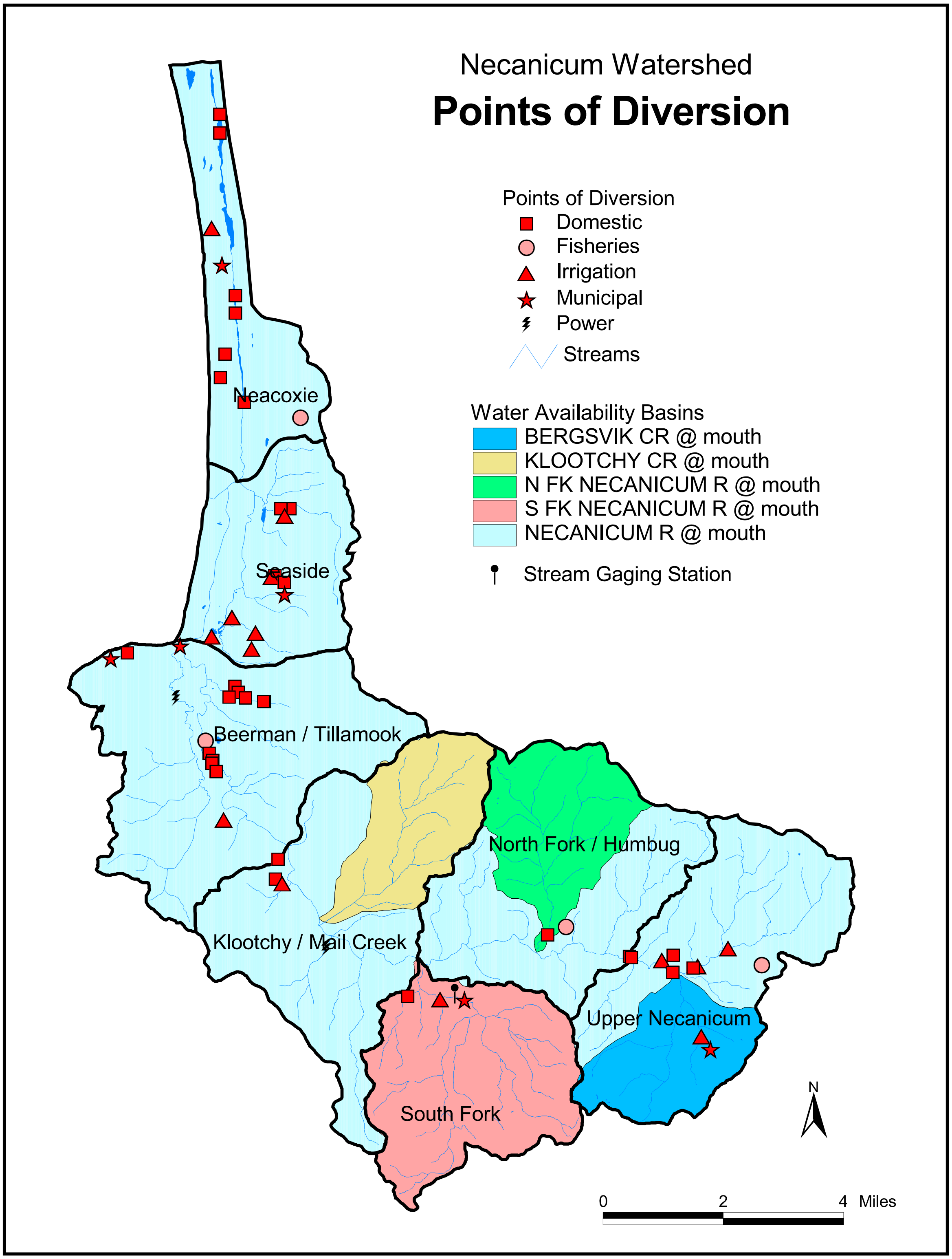


Figure 5.1. Water withdrawals in the Necanicum River watershed. Also shown are the locations of Water Availability Basins. The Necanicum River Water Availability Basin is a subsection of the Skipanon Water Availability Basin.

The City of Seaside has four separate water rights on the Necanicum River, as follows:

South Fork - 8 cfs (1924)

Mainstem @ Peterson Point - 7 cfs (1951)

Brandice Creek - 0.6 cfs (1965)

Unnamed Creek - 0.6 cfs (1965)

The main water right is on the South Fork. However, during low flow periods, the city does not withdraw more than 50 percent of the flow from that tributary. At such times, additional water is withdrawn from the mainstem at Peterson Point (Neal Wallace, City of Seaside, pers. comm., 2002).

5.3 Non-Consumptive Water Use

Significant amounts of water are also allocated for fish and wildlife (2.11 cfs, Table 5.2). The amount of water that has been appropriated for fish and wildlife in the Necanicum River watershed represents about one-fourth of the total water rights for the watershed. Most of that appropriation is in what we are designating as in the Necanicum River Water Availability Basin, which is a subsection of the Skipanon Water Availability Basin.

5.4 Water Availability

The Oregon Water Resources Department has developed models to assess the potential impacts of water withdrawals on stream flows (Robison 1991). These model outputs are available to the public on the OWRD website (*http://www.wrd.state.or.us*). They use predicted water loss based on the type of use for the appropriated water. Losses are then compared to predicted in-stream flows, based on a user- assigned exceedance level. We have chosen a 50 percent exceedance, which represents stream flows that would be expected at least 50 percent of the time.

Based on current water availability model output, there is significant concern for dewatering in the Necanicum River watershed. Three of the Water Availability Basins consistently demonstrated water loss greater than 20 percent of the predicted in-stream flows (Table 5.3). Consequently, it is likely that water withdrawals from the Necanicum River and its tributaries are having a large impact on current in-stream flows during summer and fall months. Dewatering potential was particularly evident in the South Fork Necanicum River subwatershed, which

Table 5.3. Dewatering potential in the Necanicum River watershed, based on a 50 percent exceedance*.

Water Availability Basin	Dewatering Potential (%)*					Overall Dewatering Potential	
	Jun	Jul	Aug	Sep	Oct	Average Percent Withdrawal	Potential
Necanicum River @ mouth	13.5	23.6	30.4	30.4	21.1	23.8	Moderate
Necanicum River above Klootchy Creek	11.8	20.8	28.0	29.3	19.3	21.8	Moderate
Bergsvik Creek @ mouth	0.0	0.0	0.0	0.0	0.0	0.0	Low
NF Necanicum River @ mouth	0.0	0.0	0.0	0.0	0.0	0.0	Low
SF Necanicum River @ mouth	45.5	78.2	106.7	107.4	72.3	82.0	High

* A 50% exceedance represents the amount of water than can be expected to be in the channel 50% of the time or one out of every two years.

showed a dewatering potential ranging from 72.3 percent to 107.4 percent during the months July through October. It is our recommendation that in-stream water rights continue to be protected and in-stream flows monitored during very low flow conditions.

Weber and Sheahan (1995) identified a problem with low water flows in the South Fork Necanicum River, which is dewatered during low flow months in some years. ODFW worked with the city of Seaside to attempt to provide additional summer and fall flows into 1.5 miles of the South Fork Necanicum River. An additional 7 miles of the mainstem Necanicum is also impacted below the confluence with the South Fork. A rather recent storage reservoir and filter plant gives the city flexibility to store additional water and/or pump directly from the lower river during low flow periods.

5.5 Conclusions

Appropriated water in the Necanicum River watershed represents a substantial fraction of modeled in-stream flows during the months June through October. Consequently, it is expected that surface water withdrawals generally have significant impacts on current in-stream habitat conditions. This suggests a potential for habitat degradation as a result of insufficient stream flow during low flow periods. Consequently, any surface water withdrawals during very dry months can exacerbate existing streamflow deficiencies. In-stream flow requirements for salmonids should be further evaluated to determine actual impacts of surface water withdrawals on salmonid populations. Protection of in-stream flow for salmonid habitat is needed in the Necanicum River watershed.

CHAPTER 6. SEDIMENT SOURCES

6.1 Introduction

Erosion is a natural watershed process in the Oregon Coast Range. The bedrock geology of much of the Oregon Coast is composed of weak, highly erosive rock types. However, most experts agree that land use practices have increased the rate of erosion in many coastal watersheds (WPN 1999, Naiman and Bilby 1998). High levels of sediment in rivers and streams is associated with loss of agricultural lands and the filling of bays and estuaries. Sediment is also negatively impacting many aquatic organisms, including several species of salmon that are federally listed as threatened or endangered under the Endangered Species Act. Understanding the role of erosion and its interaction with other watershed processes is critical to maintaining a healthy ecosystem.

Most Pacific Northwest estuaries are depositional environments; they accumulate sediment (Komar 1997). Sediment in the Necanicum River Estuary comes from marine sources, the rivers and streams within the watershed, and from bayshore erosion (Glenn 1978).

Upland processes that deliver sediment to the stream system include landslides and surface erosion. In lowland streams and rivers, erosion occurs principally as streambank erosion. Wildfires alter soil conditions, setting the stage for increased rates of erosion. The majority of sediment deposition into the stream system occurs during large storm events. For example, the major floods of February, 1996 focused attention on the sediment accumulating in some coastal estuaries, which is perceived to be blocking rivers and channels in some places.

There were several assumptions made about the nature of sediment in this watershed (WPN 1999). First, sediment is a normal and critical component of stream habitat for fish and other aquatic organisms. Second, the more that sediment levels deviate (either up or down) from the natural pattern in a watershed, the more likely it is that aquatic habitat conditions will be significantly altered. Third, significant human-caused increases in sediment occur at a limited number of locations within the watershed, and these can be identified by a combination of site characteristics and land use practices. Finally, sediment movement is mostly episodic, with most erosion and downstream soil movement occurring during infrequent and intense runoff events.

Knowledge of current sources of sediment can provide a better understanding of the locations and conditions under which sediment is likely to be contributed in the future. These sources can then be evaluated and prioritized based on their potential effects on fish habitat and water quality to help maintain natural ecosystem functioning.

6.2 Screening for Potential Sediment Sources

OWEB has identified eight potential sediment sources that can have a significant impact on watershed conditions (WPN 1999). Not all are present in every watershed, and they vary in influence depending on where and how often they occur. The potential sediment sources identified by OWEB include slope instability, road instability, rural road runoff, urban area runoff, crop lands, range or pasture lands, burned areas, and other identified sources. The latter can include logging operations.

In this watershed, slope instability, road instability, and rural road runoff are the most significant sediment sources. Slope instability contributes to shallow landslides and deep-seated slumps, both of which are common in the Oregon Coast Range. Streamside landslides and slumps are major contributors of sediment to streams, and shallow landslides frequently initiate debris flows which can contribute large volumes of sediment and LWD to streams. Rural roads are a common feature of this watershed, and many are present on steep slopes. Washouts from rural roads contribute sediment to streams, and sometimes initiate debris flows. The density of rural roads, especially unpaved gravel and dirt roads, indicates a significant potential for sediment contribution to the stream network.

Urban land runoff, as well as the history of fire in the watershed, are also potential contributing factors. However, urban lands occupy a small portion of the watershed on generally level terrain and are not expected to be major contributor of sediment in this watershed. Developed lands (urban and rural residential) occupy about 6 percent of the Necanicum River watershed.

6.3 Slope Instability

Landslides are the main source of sediment in the Oregon Coast Range. A landslide is defined as “the movement of a mass of rock, debris, or earth down a slope” (National Research Council 1996). Often, landslides gather large amounts of organic material, such as downed logs and woody debris, as they travel downslope. They are extremely variable in size and velocity, usually falling into two categories: “shallow-rapid” and “deep-seated” (Washington Forest Practices Board 1995). Shallow-rapid landslides are typical on steep forested hillslopes (Mills 1997). Shallow rapid landslides include rock slides, debris slides and debris flows. A small debris slide (generally occurring on steep slopes with shallow soils) becomes a debris flow if the sliding soil, moving downslope, scours and entrains additional soil and vegetation in its path. In areas with steep slopes, debris flows are the dominant erosional mechanism (Mills 1997). Deep-seated landslides are more commonly slow-moving and are also highly variable in size.

Under natural conditions, geology, topography, and climate interact to initiate landslides. With human intervention, natural conditions may be modified in ways that increase the likelihood of landslide initiation. Road-building often creates cuts and fills. In a slide-prone landscape, road-cuts may undercut slopes and concentrate runoff along roads, and road-fills on steep slopes may give way, initiating a landslide (NRC 1996). Vegetation removal, such as by logging or wildfire, may also increase the likelihood of landslide occurrence.

Landslides and debris flows can have positive and negative effects on fish in streams. A landslide from a forested hillside will contain mineral soil, organic material, and a substantial amount of LWD. This mixture causes significant changes in the affected stream reach (Chesney 1982). In the short term, a debris flow can scour a channel or remove beneficial prey (benthic macroinvertebrates) and channel structures. Over the long-term, these events deliver woody debris, organic matter, and gravel that could result in the reestablishment of productive aquatic habitat and provide an important reset mechanism to the stream ecosystem.

There are few estimates of sediment yield from forest lands in the north coast region. To date, no comprehensive aerial photo or on-the-ground inventories of landslides have been conducted in the Necanicum River watershed. Landslide data are collected by Willamette Industries within the watershed, but these data were not available in digital form for inclusion in this assessment. Upland erosion rates in the watershed are likely to have increased due to human activities, but the exact amount of increase is unclear. In 1999, the Oregon Department of Forestry compiled and mapped landslide information from state and federal agencies for all of western Oregon. However, no landslides were recorded in the Necanicum River watershed, because nearly all steep, forested terrain in this watershed is privately owned, and landslide data from the landowners were not available.

ODF created debris flow hazard maps in 1996 to characterize the potential for future landslide activity based on watershed features such as slope, soils, and geology. According to these maps, about one-quarter of the Necanicum River watershed is in the debris flow activity zone (Figure 6.1). Most of that land (22 percent of the watershed) is in the moderate hazard zone; only 4 percent was classified as high risk (Table 6.1). The subwatersheds having greatest

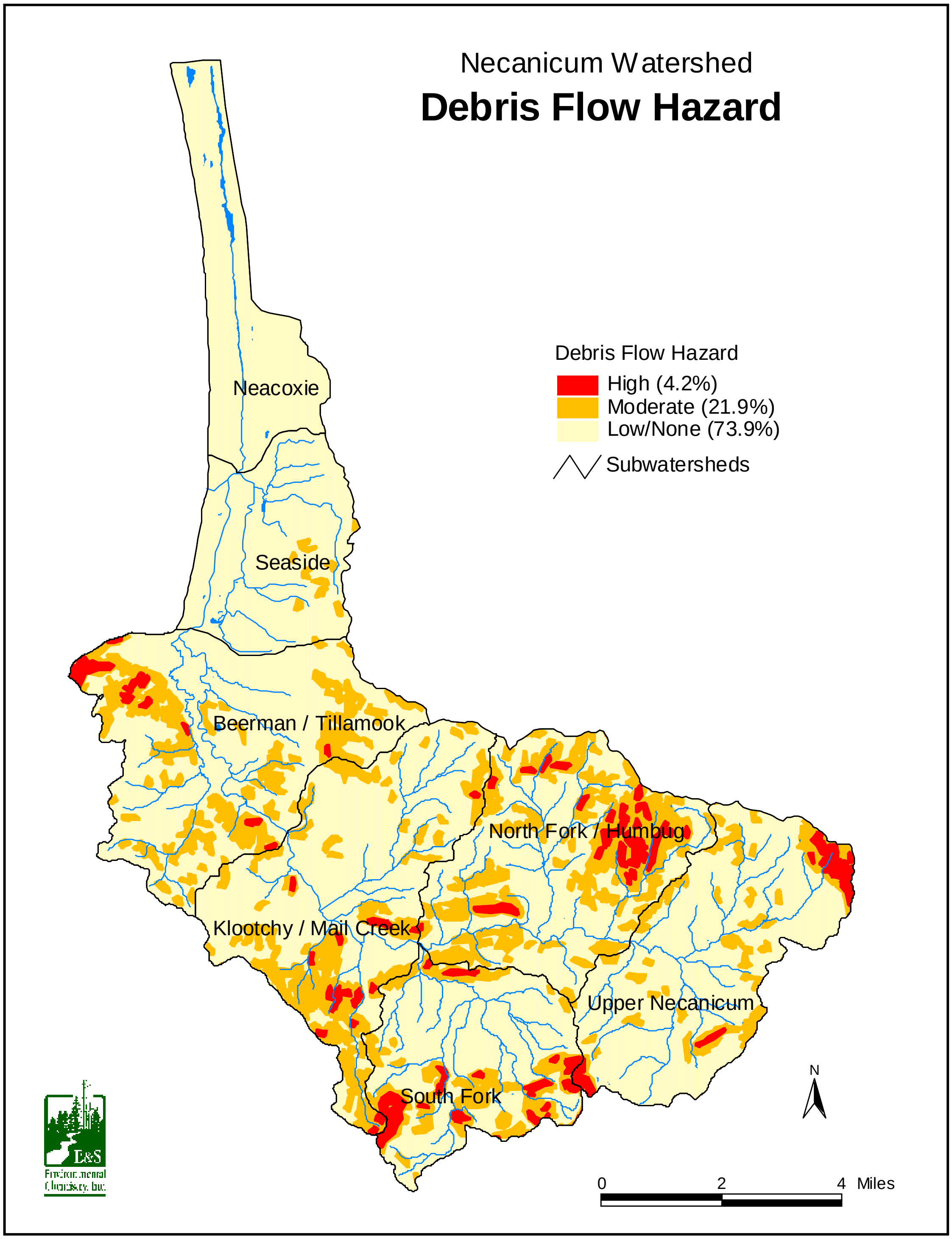


Figure 6.1 Debris flow hazard zones for the Necanicum River watershed.

Table 6.1. Potential debris flow hazard zones in the Necanicum River watershed.

Subwatershed	Area (sq. mi.)	Debris Flow Hazard Risk		
		High (%)	Moderate (%)	High+Mod (%)
Beerman/Tillamook	15.7	3.0	27.7	30.7
Klootchy/Mail Creek	15.3	3.2	27.6	30.8
Neacoxie	7.3	0.0	0.0	0.0
North Fork/Humbug	13.7	8.0	37.2	45.2
Seaside	8.3	0.0	4.1	4.1
South Fork	9.9	8.6	22.7	31.3
Upper Necanicum	13.3	4.6	15.1	19.7
TOTAL	83.5	4.2	21.9	26.1

risk are North Fork/Humbug and South Fork; each had $ 8 percent high hazard and $ 23 percent moderate hazard. Neacoxie is the only subwatershed completely outside of the debris flow risk zone.

6.4 Road Instability

Roads constitute the primary source of increased sediment from forestry-related activities in the western United States (Mills 1997). Landslide frequency can be greatly accelerated by road building and management practices (Sidle et al. 1985). Road construction, especially on steep slopes, can lead to slope failure and result in increased landslide activity (WPN 1999, Sessions et al. 1987). Road stability is partially determined by the method of construction. For example, sidecast roads are built by using soil from the inside portion of a road to build up the outside, less stable portion of the road. Sidecast roads work well in moderately steep terrain, but in steep terrain the sidecast material frequently slides off the roadbed, initiating landslides or debris flows. Road crossings with poorly designed culverts can fail and wash out, create gullies, and deliver large pulses of sediment to the channel. Sediment delivery to streams depends on the percentage of the road drainage system which discharges directly to the channel; the proximity of non-stream discharges (*i.e.*, discharges across the hillside) to a channel; the volume of water involved and the potential for gully development (stream extension); and the volume of eroded material available (Mills 1997).

We also constructed a GIS-based analysis of road-stream crossings. We found an average density of 3.2 crossings per square mile in the Necanicum River watershed. The highest densities were in the South Fork and Seaside subwatersheds, with 4.4 and 4.2 crossings per square mile, respectively. The lowest density was 0.8 crossings/sq. mi. in the Neacoxie subwatershed (Table 6.2).

Table 6.2. Stream/road crossings in the Necanicum River watershed. Data were calculated using GIS.

Subwatershed	Area (sq. mi.)	Road-Stream Crossings	
		(#)	(#/sq. mi)
Beerman/Tillamook	15.7	60.0	3.8
Klootchy/Mail Creek	15.3	40.0	40.0
Neacoxie	7.3	6.0	0.8
North Fork/Humbug	13.7	45.0	3.3
Seaside	8.3	35.0	4.2
South Fork	9.9	43.0	4.4
Upper Necanicum	13.3	40.0	3.0
TOTAL	83.5	269.0	3.2

In 1997, Willamette Industries Inc. developed a forest road inventory in conjunction with the Oregon Department of Forestry and the Oregon Forest Industries Council. The North Coast Resource Area inventoried approximately 1700 miles of road on company managed forestland in Tillamook, Columbia, and Clatsop Counties. Road features were given a priority class from one to five, with one being highest priority for repair and five being no action needed.

In 1999, the road inventory had been completed and a legacy road improvement and decommissioning plan was developed. The plan recommends that all road segments identified as needing action should either be repaired or decommissioned within the next 10 years. The plan breaks the road inventory priorities into subclasses. The subclasses, in order of singular impact or concern, are safety, sedimentation into live streams, mass wasting, sedimentation depositing outside of live streams and fish passage. As an example of the structure of this system, a priority-one road with a safety concern will be repaired/decommissioned before a priority-one road that has fish passage issues. Under the North Coast Resource Area 10-year road plan, all priority one road segments were scheduled to be repaired/decommissioned by the fall of 2001, and all road segments requiring action will be repaired/decommissioned by the fall of 2008.

Recent concern about sediment from road systems entering waters of the state has prompted Willamette Industries, Inc. to adopt new specifications for forest road location, construction and reconstruction, maintenance and erosion control. Whenever possible, existing roads that parallel stream channels are relocated or bypassed and new roads are located near ridge tops to minimize the number of stream crossings. This method of road location helps minimize the possibility of sediment entering streamwaters. Ditch relief culverts or ditchouts are placed with a minimum spacing of 300-500 feet. Ditch relief culverts are placed 50 to100 feet ahead of all stream crossing culverts. This allows ditch water to filter through vegetation on the forest floor prior to entering flowing water. Stream crossing culverts are required to be designed to pass a 50 year flood event. However, all crossings installed by the North Coast Resource Area will pass a 100 year event. Side-cast material in steeper terrain that has the potential to fail is pulled back and the road is set into the hillside. All waste material in these steeper areas in now hauled to stable waste areas.

All-weather haul roads are now surfaced with quarried rock and the top lift is usually a finer grade crushed rock that has been processed with a grader and vibratory roller. By processing the rock, the road surface is sealed and water cannot saturate the subgrade. This helps prevent the “pumping” of mud onto the road surface. Roads with natural surfaces have haul restrictions placed on them and active haul is allowed only during periods of dryer weather. All active haul roads are continually monitored and maintained. If a road begins to show signs of failing, active hauling will be suspended until the road can be repaired. All non-active haul roads are monitored on an annual basis and during periods of high flows, with routine maintenance performed as needed.

Where there is potential for erosion, a variety of erosion control methods are used. Silt fences and straw bales are used along with settling basins to help slow water and allow suspended sediment to settle out of the water. Seeding and hand mulching or hydro mulching are used to vegetate surfaces to prevent erosion.

6.5 Road Runoff

Water draining from roads can constitute a significant sediment source for streams. However, the amount of sediment potentially contained in road runoff is difficult to quantify, because road conditions and the frequency and timing of use can change rapidly. Poor road surfaces that are used primarily in dry weather may have a smaller impact on sediment production than roads with higher quality surfaces that have higher traffic and are used primarily in the rainy season. Road data were used to assess potential sediment contribution from road runoff. Road density within 200 feet of a stream and on slopes greater than 50 percent was calculated using GIS.

The density of roads within 200 feet of a stream was highest in the Beerman/Tillamook subwatershed, at 0.59 miles of road per mile of stream, while the lowest was in the Neacoxie subwatershed, at 0.17 miles of road per mile of stream. The most common road surface in the Necanicum River watershed is gravel, accounting for approximately three-fourths of all roads in the basin. Dirt roads account for 7 percent all roads, and 18 percent of roads are paved (Table 6.3).

Table 6.3. Current road conditions in the Necanicum River watershed. The ODF fire roads coverage was used to calculate these numbers in GIS (see GIS data evaluation).

Subwatershed	Stream Length (mi)	Road Length (mi)	Gravel (%)	Dirt (%)	Paved (%)	Roads <200' from Stream (mi)	(mi/mi*)	Roads <200' from Stream and >50% Slope (%)
Beerman/Tillamook	25.3	96.4	80.7	4.6	14.7	15.00	0.59	1.04
Klootchy/Mail Creek	26.6	86.5	93.6	1.2	5.3	9.94	9.94	0.47
Neacoxie	7.1	40.2	46.0	0.6	53.5	1.23	0.17	-
North Fork/Humbug	31.1	76.1	88.1	7.1	4.8	8.52	0.27	0.51
Seaside	19.0	68.7	40.7	2.6	56.7	5.78	0.30	0.20
South Fork	26.8	51.3	82.0	18.0	-	9.44	0.35	1.09
Upper Necanicum	27.5	84.1	72.7	15.2	12.2	10.79	0.39	0.32
Total	163.4	503.3	74.6	6.9	18.5	60.70	0.37	0.55

* Units are miles of road per mile of stream

Very few roads in the Necanicum River watershed are both within 200 feet of a road and located on a hillside slope gradient greater than 50 percent, based on GIS analysis. The Beerman/ Tillamook and South Fork subwatersheds were the only subwatersheds that had more than 1 percent of their roads on very steep slopes and within 200 feet of a stream (Table 6.3). On average, only 0.55 percent of the roads in the Necanicum watershed were judged to be both on steep slope and close to a stream. It must be noted, however, that slope calculations based on DEMs tend to under-represent slope steepness.

6.6 Streambank Erosion

Erosion in agricultural and urban lowlands typically takes two forms: streambank cutting, and sheet and rill erosion (Pedone 1995). Streambank erosion is the more prevalent of the two types (USDA 1978). Significant streambank erosion typically takes place due to selective stratigraphic failure, soil saturation, and sloughing during high flow events (USDA 1978). Increased bank erosion is commonly associated with the removal of riparian vegetation. Cattle accessing streambanks can also increase erosion when their hooves break up the soil matrix and remove vegetation (USDA 1978). Sheet and rill erosion is most common along unvegetated road cuts and fills, but also occurs on construction sites and roadbeds, and can contribute significant amounts of sediment in localized areas.

Thirty-two miles of streams were surveyed by ODFW in the Necanicum River watershed. Of these, on average 39 percent of the surveyed length had experienced streambank erosion. The Beerman/Tillamook subwatershed experienced the highest proportion of streambank erosion (65 percent). ODFW surveyed streams accounted for 19 percent of the length of the stream network.

Agricultural and urban lowlands occupy only approximately 4.2 percent of the Necanicum River watershed. We do not expect, therefore, that erosion in lowland portions of the watershed is a major contributor to the overall sediment budget of the Necanicum River watershed. As in upland streams, non-organic sediment plays an important role in lowland stream channel morphology. Organic sediment, including wood, contributes to channel structure, and to the aquatic habitat and food resources of the fluvial ecosystem. Human uses of the lowlands have affected the rate and character of lowland sedimentation through changes in flooding frequency and size, and by the diking or draining of floodplains and wetlands. In addition, channel modification, removal of LWD, and streamside grazing have increased streambank erosion. These changes have in turn affected the quantity and quality of riparian and aquatic habitat in the lowlands.

6.7 Conclusions

Sediment in the rivers and streams of the Necanicum River watershed is an issue of concern. The combination of the wet climate, steep slopes in some portions of the uplands, and erosive soils results in naturally moderate to high levels of sediment in the rivers and streams. Historic wildfires in the watershed, as well as resource management practices over the past century, are believed to be associated with an additional increase in sediment levels. High levels of sediment in the streams may result in increased rates of sedimentation in the estuary. Additionally, high sediment levels are associated with the declining health of salmonid populations. Whereas naturally occurring sources of sediment in the watershed are uncontrollable and in fact are beneficial, the additional sediment contributed by human activity may contribute to habitat degradation.

Based on the debris flow hazard analysis (Figure 6.1), landslide frequency in the Necanicum River watershed is probably not very high compared to other coastal watersheds. However, a comprehensive landslide inventory of the watershed is lacking, and the specific locations of landslide activity are unknown.

Roads are the primary source of sediment related to human activity. Contribution of sediment from roads is attributed to two processes: landslides originating from roads, and road runoff. Landslides coming from roads produce the largest proportion of road-associated sediment. The high density of stream-crossing culverts on sidecast dirt and gravel roads suggests that road-associated landslides are of concern in the Necanicum River watershed. Cooperation with private landowners to identify and improve sediment sources on private roads will further mitigate the impact of sediment in the watershed.

Lastly, streambank erosion is a concern in the Necanicum River watershed. While the overall contribution of sediment from streambank erosion is typically less significant that other sources, erosion from the streambank is associated with a lack of riparian shade. Restoration of riparian vegetation will lessen sediment contribution from streambank erosion.

CHAPTER 7. WATER QUALITY

7.1 Introduction

The purpose of the water quality assessment, according to the OWEB manual (WPN 1999), is to complete a screening-level analysis of water quality. A screening-level analysis serves to identify obvious areas of water quality impairment by comparing selected measurements of water quality to certain evaluation criteria. The screening-level analysis uses existing data obtained from a variety of sources. This assessment does not include statistical evaluation of seasonal fluctuations or trends through time, and does not evaluate specific sources of pollution through upstream/downstream comparisons.

7.1.1 Assessment Overview

The water quality assessment proceeds in steps. The first step is to identify uses of the water that are sensitive to adverse changes in water quality, and identify potential sources of pollution in the watershed. The second step establishes the evaluation criteria. The third step examines the existing water quality data in light of the evaluation criteria. Conclusions can then be made about the presence of obvious water quality problems in the watershed, and whether or not additional studies are necessary.

Water quality is evaluated by comparing key indicators against evaluation criteria. Indicators are selected to represent pollution categories. Some aspects of water quality, such as fine sediment and temperature processes, are addressed in other sections of this watershed assessment. Although there are many constituents that contribute to the water quality of a stream, the watershed assessment is focused on seven that are most often measured, and that may have the most direct effect on aquatic organisms: temperature, dissolved oxygen, pH, nutrients, bacteria, turbidity, and chemical contaminants. Evaluation criteria, discussed in Section 7.4, have been determined based on values of these constituents that are generally protective of aquatic life.

7.1.2 Components of Water Quality

<u>Temperature</u>

Cool water temperatures are necessary for the survival and success of native salmon, trout, and other aquatic life. Excessively warm temperature can adversely affect the survival and growth of many native species. Although there is some debate about which specific temperatures should apply, and during which part of the year, standards have been set that can be used to determine if the waters in the stream are too warm. Because temperature in the stream varies throughout the day and among the seasons, multiple measurements throughout the day and in different seasons are needed to adequately assess water temperature conditions.

Dissolved oxygen

Aquatic organisms need oxygen to survive. Oxygen from the air dissolves in water in inverse proportion to the water temperature. Warmer water contains less dissolved oxygen at saturated conditions. Organisms adapted to cool water are usually also adapted to relatively high dissolved oxygen conditions. If the dissolved oxygen is too low, the growth and survival of the organisms is jeopardized. As with temperature, dissolved oxygen can vary throughout the day and among the seasons, so multiple measurements, both daily and seasonally, are required for an adequate analysis of water quality conditions.

pH

The pH is a measure of the acidity of water. The chemical form and availability of nutrients, as well as the toxicity of pollutants, can be strongly influenced by pH. Pollutants can contribute to changes in pH as can the growth of aquatic plants through photosynthesis. Excessively high or low pH can create conditions toxic to aquatic organisms.

Nutrients

Nitrogen and phosphorus, the most important plant nutrients in aquatic systems, can contribute to adverse water quality conditions if present in too great abundance. Abundant algae and aquatic plant growth that results from high nutrient concentration can result in excessively high pH and low dissolved oxygen, can interfere with recreational use of the water, and, in some cases, can produce toxins harmful to livestock and humans.

Bacteria

Bacterial contamination of water from mammalian or avian sources can cause the spread of disease through contaminated shellfish, contact recreation or ingestion of the water itself. Bacteria of the coliform group are used as an indicator of bacterial contamination.

Turbidity

Turbidity is a measure of the clarity of the water. High turbidity is associated with high suspended solids, and can be an indicator of erosion in the watershed. At high levels, the ability of salmonids to see their prey is impaired. As discussed elsewhere, high suspended sediment can have a number of adverse effects on fish and aquatic organisms.

Chemical contaminants

Synthetic organic compounds, pesticides, and metals can be toxic to aquatic organisms. The presence of such contaminants in the water suggests the presence of sources of pollution that could be having an adverse effect on the stream ecosystem.

7.2 Beneficial Uses

The Clean Water Act requires that water quality standards be set to protect the beneficial uses that are present in each water body. ODEQ has established the beneficial uses applicable to the 18 major river basins in the State. The Necanicum River watershed is in the North Coast Basin. The beneficial uses established for all streams and tributaries in the basin are (OAR 340-41-202):

- Public domestic water supply[1]
- Private domestic water supply[1]
- Industrial water supply
- Irrigation
- Livestock watering
- Anadromous fish passage
- Salmonid fish rearing
- Salmonid fish spawning
- Resident fish and aquatic life
- Wildlife and hunting
- Fishing
- Boating
- Water contact recreation
- Aesthetic quality

Estuaries and adjacent marine waters are considered to support the above beneficial uses as well, not including public or private water supply, irrigation, or livestock watering. Water quality must be managed so the beneficial uses are not impaired.

Not all beneficial uses are equally sensitive to change in water quality. For example, use of the water body for domestic water supply would be impaired long before its use for commercial navigation. In general, water quality is managed to protect the most sensitive beneficial use. In

[1] With adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards.

the case of the Necanicum River watershed, the most sensitive beneficial use is probably salmonid fish spawning. It is assumed that if the water quality is sufficient to support the most sensitive use, then all other less sensitive uses will also be supported.

7.3 Pollutant Sources

7.3.1 Point Sources

The Clean Water Act prohibits discharge of waste to surface water. In order to discharge any waste, a facility must first obtain a permit from the State. ODEQ issues two primary types of discharge permit. Dischargers with Water Pollution Control Facility (WPCF) permits are not allowed to discharge to a water body. Most WPCF permits are issued for on-site sewage disposal systems. Holders of National Pollutant Discharge Elimination System (NPDES) permits are allowed to discharge wastes to waters of the state, directly or indirectly, but their discharge must meet certain quality standards as specified in their permits. Permits set limits on pollutants from industrial and municipal dischargers based on the ability of the receiving stream to absorb and dissipate the pollutants. Industries, municipal wastewater treatment facilities, fish hatcheries, and similar facilities typically have NPDES permits. General permits are issued to certain categories of discharger rather than to individual facilities. The current discharge permits for the Necanicum River watershed are listed in Table 7.1.

7.3.2 Non-point Sources

The largest current source of pollutants to Oregon’s waters is not point sources such as factories and sewage treatment plants. The largest source of water pollution comes from surface water runoff, often called “non-point source” pollution. Rainwater, snowmelt, and irrigation water flowing over roofs, driveways, streets, lawns, agricultural lands, construction sites, and logging operations carries more pollution, such as nutrients, bacteria, and suspended solids, than discharges from industry.

Water quality is affected by the introduction of organic matter to streams. The presence of organic matter increases biochemical oxygen demand, which means less dissolved oxygen is available for aquatic life. The introduction of untreated animal or human waste increases the possibility of bacterial contamination of water, increasing the risk of infection to swimmers. Eutrophication is the process of enrichment of water with nutrients, mainly nitrogen and

Table 7.1. Permitted facilities listed by ODEQ that have discharges to surface water in and around the Necanicum River watershed (ODEQ 2000).[1]

Facility Name	Category	Latitude	Longitude	Type	RM
Arch Cape Sewage Treatment Plant	Domestic	45.80330	123.95310	NPDES	0.5
Ready Mix Division - Gearhart	Industrial	45.92310	123.54000	GEN12A	0
Square Creek Quarry - Cannon Beach	Industrial	46.01670	123.94840	GEN12A	5.2
Park Drive Plaza	Domestic	46.02500	123.91120	GEN51	0
Laurelwood Farm Composting Facility	Industrial	45.91980	123.89390	GEN12C	9
Laurelwood Farm Composting Facility	Industrial	45.91980	123.89390	GEN12Z	9
Cannon Beach Sewage Treatment Plant	Domestic	45.89580	123.94840	NPDES	0
Don's Union Service (Inactive)	Industrial	45.98330	123.91670	GEN15A	2.3
Johnson Quarry	Industrial	45.95010	123.91980	GEN12A	6.3
Captain Morgan's Restaurant	Domestic	46.03640	123.91330	GEN52A	0.2
Pinehurst Estates	Industrial	46.05560	123.92530	GEN12C	0.4
Seaside Sewage Treatment Plant	Domestic	46.00830	123.92230	NPDES	0.2

[1] The type of discharge allowed by each permit can be found by examining the individual permit. Permits can be accessed through the ODEQ website at *http://www.deq.state.or.us/wq*.

phosphorous compounds, which results in excessive growth of algae and nuisance aquatic plants. It increases the amount of organic matter in the water and also increases pollution as this matter grows and then decays. Through photosynthesis, algae and aquatic plants consume carbon dioxide (thus raising pH) and produce an abundance of oxygen. At night the algae and plants respire, depleting available dissolved oxygen. This results in large variations in water quality conditions that can be harmful to other aquatic life. While natural sources of nutrients can influence eutrophication, the introduction of nutrients strengthens the process.

Sources of nutrients include wastewater treatment facility discharge and faulty septic systems, runoff from animal husbandry, fertilizer application, urban sources, and erosion. High water temperatures compound the decline in water quality by causing more oxygen to leave the water and by increasing the rate of eutrophication. Removal of streamside vegetation, among other factors, influences high stream temperature and, via erosion, increases sedimentation of streams.

Land use can have a strong influence on the quantity and quality of water flowing from a watershed. An undisturbed watershed with natural vegetation in and along streams and rivers and a diversity of habitats on the uplands provides clean water that supports the desirable beneficial uses of the waterway. As the watershed is affected by activities such as logging, agriculture, and urban development, the water quality in the waterways can become degraded. The percent of the land area of the Necanicum River watershed affected by these land uses is shown in Table 7.2. Table 1.4 shows the distribution of all land use types in the watershed.

Table 7.2. Percent area of the Necanicum River watershed by selected land uses.

Land Use Type	Area (sq mi)	Percent of Total Area
State Forest	1.50	1.79
Private Industrial Forest	69.01	82.45
Agriculture	0.56	0.66
Developed	5.04	6.02
Other	7.59	9.07

The most prominent type of land use in the Necanicum River watershed is forested, with relatively little land in developed areas or agriculture. This land use pattern suggests that water quality problems associated with toxic industrial chemicals may be of relatively little importance while problems associated with sediment, turbidity, temperature, and possibly bacteria are likely to be more important. To the extent that herbicides and pesticides are used in forestry and agriculture operations, these compounds may assume greater importance.

7.3.3 Water Quality Limited Water Bodies

Sometimes, applying the best available treatment technology to all the point sources in a basin does not bring the stream into compliance with water quality standards. The combination of pollutants from all sources, point and non-point, within the watershed may contribute more pollution than the stream can handle. Under this circumstance, when a stream consistently fails to meet water quality standards for a particular pollutant, it is declared by ODEQ to be “water quality limited” as required by the Clean Water Act Section 303(d). Water bodies on the “303d List” must be analyzed to determine the total amount of pollutant that can be accommodated by the stream (the total maximum daily load –TMDL). This load is then allocated to all the dischargers, including non-point. Dischargers must then take the steps necessary to meet their allocated load. The water quality limited water bodies in the Necanicum River watershed are listed in Table 7.3.

Table 7.3. Water quality limited water bodies in the Necanicum River watershed (DEQ 1999).

Water Body	Segment	Parameter	Season
Necanicum River	Mouth to Headwaters	Bacteria	Summer

7.3.4 Oregon Water Quality Index

Although the 303(d) list identifies water bodies that are known not to meet current water quality standards, the list is not necessarily a complete indicator of water quality in a particular basin. For many stream reaches there are not enough data to make a determination. In addition, the 303(d) listing is tied to the total amount of monitoring done, which is influenced by the number of special monitoring studies completed by ODEQ. Because special studies are frequently concentrated where water quality degradation is a concern, the sampling is weighted toward poorer quality waters. Consequently the ODEQ has developed the Oregon Water Quality Index (OWQI) as a water quality benchmark that is keyed to indicator sites monitored regularly by ODEQ.

The OWQI integrates measurements of eight selected water quality parameters (temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+nitrate nitrogen, total phosphates, total solids, fecal coliform) into a single index value that ranges from 10 (the worst) to 100 (the best). Land use, geology, hydrology, and water quality vary widely throughout the North Coast basin. Oregon Water Quality Index (OWQI) values for some streams in the North Coast basin are included in Table 7.4. Water quality in the Necanicum River is good to excellent according to the OWQI, and generally as good as, or better than, water quality in other near-by rivers (Table 7.4).

7.3.5 Data Sources

In order to assess more adequately the water quality conditions in the Necanicum River watershed, we assembled available data from a variety of sources. Data were obtained from the EPA STORET[2] database for the period 1967 through 1998 and from the ODEQ LASAR

[2] STORET data are available on CD-ROM from Earth Info, Inc. 5541 Central Ave., Boulder, CO 80301; (303) 938-1788.

Table 7.4. Seasonal Average OWQI Results for the Necanicum River, along with selected additional rivers in the North Coast Basin for comparison purposes (WY 1986 - 1995).

Site	STORET Number	River Mile	Summer Average	FWS Average	Minimum Seasonal Average
Necanicum River	402191	5.8	89	91	89
Miami R. @ Moss Ck. Rd.	412120	1.7	81	86	81
Wilson R. @ HWY 6	412133	8.5	91	90	90
Wilson R. @ HWY 101	412130	1.8	82	82	82
Skipanon R. @ Hwy 101	402489	4.9	70	76	70
Nehalem R. @ Foley Rd.	404545	7.8	89	84	84
Lewis and Clark R. @ Stavebolt Ln.	402494	7.6	88	78	78

Summer: June - September; FWS (Fall, Winter, & Spring): October -May
Scores - Very Poor: 0-59, Poor: 60-79, Fair: 80-84, Good: 85-89, Excellent: 90-100

database (*http://www.deq.state.or.us/wq/lasar/lasarhome.htm*) for 1967 through 2000. In addition, temperature data were collected from six sites in the Necanicum watershed by members of the Necanicum River Watershed Council.

7.4 Evaluation Criteria

The evaluation criteria used for the watershed assessment are based on the Oregon Water Quality Standards for the North Coast Basin (ORS 340-41-205) and on literature values where there are no applicable standards, as for example, for nutrients (WPN 1999). They are not identical to the water quality standards in that not all seasonal variations are included. The evaluation criteria are used as indicators that a possible problem may exist. The evaluation criteria are listed in Table 7.5.

The water quality evaluation criteria are applied to the data by noting how many, if any, of the water quality data available for the assessment exceed the criteria. If sufficient data are available, a judgement is made based on the percent of values that exceed the criteria as shown in Table 7.6. If insufficient, or no, data are available, it is noted as a data gap to be filled by future monitoring. If any water quality parameter is rated as “moderately impaired” or

Table 7.5. Water quality criteria and evaluation indicators (WPN 1999).

Water Quality Attribute	Evaluation Criteria
Temperature	
Salmonid spawning	Daily maximum of 55° F (17.8° C) (7-day moving average)
Salmonid rearing	Daily maximum of 64° F (17.8° C) (7-day moving average)
Dissolved Oxygen	
Salmonid spawning	11.0 mg/L
Salmonid rearing	8.0 mg/L
pH	Between 6.5 and 8.5 units
Nutrients	
Total Phosphorus	0.05 mg/L
Total Nitrate	0.30 mg/L, as N
Bacteria	Water-contact recreation 126 E. coli/100 mL (30-day log mean, 5 sample minimum) 406 E. coli/100 mL (single sample maximum) Marine water and shellfish areas 14 fecal coliform/100 mL (median) 43 fecal coliform/100 mL (not more than 10% of samples)
Turbidity	50 NTU maximum
Organic Contaminants	Any detectable amount
Metal Contaminants	
Arsenic	190 µg/L
Cadmium	0.4 µg/L
Chromium (hex)	11.0 µg/L
Copper	3.6 µg/L
Lead	0.5 µg/L
Mercury	0.012 µg/L
Zinc	32.7 µg/L

Table 7.6. Criteria for evaluating water quality impairment (WPN 1999).

Percent of Data Exceeding the Criterion	Impairment Category
Less than 15%	No impairment
15 to 50%	Moderately impaired
More than 50%	Impaired
Insufficient data	Unknown

"impaired", water quality in the stream reach in question is considered impaired. The condition that caused the impairment should be addressed through stream restoration activities.

7.5 Water Quality Data

7.5.1 STORET

Data were obtained from the EPA STORET database for the period 1965 through 1998. There were 112 sites in the USGS hydrologic unit 1710020101, which includes the Necanicum River, that had water quality data in the STORET database. Of these 112 sites, 50 were from ambient stream stations. The remaining sites were from such locations as point discharges, wells, sewers, pump stations, and similar locations.

Sites sampled only once over a period of 30 years do not provide adequate data to make judgements about water quality. For this reason, only sites that had been sampled multiple times were used in this analysis. There were 16 sites in the watershed that had been sampled more than once since 1966. The sites sampled more than once are listed in Table 7.7 and displayed in Figure 7.1.

7.5.2 ODEQ Sites

ODEQ currently maintains one site in the Necanicum River watershed in Seaside at Riverside Lake Camp (RM 5.8) as part of their ambient water quality monitoring network This site is the most frequently sampled, and is the STORET site with the most recent data. Additional sites in the watershed have been sampled occassionally by ODEQ for various special studies. Data for these sites were obtained from the ODEQ laboratory database (LASAR). Table 7.8 shows a numerical summary of grouped data from all the STORET and LASAR sites with more than one sample in the Necanicum River for the parameters under consideration in this assessment.

7.5.3 Other Data Sources

Necanicum River Watershed council members collected temperature data from various streams in the watershed using TidBit® temperature data loggers manufactured by Onset Computer Co. Temperature data loggers were installed at six sites in June and retrieved in October of 2000 and 2001. The six sites are listed in Table 7.9.

Figure 7.1. EPA STORET sampling sites in the Necanicum River watershed. Site descriptions are provided in Table 7.7.

Table 7.7. Ambient water quality sampling sites used for water quality assessment in the Necanicum River watershed (EPA 2000).

STORET ID	DEQ ID	Latitude	Longitude	Description	No. Samples	No. Analyses
	10803	46.02440	123.91560	Neacoxie Cr. At So.side Pacific Way Culvert	4	49
	10804	46.05760	123.92040	Neacoxie Cr. @ N.side E Gearhart Tlp.Rd.culvert.	4	29
	10805	46.04400	123.91580	Neacoxie Cr. @ So. Side of Surf Pine Rd. Bridge	4	30
	22935	45.89980	123.95540	Ecola Cr. Side Channel below Cannon Beach St	3	16
	22937	45.89990	123.95570	Ecola Cr. Side Channel 200 Ft West of Cannon Beach	3	20
	22941	45.89940	123.95240	Ecola Cr. At Hwy 101	3	19
	22949	45.89960	123.95500	Ecola Cr. Side Channel @ mouth, nr Cannon Beach	2	15
	22951	45.89960	123.95520	Ecola Cr. Side Channel 5 ft D/s Cannon Beach Stp	3	24
402191	10521	45.95250	123.92389	Necanicum River at Riverside Lake Camp (Seaside)	64	682
402480	10803	46.02250	123.91389	Neacoxie Cr. At So.side Pacific Way Culvert	4	70
402906	11226	45.90222	123.84278	Necanicum River at 12th Ave (Seaside)	12	28
405122	12367	46.04972	123.91806	Neacoxie Creek at So. Side Del Ray Beach Rd.	5	19
405123		46.01917	123.91417	Neacoxie Cr @ So. Side of G Street Culvert	2	16
405433	12649	45.98167	123.91389	Neawanna Cr.@ Jntn. Of Sunquist & Wahanna Rds.	2	25
405439	12654	45.98889	123.89278	Neawanna Cr. Tributary (Unnamed) at N-m Road	2	10
	22950	45.89960	123.95520	Ecola Cr. Side Channel 50 ft W of Cannon Beach	2	9

Note: Not all constituents were analyzed for every sample. The number of samples listed is the number of samples for which all or most of the constituents under consideration were analyzed.

Table 7.8. Numerical data summary for water quality parameters: Necanicum River Watershed water quality sampling sites.

Item Units	Dissolved Oxygen (mg/L)	*E. Coli* (No./100 mL)	Fecal coliform (No./100 mL)	Nitrate-N (mg/L)	pH (Units)	Temperature (Degrees C)	Total P (mg/L)	Turbidity (NTU)
Number of observations	119	71	118	138	128	151	85	142
Minimum	3.6	2	0	0.01	6	3	0.009	1
Maximum	12.7	630	2400	0.682	8.4	23	2.32	54
Mean	9.93	90.08	168.25	0.26	6.99	11.82	0.24	3.44
Std. dev.	1.98	130.70	285.98	0.16	0.30	4.09	0.52	5.94
1st quartile[1]	9.25	30.00	36.00	0.12	6.80	9.00	0.01	1.00
Median[2]	10.30	56.00	65.50	0.24	7.00	11.00	0.02	2.00
3rd quartile[3]	11.25	91.00	170.00	0.38	7.11	14.70	0.25	3.00

[1] 25% of values were less than or equal to the 1st quartile value
[2] 50% of values were less than or equal to the median value
[3] 75% of values were less than or equal to the 3rd quartile value

Table 7.9. TidBit sample sites in the Necanicum River watershed, summers of 2000 and 2001 .

Site	TidBit ID No.	Latitude	Longitude	Site Description
1	16097	45.89342	123.8339	South Fork Necanicum above diversion
2	16121	45.90101	123.8685	Mail Creek
3	16098	n.a.	n.a.	Beerman Creek
4	16111	45.90475	123.7753	Warner Creek 150 ft upstream of the river.
5	16103	45.90533	123.7735	Charlie Creek 200 ft upstream of the mouth of the creek
6	16092	45.90678	123.7842	Little Humbug Creek 200 ft downstream of the highway bridge

n.a. = not available

7.6 Water Quality Constituents

7.6.1 Temperature

Available temperature data from STORET and LASAR are shown in Figure 7.2. Of the 151 available temperature measurements, 10 (6.6 percent) exceed 17.8° C, and 56 (37 percent) exceed 12.8° C.

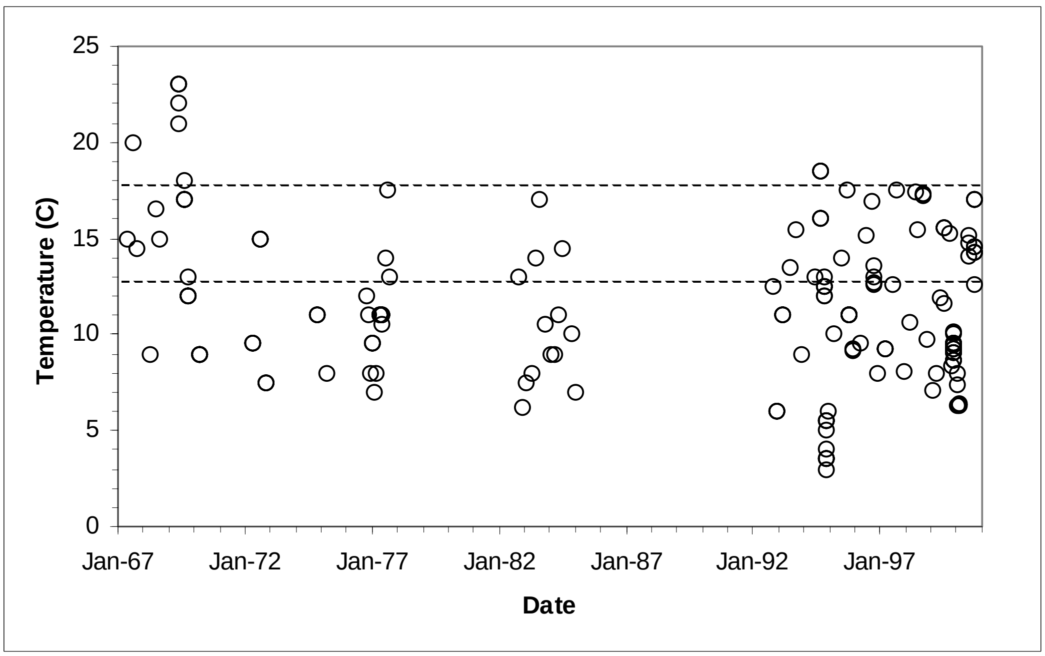


Figure 7.2. Temperature measurements taken in the Necanicum River basin 1967- 2000. The horizontal lines mark the screening criteria of 12.8° C and 17.8° C. (Data from STORET and LASAR)

Temperature loggers placed at several sites in the Necanicum River watershed collected temperature at intervals of between two to three hours between June and October of 2000 and 2001. Data have been statistically processed to yield the 7-day average of the daily maximum temperatures (commonly referred to the *7-day statistic*). These 7-day statistics are used to specify if the sampled stream temperatures violate State water quality standards. Figure 7.3 shows the 7-day statistic for the six sites in the Necanicum River watershed. Figure 7.4 shows a box plot[3] of the distribution of maximum daily temperature for each of the monitoring sites.

The general trend of temperature through the summer is similar at all sites, as would be expected, because water temperature is largely a function of sunlight and ambient air temperature. The 7-day mean maximum temperature did not exceed 17.8° C at any site at any time during the summer, but it did exceed 12.8° C (the ODEQ temperature criterion for salmonid spawning) at all sites during much of the summer.

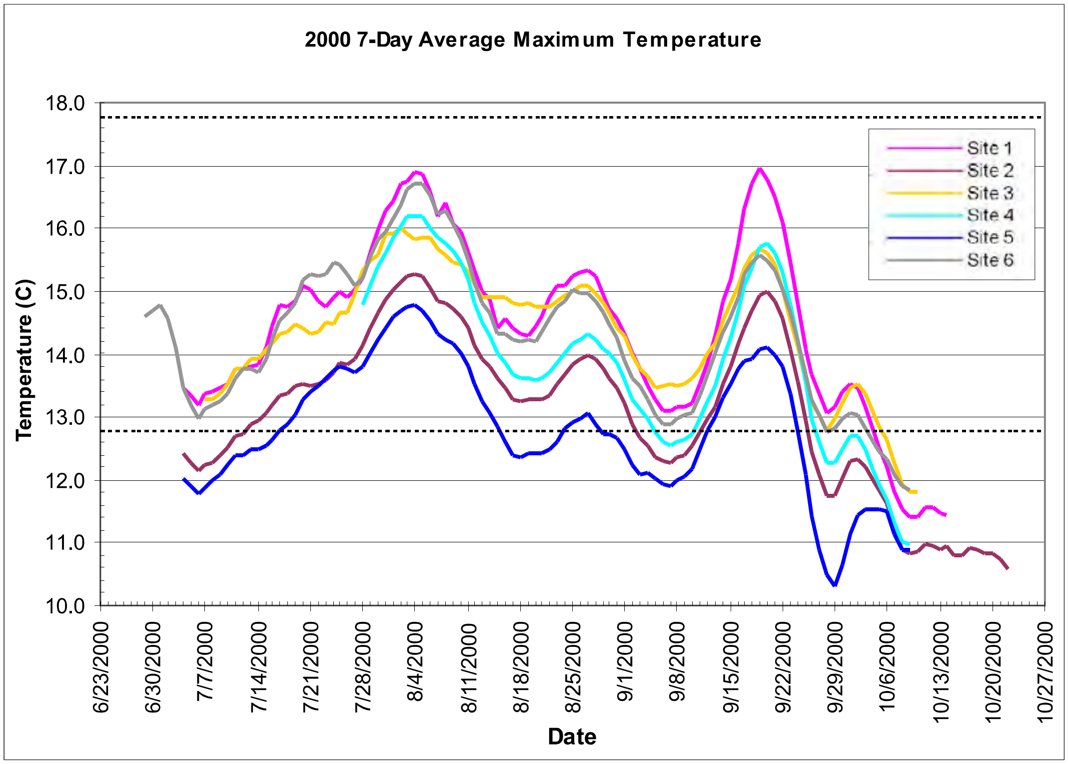
In both Figure 7.3 and Figure 7.4 it is evident that, even though the pattern is similar, there are distinct differences among the sites. Site 1, South Fork above the diversion, is the warmest site, while Site 5, Charlie Creek is the coolest. Site 2, Mail Creek, while generally warmer than Charlie Creek, is cooler than the rest of the sites. Site 3, Beerman Creek, Site 6, Little Humbug Creek, and Site 4, Warner Creek, are similar in both pattern and magnitude, falling intermediate between South Fork and Mail Creek.

These data suggest that the Necanicum River is not impaired for temperature relative to salmonid rearing and growth, but may be moderately impaired for salmonid spawning and incubation. Specific determination about impairment for salmonid depends on the periodicity of spawning activity.

7.6.2 Dissolved Oxygen

Dissolved oxygen data are presented in Figure 7.5. Of the 119 available dissolved oxygen measurements, 15 (12.6 percent) were below 8.0 mg/L, and 77 (64.7 percent) were below 11.0 mg/L. These data suggest that at least portions of the Necanicum River may be impaired with

[3]A box plot shows the distribution of the data. The solid line through the box shows the median, the dashed line the mean. The top and bottom of the box are at the 75th and 25th percentiles, respectively, so that the box includes the central 50 percent of the distribution. The whiskers extend to 1.5 times the interquartile distance above and below the box. Points beyond the whiskers are outliers. The extreme values of the distribution are represented by solid circles.



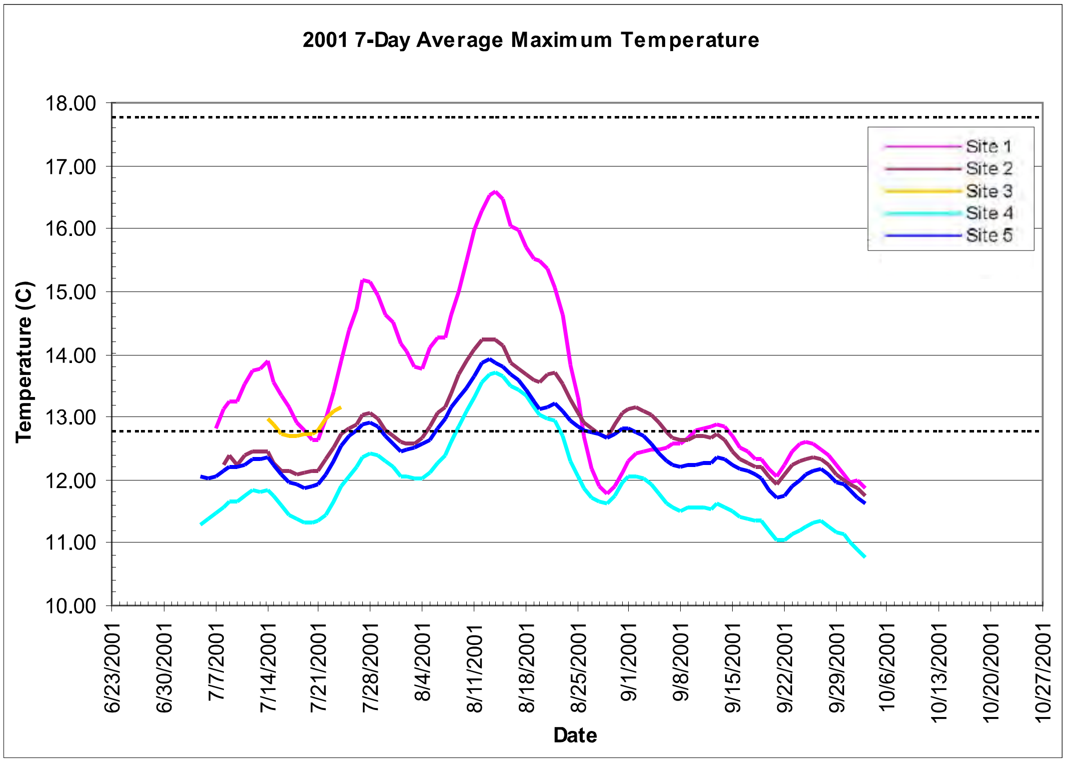


Figure 7.3. 7-day mean maximum daily temperature measured at six sites in the Necanicum River watershed during summer 2000 and at five sites during summer 2001. The horizontal dashed lines show the 12.8° C and 17.8° C criteria. Site locations are provided in Table 7.9. The monitor at site 6 malfunctioned during 2001.

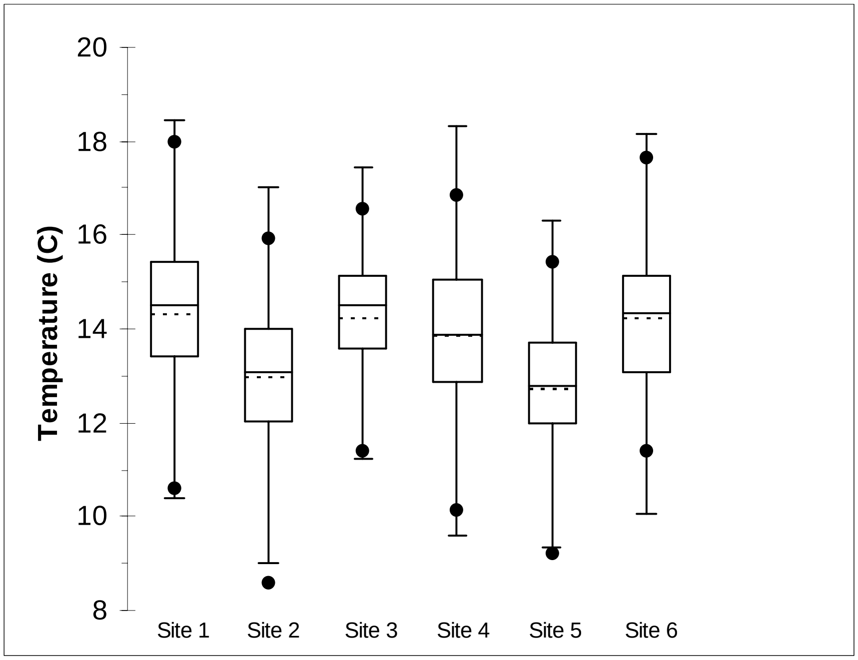


Figure 7.4. Box plot of maximum daily temperature measured at six sites in the Necanicum River watershed during June through October, 2000. Site locations are provided in Table 7.9.

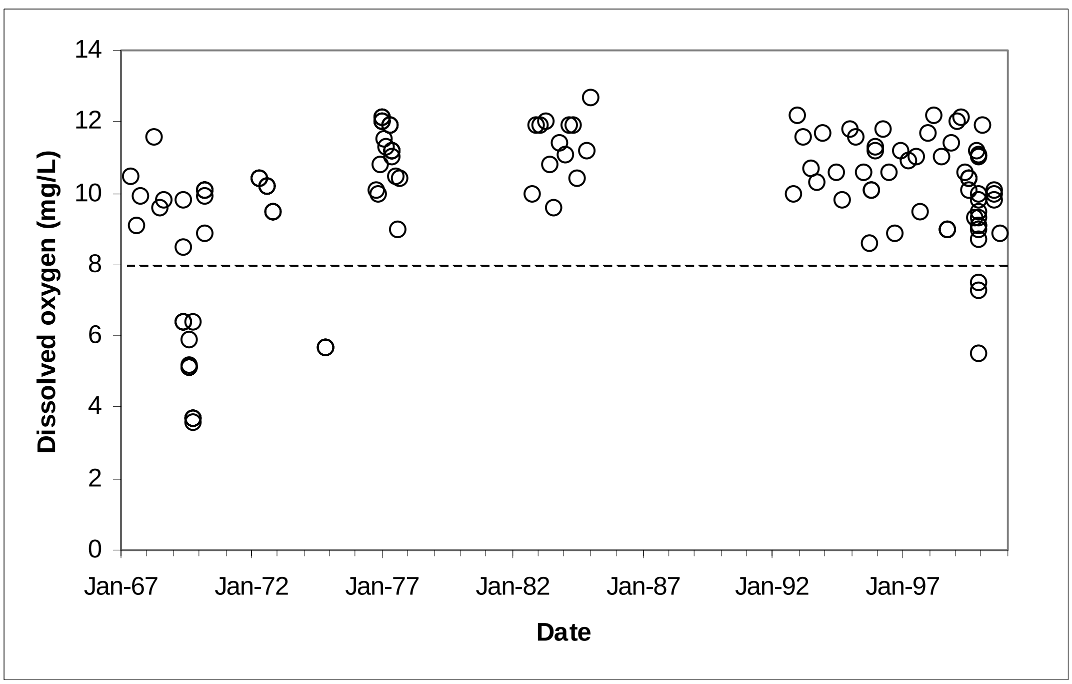


Figure 7.5. Dissolved oxygen measurements taken in the Necanicum River basin, 1967-2000. The horizontal line marks the screening criterion of 8.0 mg/L. (Data from STORET and LASAR)

respect to dissolved oxygen to support salmonid spawning and incubation, depending on the seasonality of spawning activity.

7.6.3 pH

Data for pH are presented in Figure 7.6. Only 3.1 percent of the 128 available measurements fall outside the range of the screening criteria. Based on these data, there is no reason to suspect that water quality in the Necanicum River is impaired for pH.

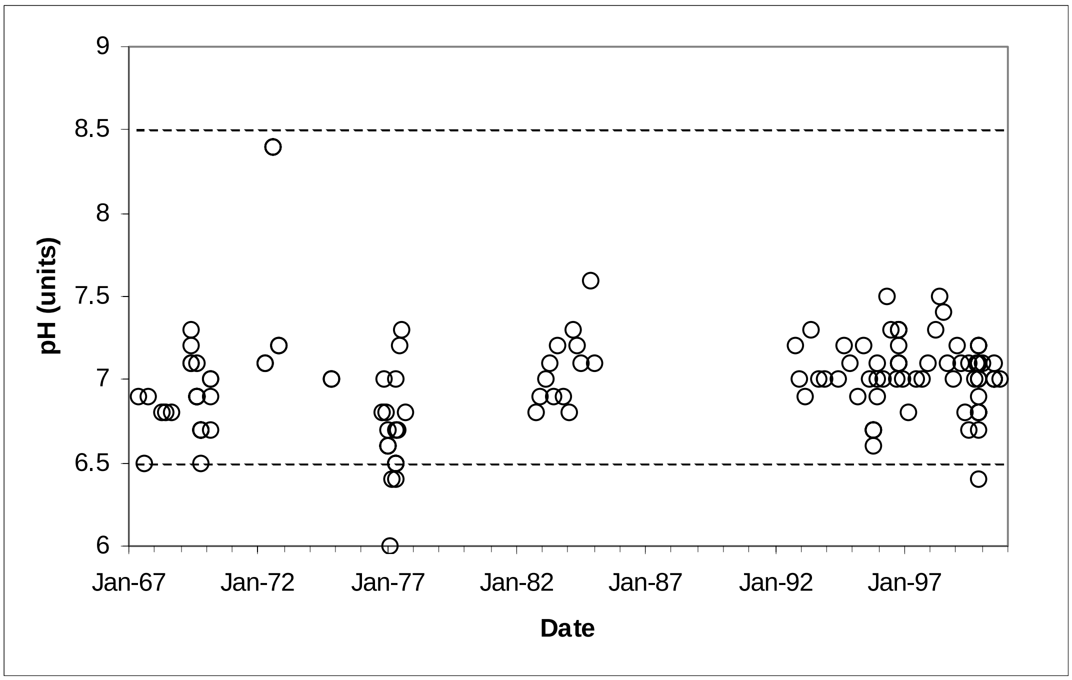


Figure 7.6. pH measurements taken in the Necanicum River basin, 1967-2000. The horizontal lines mark the screening criteria of 6.5 and 8.5. (Data from STORET and LASAR)

7.6.4 Nutrients

<u>Phosphorus</u>

Data for total phosphorus are presented in Figure 7.7. Of the 85 measurements for total phosphorus, 37 (43.5 percent) are greater than the screening criterion of 0.05 mg/L. These data suggest that the Necanicum River may be moderately impaired with respect to phosphorus.

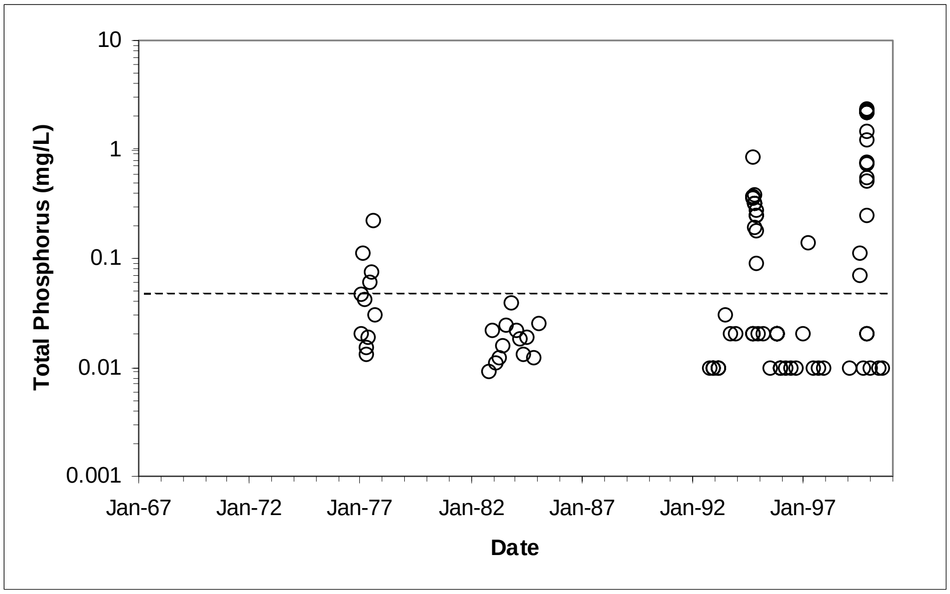


Figure 7.7. Total phosphorus measurements taken at all sites in the Necanicum River basin 1967-2000. The horizontal line marks the screening criterion of 0.05 mg/L total phosphorus (as P). (Data from STORET and LASAR)

A seasonal analysis of the STORET data from the Wilson River through 1995 conducted by ODEQ (Hinzman and Nelson 1998) showed that total phosphorus concentration in the Wilson River did not vary much seasonally. Sullivan et al. (1998) measured total phosphorus in the Wilson River during 1997. Total phosphorus concentrations were typically less than about 0.1 to 0.2 mg/L, except during storms when the concentrations sometimes exceeded 0.5 mg/L. Total phosphorus at the forest/ agriculture interface exhibited similar patterns, although concentrations were often somewhat lower than at the lower watershed sites.

Total phosphorus is closely related to total suspended solids (TSS) concentration, which suggests that the phosphorus is bound to soil particles. It is likely that the sources of the total phosphorus and TSS are the same and that the phosphorus is geologic in origin. Additionally, paired sample analyses on the Wilson River between RM 3.5 and the forest/agriculture interface site suggested that the contribution of total phosphorus from the agricultural parts of the watershed was minimal and that total phosphorus was mostly generated in the forested part of the watershed where most of the sediment originates.

These data suggest that, although the screening criterion of 0.05 mg/L is exceeded in the Necanicum River by more than 43 percent of the samples, the higher concentration of total phosphorus may not contribute to excess plant growth. Although the screening criteria require noting the Necanicum River to be moderately impaired with respect to phosphorus, further investigation may be needed to determine if the relatively high concentrations are actually causing impairment.

<u>Nitrogen</u>

Data for total nitrate-nitrogen (NO_3-N) are presented in Figure 7.8. Of 138 measurements, 52 (37.7 percent) exceed the screening criterion of 0.3 mg/L. Based on this, the Necanicum River would be considered moderately impaired with respect to nitrogen. Recent work in the Wilson River watershed provides some insight into nitrogen dynamics in watersheds in the North Coast Basin.

A seasonal analysis of STORET data from the Wilson River through 1995 conducted by the Tillamook Bay National Estuary Program (TBNEP) (Hinzman and Nelson 1998) showed that nitrate-nitrogen concentration in the Wilson River varied seasonally. Nitrate-nitrogen was typically low, with median values less than 0.3mg/L, in the summer (Jun to Aug) with the highest concentrations occurring in November and December, at median values 0.65 and 0.75 mg/L respectively.

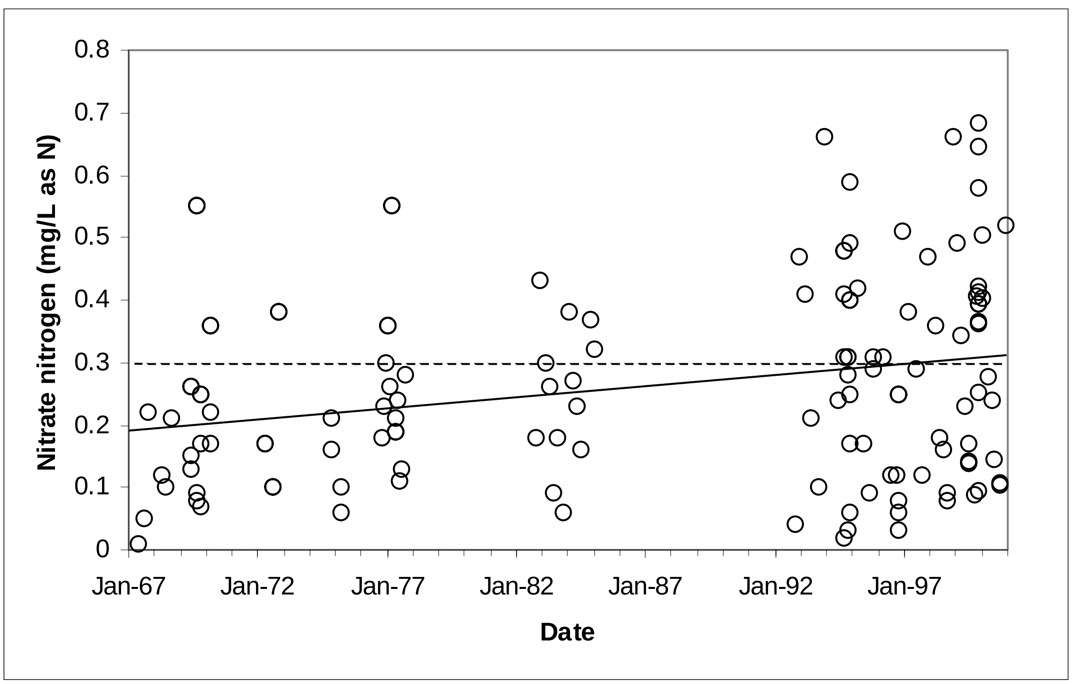


Figure 7.8. Nitrate nitrogen measured in the Necanicum River watershed 1967-2000. The horizontal dashed line marks the screening criterion of 0.3 mg/L. The solid line shows the linear regression of concentration vs. date. (Data from STORET and LASAR)

Sullivan et al. (1998) found that total inorganic nitrogen concentrations (TIN=nitrate (NO_3-N) + ammonia (NH_4-N)) were generally near 1 mg/L (± 0.2 mg/L) in the Wilson River. TIN was typically composed of more than 95 percent NO_3^-, with a very small NH_4^+ component. Limited data from the forest/agriculture interface sites showed similar patterns. Paired sample analyses (samples taken within a few hours of each other) between the primary and forest/agriculture interface sites showed there was little contribution of TIN to the rivers from the lower agricultural portions of the watershed.

Concentrations of TIN were reduced during the summer and were higher during the winter. This was likely due to greater biological demand for N in the aquatic and terrestrial systems during summer months. The greatest amount of seasonal variability in TIN loads occurred during the winter months, and may have been associated with the greater variability in winter flows. However, there was no clear relationship between TIN concentrations and flow.

Figure 7.8 suggests that nitrate concentration may be increasing in the Necanicum River. The cause of such an increase in nitrate can not be determined from the available data. It is possible that nitrogen fixation in large alder stands in the Necanicum River watershed that have developed subsequent to logging activities may be contributing to higher nitrogen concentration in the river (c.f. Stottlemyer 1992).

7.6.5 Bacteria

The Necanicum River is included on the 1998 ODEQ 303d list of water quality impaired water bodies for bacteria from the mouth to the headwaters. The bacteria water quality standard for recreational contact applies to both fresh and saline waters and is intended to protect people in contact with water, such as swimmers. The shellfish water quality standard is designed to protect people from pathogens which might be consumed with raw shellfish.

Data for bacteria in the Necanicum River are presented in Figures 7.9 (fecal coliform bacteria [FCB]) and 7.10 (*E. coli*). In unimpaired waters, not more than 50 percent of estuarine samples should exceed 14 fecal coliform bacteria per 100 mL, and not more than 10 percent should exceed 43 per 100 mL (shellfish standards). For the available data for FCB, 86.4 percent of the 118 measurements exceed 14 colony forming units (cfu) per 100 mL, and 70.3 percent exceed 43 cfu/100 mL. For *E. coli*, 18.7 percent of the 75 available measurements exceed 126 cfu/100 mL and 6.7 percent exceed the single sample maximum of 406 cfu/100 mL.

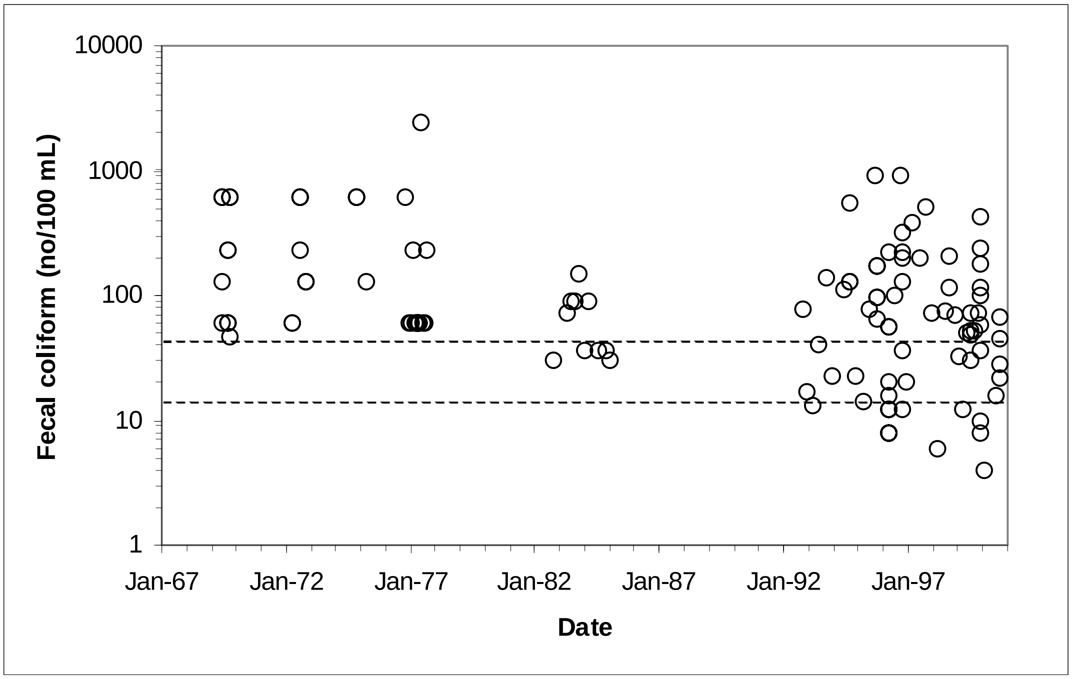


Figure 7.9. Log transformed fecal coliform bacteria measurements taken at all sites in the Necanicum River basin, 1967-2000. The horizontal lines mark the screening criteria of 14 and 43 colony forming units per 100 mL. (Data from STORET and LASAR)

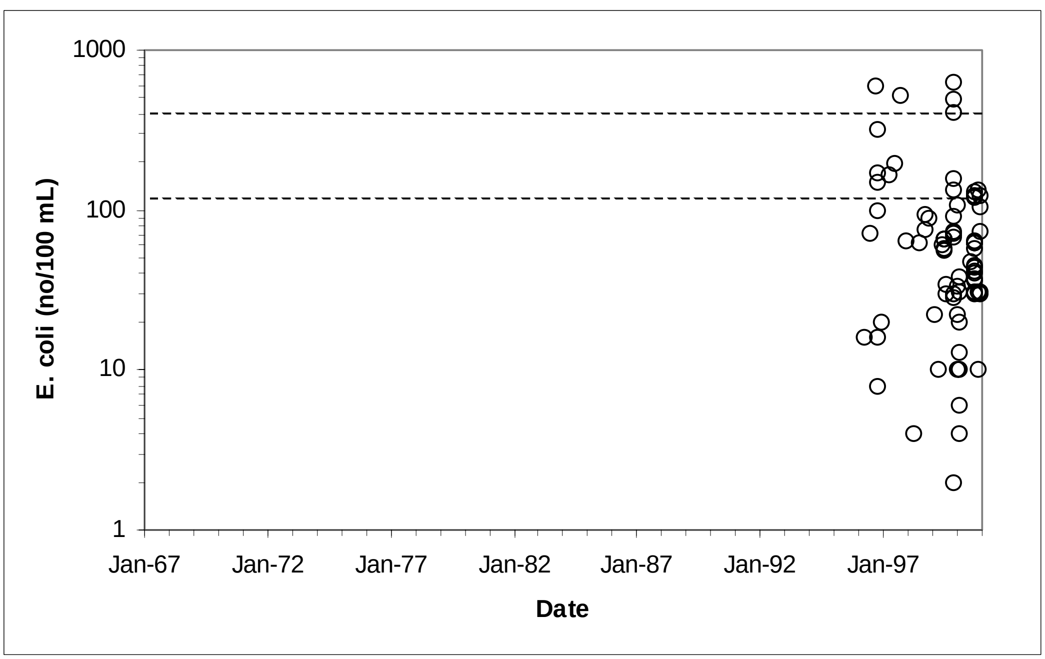


Figure 7.10. Log transformed E. coli measurements taken at all sites in the Necanicum River basin, 1967-2000. The horizontal lines mark the screening criteria of 26 and 406 cfu/mL. (Data from STORET and LASAR)

Based on the available data, water quality in the Necanicum River is impaired with respect to fecal coliform bacteria for shellfish production, and moderately impaired with respect to *E. coli* for water contact recreation.

7.6.6 Turbidity

Data for turbidity are presented in Figure 7.11. Only 1 of 142 measurements exceed the evaluation criterion of 50 NTU. This suggests that there is no impairment of water quality in regard to turbidity. However, it is likely that few of the samples considered in the assessment were taken during rainfall runoff events. It is probable, therefore that they do not represent the true range of values of turbidity. Additional sampling during rainfall events would be necessary to adequately evaluate water quality with regard to turbidity.

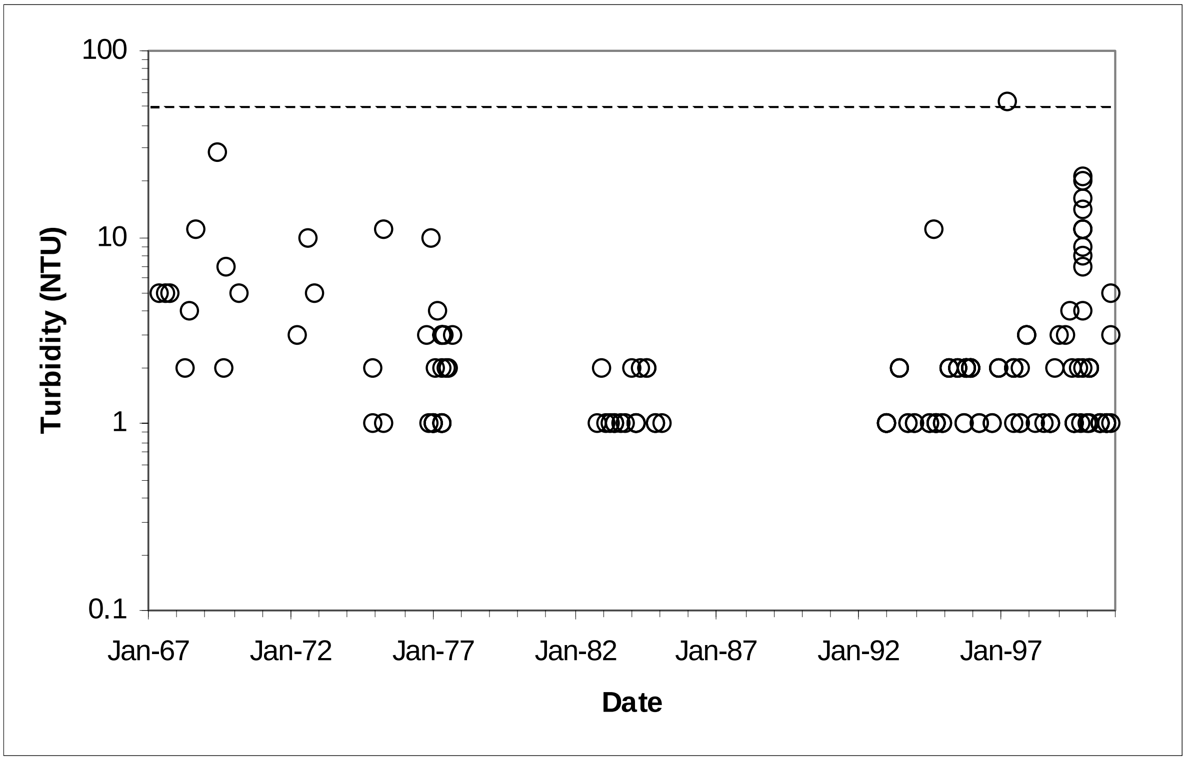


Figure 7.11. Turbidity measurements taken at all sites in the Necanicum River, 1967-2000. The horizontal line marks the screening criterion of 50 NTU. (Data from STORET and LASAR.)

7.6.7 Contaminants

From 1967 to 2000, nine sites in the Necanicum River watershed have been sampled and analyzed for one or more toxic metals. Of the 36 analyses, only one, a single sample for lead, had positive results greater than the detection limit and higher than the value for metals considered in our screening criteria. The results are shown in Table 7.10 and Figure 7.12. These results are not sufficient to determine whether or not the Necanicum River is impaired for trace metals. This is a data gap that could be filled by further sampling and analysis.

Table 7.10. Concentration of trace metals measured at various sites in the Necanicum River watershed 1967-2000. (Values in µg/L.)

Parameter	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)	Lead (Pb)
N	4	5	10	16	1
Minimum	0.11	0.23	0.3	0.66	0.31
Maximum	0.18	0.45	0.30	12.60	0.31
Mean	0.15	0.31	0.18	4.83	--
Criterion	0.40	11.00	0.36	32.70	0.05

On March 26, 1996 four sites (Table 7.11) in the Necanicum River watershed were sampled for a suite of 45 organic contaminants including pesticides and herbicides. None of the organic contaminants were present at any of the sites in quantities greater than the limit of quantitation of the analytical method. These results suggest that it is unlikely that the Necanicum River is impaired for organic contaminants.

Table 7.11. Sites in the Necanicum River watershed sampled for organic contaminants, 3/26/96.

STORET ID	DEQ ID	Latitude	Longitude	Description
	10803	46.02440	123.91560	Neacoxie Cr. @ S.side Pacific Way Culvert
	10804	46.05760	123.92040	Neacoxie Cr. @ N.side E. Gearhart Tlp.Rd.culvert
	10805	46.04400	123.91580	Neacoxie Cr. @ S. side of Surf Pine Rd. Br.
405122	12367	46.04972	123.91806	Neacoxie Cr. @ S. side Del Ray Beach Rd.

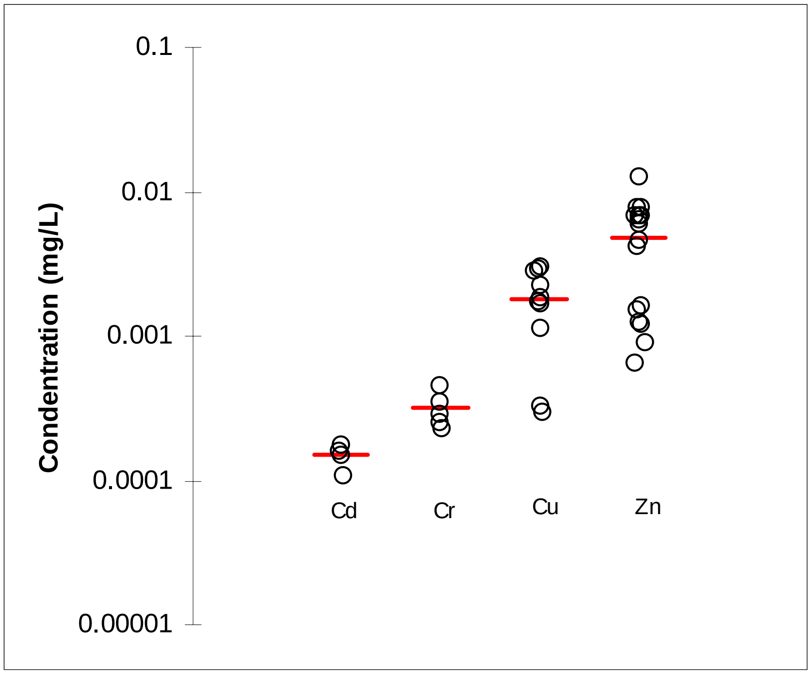


Figure 7.12. Scattergram of trace metal analysis from various sites in the Necanicum River watershed between 1967 and 2000. Short horizontal lines show the mean of values for each metal. (Data from STORET and LASAR)

7.7 Water Quality Conditions

At the screening level of this assessment, water quality in the major streams of the Necanicum River watershed would be considered impaired because of the frequency of exceedence of the evaluation criteria for total phosphorus, nitrogen, and fecal coliform bacteria. Dissolved oxygen and temperature may also be a problem with respect to salmonid spawning and incubation. There is no reason to suspect that the river suffers from impairment with respect to pH, turbidity, or organic contaminants. There is not sufficient data to make a determination with respect to trace metals (Table 7.12).

Issues with regard to bacterial contamination could be addressed through development and implementation of a coordinated management plan. Temperature and dissolved oxygen issues can be addressed by stream and watershed restoration activities. In order to adequately address the causes of impairment with respect to nutrients and trace metals, additional data should be obtained through a carefully designed water quality monitoring program.

Table 7.12. Level of impairment found in the Necanicum River watershed based on Watershed Assessment screening criteria.

Constituent	Criterion	Number of Samples	Number Exceeding Criterion	Percent Exceeding Criterion	Impairment Status[1]
Temperature	12.8 C	151	56	37.0	M
	17.8 C		10	6.6	N
Dissolved Oxygen	11.0 mg/L	119	77	64.7	I
	8.0 mg/L		15	12.6	N
pH	6.5-8.5	128	4	3.1	N
Total Phosphorus	0.03 mg/L	85	37	43.5	M
Nitrate Nitrogen	0.5 mg/L	138	52	37.7	M
E. coli	126 /100 mL	75	14	18.7	M
	406/100 mL		5	6.7	N
Fecal coliform bacteria	14/100 mL	118	102	86.4	I
	43/100 mL		83	70.3	I
Turbidity	50 NTU	142	1	0.7	N
Organic contaminants	any detected	4	0	0	N
Metal contaminants	varies	36	1	2.8	NSF

[1]Impairment status: N = not impaired, M = moderately impaired, I = impaired, NSF=insufficient data.

CHAPTER 8. WATERSHED CONDITION SUMMARY

8.1 Introduction

Summarizing current conditions and data gaps within the watershed will help to identify how current and past resource management is impacting aquatic resources. This summarization can contribute to development of a decision-making framework for identifying key restoration activities that will improve water quality and aquatic habitats. Following is a summary of key findings and data gaps derived from the primary components of this watershed assessment, including fisheries, fish habitat, hydrology, water use, sediment sources, and water quality.

8.2 Important Fisheries

Fisheries within the Necanicum River watershed have undergone significant changes during the twentieth century. The types of fish present and their locations and abundance have been altered from historical conditions in the watershed. Arguably, the most significant activities to affect the fisheries during the last one hundred years have been habitat modifications, hatchery programs and harvest.

The National Marine Fisheries Service (NMFS) has listed as threatened, or is considering as candidates for listing, several anadromous fish species in the watershed (Table 8.1). Listing occurs for entire Evolutionarily Significant Units (ESU), defined as genetically or ecologically distinctive groups of Pacific salmon, steelhead, or sea-run cutthroat trout.

Necanicum River coho salmon, chum salmon, steelhead trout, and sea-run cutthroat trout populations all appear to be depressed. At least part of these species' decline can be attributed to recent changes in oceanic conditions that, since about 1975, have been less favorable for the coasts. Coho salmon have been particularly hard hit by the poor ocean conditions because they

Table 8.1. Status of anadromous fish occurring in the Necanicum River watershed.

Fish	ESU	Status
Coho	Oregon Coast	Threatened
Coastal Cutthroat	Oregon Coast	Candidate
Chum	Pacific Coast	Not Warranted
Chinook	Oregon Coast	Not Warranted
Steelhead	Oregon Coast	Candidate

* An Evolutionarily Significant Unit or "ESU" is a distinctive group of Pacific salmon, steelhead, or sea-run cutthroat trout.

rear off the northern California and Oregon coasts and do not migrate into the more productive waters of the Gulf of Alaska. Overharvesting of coho salmon when ocean conditions were poor exacerbated the problem. Harvest management has been changed recently to adjust for the poor ocean conditions.

Hatchery fish spawning with wild fish may have caused genetic problems for coho salmon, steelhead trout, and/or sea-run cutthroat trout in the Necanicum River Basin. Although many contributors to the observed decline of anadromous fisheries are well known, the interactions among the various contributing factors are poorly understood. Information gaps for salmonids in the freshwater environment include:

- scientifically designed long-term monitoring programs to measure changes in key habitat variables through time;
- biological measures of habitat condition such as smolt production, density of juveniles per unit area of rearing habitat, and benthic macroinvertebrate abundance; and
- understanding of the amount of genetic mixing that has occurred between hatchery and wild stocks.

Information gaps for salmonids in the estuarine environment include:

- information on the quantity or quality of juvenile salmonid rearing habitat in the estuary;
- information on present use of various major estuarine habitats by juvenile salmonids; and
- long-term monitoring designed to evaluate effects of changes in watershed inputs of sediment, plant nutrients, large woody debris, and toxic substances on estuarine habitat conditions and estuarine biological communities.

Little of the existing information on fisheries populations was developed from statistically designed sampling programs. Inferences regarding population status were often based on potentially biased data. This can be a serious problem, particularly if management decisions are based on what may be inaccurate information. It is important, therefore, that scientifically designed sampling schemes be built into any short-term or long-term sampling program used for the management of the valued resources of the Necanicum River Basin. In addition, reliable long-term monitoring data were generally not available. Without long-term data sets, it is impossible to evaluate trends through time or to separate out effects of natural phenomena from human-induced changes.

Finally, there have been no comprehensive studies relating the condition of the watershed to conditions in the estuary, especially with respect to important impacts on valued resources. Many of the changes that have taken place in the estuarine environment are likely caused by, or related closely to, disturbances in the watershed that have altered flow, sediment input rates, and water quality. Monitoring and research directed at linking conditions in the watershed to conditions in the estuary are lacking.

8.3 Hydrology and Water Use

8.3.1 Hydrology

Human activities in a watershed can alter the natural hydrologic cycle, potentially causing changes in water quality and aquatic habitats. These types of changes in the landscape can increase or decrease the volume, size, and timing of runoff events and affect low flows by changing groundwater recharge. Some examples of human activities that can impact watershed hydrology are timber harvesting, urbanization, conversion of forested land to agriculture, and construction of road networks. The focus of the hydrologic analysis component of this assessment was to evaluate the potential impacts from land and water use on the hydrology of this watershed (WPN 1999). It is important to note, however, that this assessment only provides a screen for potential hydrologic impacts based on current activities in the watershed. Identifying and quantifying those activities that are actually affecting the hydrology of the watershed would require a more in-depth analysis and is beyond the scope of this assessment.

Screening for land management activities that may be affecting natural hydrologic conditions suggests that forest roads have little effect on current hydrologic regimes with regard to peak flows, but other hydrologic impacts may have occurred in response to the upland management and/or development in the valley bottoms. Rural residential roads were judged to cause moderate to high peak flow enhancement in most of the subwatersheds (Table 8.2), but occupy relatively little area. Therefore, their overall contribution to discharge should be minimal. The Necanicum River watershed has an extensive floodplain that occupies 7 percent of the watershed. There are substantial palustrine and estuarine wetlands in the lower watershed. Loss of historical flood plain acreage and land cover (such as wetlands, forested valley bottoms) have likely had minimal impact on hydrologic conditions in the watershed. The existing wetlands likely exert considerable control on watershed-scale hydrologic function. There is a

Table 8.2. Potential effects on peak flows from land use practices.

Subwatershed	Area (mi^2)	Forestry Impacts	Forest Road Impacts	Rural Residential Road Impacts*
Beerman/Tillamook	15.8	Low	Low	High
Klootchy/Mail Creek	15.3	Low	Low	High
Neacoxie	7.4	Low	Low	Low
North Fork/Humbug	13.7	Low	Low	Moderate
Seaside	8.3	Low	Low	Moderate
South Fork	9.9	Low	Low	High
Upper Necanicum	13.3	Low	Low	Moderate

* Rural residential roads were estimated to cause moderate to high impacts on peak flows within the areas where they occur. However, rural residential areas occupy less than 1% of all subwatersheds except Neacoxie (1.3%), and so the overall impact on watershed hydrology is expected to be small.

clear need for floodplain and wetland protection, and perhaps enhancement, to regulate flood attenuation and water storage.

8.3.2 Water Use

Water is withdrawn from both surface and subsurface water supplies within almost all of the watersheds in Oregon. Much of this water is withdrawn for beneficial uses, such as irrigation, municipal water supply, and stock watering. When water is removed from these stores, a certain percentage is lost through processes such as evapotranspiration. Water that is "consumed " through these processes does not return to the stream or aquifer, resulting in reduced in-stream flows, which can adversely affect aquatic communities that are dependent upon this water. In fact, the dewatering of streams has often been cited as one of the major reasons for salmonid declines in the state of Oregon.

The largest amount of water appropriated in the Necanicum River watershed is for domestic water use, especially in the South Fork Necanicum River subwatershed. During dry seasons, domestic water use may have deleterious effects on in-stream habitats by reducing flows.

Water availability was assessed by ranking subwatersheds according to their dewatering potential. Half of the water availability subwatersheds were judged to have moderate or high dewatering potential (Table 8.3), which is defined as the potential for large proportions of in-stream flows to be lost from the stream channel through consumptive use. The South Fork

Necanicum River was judged to have high dewatering potential, largely as a result of municipal withdrawals (Table 8.3). The Necanicum River was judged to have moderate dewatering potential.

Table 8.3. Dewatering potential and associated beneficial uses of water in the Necanicum River watershed.

Subwatershed	Fish Use[1]	Average Percent Withdrawn[2]	Dominant Water Use	Dewatering Potential[3]
Necanicum River @ mouth	C, FC, WS, CH	23.8	Irrigation/ Agricultural	Moderate
Necanicum River above Klootchy Creek	C, FC, WS, CH	21.8	--	Moderate
Bergsvik Creek @ mouth	C, WS	0.0	Fish/Wildlife	Low
NF Necanicum River @ mouth	C, FC, WS	0.0	Municipal/ Domestic	Low
SF Necanicum River @ mouth	C, FC, WS	82.0	Municipal/ Domestic	High
Klootchy Creek @ mouth	C, FC, WS, CH	0.0	--	Low

[1] C=coho, FC=fall chinook, WS=winter steelhead, CH=chum
[2] Average of low flow months (June, July, August, September, October).
[3] Greater than 30% is high, 10 to 30% is moderate, and less than 10% is low.

Based on current water availability model outputs, there appears to be significant concern for dewatering in the Necanicum River watershed. Three of the subwatersheds demonstrated water loss greater than 20 percent of the predicted in-stream flows. In the South Fork Necanicum River, dewatering potential exceeded 100 percent of flows one out of every two years. It is likely that water withdrawals from the Necanicum River and its tributaries may be having a large impact on current flows during periods of low flow.

Assuming that the in-stream water right for fish and wildlife is a good indicator of habitat conditions for salmonids, there is a potential for low flow conditions to have a deleterious effect on local salmonid populations. Consequently, any out-of-stream water use during these low flow situations will only exacerbate habitat problems. In-stream flow requirements for salmonids should be further evaluated to determine actual impacts of surface water withdrawals on salmonid populations. It is our recommendation that in-stream water rights continue to be protected and flows monitored during very low flow conditions.

8.4 Aquatic Habitats

Distribution and abundance of salmonids within a given watershed vary with habitat condition, such as substrate and pool frequency, and biological factors such as food distribution (i.e. insects and algae). In addition, salmonids have complex life histories and use different areas of the watershed during different parts of their life cycle. For example, salmonids need gravel substrates for spawning but may move to different stream segments during rearing. The interactions of these factors in space and time make it difficult to determine specific factors affecting salmonid populations. Consequently, entire watersheds, not just individual components, must be managed to maintain fish habitats (Garono and Brophy 1999).

The Endangered Species Act requires that all lands providing habitat for endangered species must be protected (Tuchmann et al. 1996). An understanding of the land patterns associated with the distribution of threatened and endangered species can lead to a better understanding of how to conserve these species. The OWEB process focuses primarily on salmonid habitat in the watershed. It is assumed, however, that other species will also benefit.

For all of the salmonid species that are found in the watershed, habitat conditions appear to be degraded. One of the biggest habitat-related problems in the watershed is the general lack of LWD. Other major problems identified were the general lack of channel complexity and off-channel habitat. The poor ratings for LWD recruitment from riparian areas indicate that recovery of habitat complexity in many areas will be a long process due to the lag time required to reestablish conifer communities in the riparian zone. Better management practices have eliminated a number of the man-caused disturbances that have contributed to the present condition of the freshwater habitat. A watershed approach to stream habitat restoration is needed to ensure continued recovery.

8.4.1 Fish Passage

Culverts can pose several types of fish passage problems, including excess height, excessive water velocity, insufficient water depth in culvert, disorienting flow patterns, and lack of resting pools between culverts. In some cases, culverts limit fish passage during only certain parts of the species' life cycle. For example, a culvert may be passable to larger adult anadromous fish and not juveniles. Culverts may also act as passage barriers only during particular environmental conditions such as high flow or low flow events. Because of these variable effects, it is important to understand the interactions between habitat conditions and life stage for anadromous fish.

Only 23 culverts in the Necanicum River watershed have been surveyed by ODFW to determine fish passage characteristics. Of those surveyed, however, 69 percent were judged to be impassable (Table 8.4).

Table 8.4. Fish passage conditions in the Necanicum River watershed.

Subwatershed	Stream Length (mi)	Fish Use[1]	Miles Salmonid Use	# Known Impassable Culverts	# Road/ Stream Crossings
Beerman / Tillamook	24	C, FC, WS, CH	19.2	4	60
Klootchy / Mail Creek	27	C, FC, WS, CH	13.9	1	40
Neacoxie	7	C	0.7	0	6
North Fork / Humbug	31	C, FC, WS	10.5	1	45
Seaside	19	C, FC, WS, CH	11.4	2	35
South Fork	27	C, FC, WS	6.3	0	43
Upper Necanicum	27	C, FC, WS	12.5	8	40

[1] C=coho, FC=fall chinook, WS=winter steelhead, CH=chum

8.4.2 Fish Habitats

Understanding the spatial and temporal distribution of key aquatic habitat components is the first step in learning to maintain conditions suitable to sustain salmonid populations. These components must then be linked to larger scale watershed processes that may control them. For example, a stream that lacks sufficient LWD often has poor LWD recruitment potential in the riparian areas of that stream. By identifying this linkage, riparian areas can be managed to include more conifers to increase LWD recruitment potential. Also, high stream temperatures can often be linked to lack of shade as a result of poorly vegetated riparian areas. By linking actual conditions to current watershed-level processes, land mangers can better understand how to manage the resources to maintain these key aquatic habitat components.

Stream Morphology

Pools are important features for salmonids, providing refugia and feeding areas. Substrate is also an important channel feature since salmonids use gravel beds for spawning. Gravel beds can be buried by heavy sedimentation, resulting in loss of spawning areas as well as reduced invertebrate habitat quality. For streams that were surveyed, stream morphology and substrate were compared with ODFW benchmarks to evaluate current habitat conditions. In the streams surveyed, pool conditions were generally moderate and gravel conditions were generally desirable (Table 8.5).

Table 8.5 Stream morphologic conditions in the Necanicum River watershed. Data were collected by ODFW (1990-1995).

Subwatershed	Stream Miles	Fish Use[1]	Miles Surveyed [2]	Pool Frequency[2]	Percent Pools[2]	Residual Pool Depth[2]	Gravel[2]
Beerman / Tillamook	24	C, FC, WS, CH	7.6 (7)	Moderate (4)	Desirable (4)	Moderate (7)	Desirable (5)
Klootchy / Mail Creek	27	C, FC, WS, CH	6.6 (7)	Moderate (5)	Moderate (6)	Desirable (5)	Desirable (5)
Neacoxie	7	C	--	--	--	--	--
North Fork / Humbug	31	C, FC, WS	3.7 (6)	Moderate (2)	Moderate (3)	Moderate (3)	Desirable (3)
Seaside	19	C, FC, WS, CH	--	--	--	--	--
South Fork	27	C, FC, WS	5.1 (6)	Moderate (4)	Moderate (3)	Moderate (4)	Moderate (5)
Upper Necanicum	27	C, FC, WS	8.6 (8)	Desirable (4)	Moderate (5)	Moderate (6)	Desirable (6)

[1] C=coho, FC=fall chinook, WS=winter steelhead, CH=chum
[2] Number in parentheses is the number of reaches in that category from ODFW surveys.

Large Woody Debris

Large woody debris is an important feature that adds to the complexity of the stream channel. LWD in the stream provides cover, produces and maintains pool habitat, creates surface turbulence, and retains small woody debris. Functionally, LWD dissipates stream energy, retains gravel and sediments, increases stream sinuosity and length, slows the nutrient cycling process, and provides diverse habitat for aquatic organisms (Bischoff et al. 2000, BLM 1996). LWD conditions were poor throughout the watershed, as was LWD recruitment potential (Table 8.6).

Wetlands

Wetlands contribute critical functions to watershed health, such as water quality improvement, flood attenuation, groundwater recharge and discharge, and fish and wildlife habitat (Mitsch and Gosselink 1993). Because of the importance of these functions, wetlands are

Table 8.6 Riparian and in-stream LWD conditions in the Necanicum River watershed.

Subwatershed	Str Length (mi)	Salmonid Use[1]	Riparian Recruitment[2]	Riparian Shade[2]	In-stream LWD[3]		
					Pieces	Volume	Key Pieces
Beerman / Tillamook	24	C, FC, WS, CH	low	high	Poor (7)	Poor (6)	Poor (7)
Klootchy / Mail Creek	27	C, FC, WS, CH	low	high	Poor (5)	Poor (6)	Poor (7)
Neacoxie	7	C	mod	low	-	-	-
North Fork / Humbug	31	C, FC, WS	low	high	Poor (3)	Poor (3)	Poor (4)
Seaside	19	C, FC, WS, CH	low	high	-	-	-
South Fork	27	C, FC, WS	low	high	Poor (3)	Poor (5)	Poor (3)
Upper Necanicum	27	C, FC, WS	low	high	Poor (5)	Poor (6)	Poor (8)

1 C=coho, FC=fall chinook, WS=winter steelhead, SS=summer steelhead, SC=spring chinook, CH=chum
2 From aerial photo interpretation by E&S Environmental Chemistry, Inc.
3 Subwatersheds were assigned categories (good, moderate, poor) based on the most prevalent category among all reaches surveyed in that subwatershed. The categories were based on how the data compared to ODFW habitat benchmarks. Number in parentheses is the number of reaches in that category.

regulated by both State and Federal agencies. Additionally, wetlands play an important role in the life cycles of salmonids (Lebovitz 1992). Estuarine wetlands provide holding and feeding areas for salmon smolts migrating out to the ocean. These estuarine wetlands also provide an acclimation area for smolts while they are adapting to the marine environment. Riparian wetlands can reduce sediment loads by slowing down flood water, allowing sediments to fall out of the water column and accumulate. Wetlands provide cover and food in the form of a diverse aquatic invertebrate community. Backwater riparian wetlands also provide cover during high flow events, preventing juvenile salmon from being washed downstream.

Estuarine wetlands and, in particular, palustrine wetlands are common landscape features in the Necanicum River watershed, especially along the mainstem river and in the Neacoxie and Seaside subwatersheds. Existing wetlands currently accessible to salmonids should be protected or restored. Those wetlands disconnected by hydrological modifications should be evaluated for potential reconnection and restoration.

8.5 Sediment Sources

Sediment in the rivers and streams of the Necanicum River watershed is an issue of concern. The combination of the wet climate, steep slopes in the uplands, and erosive soils results in naturally high levels of sediment in the rivers and streams. Historic wildfires in the watershed, as well as resource management practices over the past century are associated with an additional increase in sediment levels. High levels of sediment in the streams have been associated with declining health of salmonid populations. While naturally occurring sources of sediment in the watershed may be uncontrollable (and perhaps to some degree beneficial), the additional sediment contributed by human activity can, in some cases, contribute to habitat degradation.

In this watershed, slope instability, road instability, rural road runoff, and streambank erosion are significant sediment sources (Table 8.7). Slope instability contributes to shallow landslides and deep-seated slumps, which are known to be common in the Oregon Coast Range. Streamside landslides and slumps can be major contributors of sediment to streams, and shallow landslides frequently initiate debris flows. Rural roads are a common feature of this watershed, and some forest roads are present on steep slopes. Washouts from rural roads contribute sediment to streams, and sometimes initiate debris flows. The density of roads, especially unpaved gravel and dirt roads, indicates a significant potential for sediment contribution to the stream network. However, few roads are both in close proximity to a stream and situated on a steep slope. It is therefore unlikely that roads contribute an excessive amount of sediment to streams in this watershed.

Table 8.7. Potential sediment source conditions in the Necanicum River watershed.

Subwatershed	Area (sq. mi.)	Slope Instability[1]	Road Instability	Road Runoff	Stream Bank Erosion[2]
Beerman/Tillamook	15.8	High	Insufficient Data	Insufficient Data	High
Klootchy/Mail Creek	15.3	High	Insufficient Data	Insufficient Data	Moderate
Neacoxie	7.4	Low	Insufficient Data	Insufficient Data	Insufficient Data
North Fork/Humbug	13.7	High	Insufficient Data	Insufficient Data	Moderate
Seaside	8.3	Low	Insufficient Data	Insufficient Data	Insufficient Data
South Fork	9.9	High	Insufficient Data	Insufficient Data	Moderate
Upper Necanicum	13.3	Moderate	Insufficient Data	Insufficient Data	Moderate

[1] High was >20% area in high and moderate categories from ODF slope instability analysis. Moderate was 10 to 20% and low was < 10%.
[2] Based on percentage of surveyed stream length experiencing erosion.
0-25% = Low; 25-50% = Moderate; 100% = High

8.6 Water Quality

Water quality is controlled by the interaction of natural and human processes in the watershed. Processes that occur on the hillslope can ultimately control in-stream water quality. Pollutants are mobilized through surface and subsurface runoff and can cause degradation of stream water quality for both human use and fish habitat. Consequently, many water quality parameters are highly episodic in nature and often associated with certain land use practices. The water quality assessment is based on a process that identifies the beneficial use of water, identifies the criteria that protect these benefits, and evaluates the current water quality conditions using these criteria as a rule set (WPN 1999).

Comparing minimum seasonal Oregon Water Quality Index (OWQI) values, water quality in the Necanicum River ranges from good to excellent according to OWQI, and generally as good as, or better than, water quality in other near-by rivers. Water quality data are collected by the ODEQ for the Necanicum River at Seaside as part of their ambient water quality network. In addition, STORET contains water quality monitoring data for 16 sites in the watershed that have been sampled more than once since 1966.

Major tributaries were sampled for temperature during the summers of 2000 and 2001 by the watershed council. Temperature data have been statistically processed to yield the 7-day average of the daily maximum temperatures (commonly referred to the *7-day statistic*). These 7-day statistics are used to specify if the sampled stream temperatures violate State water quality standards. Based on these data, none of the tributaries appear to be temperature limited for salmonid rearing and growth, but may be moderately impaired for salmonid spawning and incubation. In summer months, the various tributaries reach stream temperatures in the range of about $14^{o}$to 17^{o} C.

At the screening level of this assessment, water quality in the major streams of the Necanicum River watershed would be considered impaired because of the frequency of exceedence of the evaluation criteria for temperature, nitrogen, total phosphorus, and bacteria. Dissolved oxygen may also be a problem with respect to salmonid spawning and incubation. There is no reason to suspect that the river suffers from impairment with respect to pH, turbidity, or trace metals. There are not sufficient data to make a preliminary judgement with respect to organic contaminants. It should be noted, however, that available water quality data are not adequate for water quality characterization in this watershed, especially with respect to spatial variability and the response of parameters that tend to be episodic in nature, such as bacteria, turbidity, and total phosphorus.

CHAPTER 9. RECOMMENDATIONS

General

- Prioritize restoration and watershed management activities based on information in this assessment and any other assessment work conducted in the watershed. Prioritize areas with known salmonid use for both spawning and rearing. Focus on areas with sufficient water quality for salmonids (low temperature) and areas with relatively good stream channel characteristics (responsive channel habitat type, good geomorphologic conditions, and good riparian shade).

- Maintain relationships and contacts among the watershed council, the county, the city of Seaside and private timber owners to keep up-to-date on data collection, further assessment, and restoration activities in the watershed. Update assessment data sets periodically.

Data

- Use a standardized base map. As a part of this assessment, a series of 1:24,000 base map layers were developed. We recommend that these layers be used as a base map and additional data be maintained at a scale of 1:24,000 or larger (i.e. 1:12,000). All of these layers will relate directly to the USGS 7.5 minute quadrangles which can be used to develop additional data layers and find locations in the field.

- Georeference all field data at a scale of 1:24,000 or better. This can be accomplished by using GPS to record latitude and longitude or by marking the location on the USGS quadrangle maps.

- Maintain data in an accessible location and format. The watershed council would be the best place for this. Most data should be maintained in a GIS format and updated annually. Some coverages will be updated periodically by the agency that created the coverage (i.e. salmonid distribution data from ODFW). These data sets should be kept current in the database.

- Collect additional data in priority areas. The decision-making framework provided by this document allows the user to select strategic locations for data collection based on features such as channel habitat type, known salmonid distribution, land use, and water quality conditions.

- Get expert advice on data collection and processing. Consult with the Technical Advisory Committee, federal and state agencies, and consultants to develop appropriate sampling collection, quality control, and data analysis protocols.

- Evaluate and ground-truth the GIS data layers. Several of the data sets used to develop this assessment need to be evaluated and compared to on-the-ground conditions before restoration actions are taken or final conclusions are made about ecosystem processes. Layers that need further evaluation or updating include, in particular, land use, roads, channel habitat types, wetlands, and riparian vegetation and shade.

- Refine the land use layer. Continue to develop the land use layer to reflect changes in land use. Update the layer with digital National Wetlands Inventory data as they become available.

Fisheries

- Develop and update a fish limits coverage, in cooperation with ODFW.
- Efforts to inventory anadromous salmonid habitat throughout the watershed should continue.
- Work with ODFW to identify viable populations and distributions of sensitive species, particularly salmonids. These data are critical in developing watershed enhancement strategies.
- Identify and survey areas currently used by salmonids. Collect stream survey data according to ODFW protocols. These data will help identify habitat limitations and areas that may provide good habitat but are currently blocked by a barrier.

Aquatic Habitats

- Field verify the channel habitat type GIS data layer.
- Field verify the riparian GIS data layers.
- Areas of good habitat should be identified and protected. This should include an analysis of the watershed upstream from the good habitat to locate potential problems that could result in future degradation of the habitat.
- Where feasible, habitat should be improved through the creation of off-channel winter refugia and introduction of LWD. Efforts should focus first on locations where the target fish species are known to be present.
- Long-term monitoring in the watershed is needed to evaluate changes in habitat and system productivity for juvenile salmonids through time. One approach might be to select representative reaches in upper, mid, and lower sections of the major subwatersheds as monitoring sites. Parameters to monitor would need to be carefully selected to provide the most information with the least expenditure of time and money.
- In the estuary, information is needed on the relative importance of major habitat types to the various anadromous salmonid species. This could be accomplished through focused sampling of specific habitat types when the various salmonid species are present.
- Integrated long-term monitoring should be designed to provide the data needed to test hypotheses regarding the effects of changes in estuarine conditions on juvenile salmonid rearing habitat in the estuary.

- Develop quantitative or semi-quantitative measures of estuarine habitat quality — similar to those used in the freshwater environment to classify stream habitat — to help in the monitoring of long-term trends in estuarine habitat quality.

- Prioritize stream reaches for restoration of riparian vegetation. Start in areas currently used by salmonids and lacking in LWD recruitment potential, good shade conditions, or in-stream LWD.

- Plant riparian conifers and native species in areas lacking LWD recruitment potential. Start in areas of known salmonid use, and use the riparian vegetation map provided with this assessment and ODFW stream surveys to identify candidate reaches. Before any reaches are targeted for planting, they should be field verified for actual conditions and suitability. Vegetation planting should use only native species and mimic comparable undisturbed sites.

- Work with private industrial landowners to obtain available information regarding culverts and fish passage.

- Complete a culvert survey of all culverts that have not been evaluated for fish passage. Data should be maintained in a GIS. The road/stream crossing coverage is a good place to start. The culvert survey should begin in priority subwatersheds at the mouth of each of the streams. Establish priorities for culvert replacement.

- Replace priority culverts identified in the culvert survey.

- Install fish passages at known fish passage barriers that are caused by human influences.

- Prioritize estuarine wetlands for restoration, protection, or maintenance based on their value to salmonids and other fish and wildlife. Landowners with priority wetlands can then be contacted for possible wetland restoration.

- Prioritize for restoration, protection, or maintenance, palustrine wetlands that are connected to streams and provide back water rearing areas for salmonids. Start in areas with known salmonid rearing and spawning habitat.
- Identify and protect high-quality floodplain vegetative communities.

- Restore floodplain vegetation in priority lowland restoration areas.

- Educate the public about the historic function of the rivers and their floodplains.

Hydrology and Water Use

- Update and refine the roads layer. Keep in contact with land owners as the roads layer is updated to evaluate its accuracy.

- Develop an outreach program to encourage water conservation. Educate the public about dewatering effects and how water conservation will help salmonids in the watersheds.

- Identify water rights that are not currently in use and that may be available for in-stream water rights through leasing or conversion.

Sediment

- Identify roads that have not been surveyed for current conditions and fill these data gaps. Work with ODF to develop road survey methodologies.
- Map road failures in areas where data are lacking. Coordinate with watershed stakeholders that are currently collecting road data, such as private timber companies. Develop a strategy to fill in the data gaps.
- Map culvert locations and conditions in conjunction with the culvert survey conducted for fish passage barriers. Check with ODF, ODFW, and local foresters for the best methodologies and data to collect.
- Map all debris flows and landslides. Begin in the areas most susceptible to landslide activity.
- Where possible, conduct road restoration activities such as road reconstruction, decommissioning, and obliteration.
- Replace undersized culverts that are at risk of washing out. Prioritize these culverts from the culvert surveys.

Water Quality

- Develop a comprehensive water quality monitoring plan, in conjunction with ODEQ and private water quality experts.
- Conduct a water quality characterization study to determine the spatial and temporal patterns in water quality within the watershed.
- Based on the water quality monitoring plan and the results of the characterization study, develop and implement a systematic water quality monitoring program that includes routine monitoring and targeted monitoring of areas with high priority for restoration activity. Where appropriate, focus the water quality monitoring on constituents that are important for the specific area being restored. Use the water quality data to refine the restoration plans.
- Develop a continuous temperature monitoring network with monitors at strategically located points such as the mouths of tributary streams, locations of known spawning beds, at the interface between major land use types, or downstream of activities with the potential to influence water temperature.

- Include a plan for long-term monitoring in any restoration plan to measure the effects of the restoration activity.

- Begin to develop the capacity within the watershed council to conduct high quality, long term water quality monitoring to document the success of restoration activities.

- Locate and map potential sources of nitrogen, phosphorus, turbidity, and bacteria in the watershed.

- Conduct all water quality monitoring activities according to established guidelines such as those published by the Oregon Plan for Salmon and Watersheds or EPA.

- Cooperate with DEQ and other agencies to share data and expertise. Coordinate the council's monitoring activities with those of the agencies, including DEQ's efforts to develop Total Maximum Daily Loads for water quality limited stream segments.

CHAPTER 10. REFERENCES

Bastasch, R. 1998. Waters of Oregon. A Source Book on Oregon's Water and Water Management. Oregon State University Press, Corvallis, OR

Beschta, R. L. 1997. Riparian shade and stream temperature: an alternative perspective. Rangelands. 19:25-28.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperatures and aquatic habitat: Fisheries and forestry interactions. p. 191-232 In: Streamside management: Forestry and fisheries interactions. Contribution No. 57, Institute of Forest Resources. University of Washington, Seattle.

Binkley, D. and T.C. Brown. 1993. Forest Practices as Nonpoint Sources of Pollution in North America. Water Resources Bulletin 29(5):720-729.

Bischoff, J.M., R B. Raymond, K.U. Snyder, L. Heigh, and S.K. Binder. 2000. Youngs Bay Watershed Assessment. E&S Environmental Chemistry, Inc. and Youngs Bay Watershed Council. Corvallis, OR.

Bottom, D.L., J.A. Lichatowich, and C.A. Frissell. 1998. Variability of Pacific Northwest Marine Ecosystems and Relation to Salmon Production. In McMurray, G.R. and R.J. Bailey (eds.). Change in Pacific Northwest Coastal Ecosystems. NOAA Coastal Ocean Program, Decision Analysis Series No. 11, Silver Spring, MD. pp. 181-252.

Boulé, M.E. and K.F. Bierly. 1987. The history of estuarine development and alteration: what have we wrought? Northwest Environmental Journal 3(1):43-61.

Boyd, M and D. Sturdevant. 1997. The scientific basis for Oregon's stream temperature standard: common questions and straight answers. Oregon Department of Environmental Quality. Portland, OR.

Boyd, M., B. Kasper, and A. Hamel. 1999. Tillamook Basin Temperature Total Maximum Daily Load (TMDL), draft. Oregon Department of Environmental Quality. *http://gisweb.co.tillamook.or.us/library/reports/TillamookBasinTempTMDL.pdf*.

Bureau of Land Management (BLM). 1996. Thomas Creek Watershed Analysis. U.S. Department of the Interior, Bureau of Land Management, Salem District Office, Salem, OR.

Busby, P., T. Wainwerght, G. Bryant, L. Lierheimer, R. Waples, F. Waknitz, and I. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS–NWFSC–27. 195 pp. + appendices.

Cederholm, C.J., M.D. Kunze, T. Murota, and A. Sibatani. 1999. Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems. Fisheries 24(10): 6-15.

Chesney, C..J. 1982. Mass Erosion Occurrence and Debris Torrent Impacts on Some Streams in the Willamette National Forest. MS Thesis, Department of Forest Engineering, Oregon State University, Corvallis.

Connolly, T.J. 1992. Human Responses to Change in Coastal Geomorphology and Fauna on the Southern Northwest Coast: Archaeological Investigations at Seaside, Oregon. Anthropological Paper 45, University of Oregon, Eugene, OR. 198 pp.

Conroy, S.C. 1997. Habitat lost and found. Washington Trout Report. Vol. 7:1.

Coulton, K., P. Williams, and P. Brenner. 1996. An Environmental History of the Tillamook Bay Estuary and Watershed. Report to the TBNEP, Garibaldi, OR.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-79/31.

Craig, J.A. and R.L. Hacker. 1940. The history and development of the fisheries of the Columbia River. Bull. Bureau of Fisheries, No. 32.

Daly, C., R.P. Neilson, and D.L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology, 33, 140-158.

Emmett, R.L., S.A. Hinton, S.L. Stone and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Volume II: Species life history summaries. ELMR Rep. No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD. 329 pp.

Flemming, I.A. and M.R. Gross. 1993. Breeding success of hatchery and wild coho salmon (*Oncorhynchus kisutch*) in competition. Ecol. Applic. 3:230-245.

Flemming, I.A. and M.R. Gross. 1989. Evolution of adult female life history and morphology in a Pacific salmon (coho: *Oncorhynchus kisutch*). Evolution 43:141-157.

Franklin, J. and C. Dyrness. 1973. Natural Vegetation of Oregon and Washington, USDA Forest Service, Portland, OR.

Frenkel, R.E. and J.E. Morlan. 1991. Can we restore our salt marshes? Lessons from the Salmon River, Oregon. Northwest Environmental Journal 7:119-135.

Garono, R. and L. Brophy. 1999. Rock Creek (Siletz) Watershed Assessment Final Report. Earth Design Consultants, Inc., Corvallis, OR.

Glenn, J. 1978. “Sediment sources and Holocene sedimentation history in Tillamook Bay, Oregon: Data and preliminary interpretations.” Prepared by U.S. Geological Survey in cooperation with the Soil Conservation Service. Open file report 78-680.

Good, J.W. 2000. Summary and current status of Oregon's estuarine ecosystems. Chapter III, Section 3.3, In Oregon State of the Environment Report.

Good, J.W. 1999. Estuarine Science, Management, and Restoration. Chapter II-10, In: Watershed Stewardship: A Learning Guide. EM 8714. Oregon State University Extension Service, Corvallis. 50 p.

Hargreaves, N.B. and R.J. LeBrasseur. 1986. Size selectivity of coho (*Oncorhynchus kisutch*) preying on juvenile chum salmon (*O. keta*). Can. J. Fish. Aquat. Sci. 43:581-586.
Harr, R.D. 1983. Potential for augmenting water yield through forest practices in western Washington and western Oregon. Water Resour. Bull. 19:383-393.

Harr, R.D., W.C. Harper, J.T. Krygier, and F.S. Hsieh. 1975. Changes in storm hydrographs after road building and clear-cutting in the Oregon Coast Range. Water Resour. Res. 11:436-444.

Hatch, K.M. 1990. A phenotypic comparison of thirty-eight steelhead (*Oncorhynchus mykiss*) populations from coastal Oregon. M.S. Thesis. Oregon State University, Corvallis.

Healey, M.C. 1982. Juvenile pacific salmon in estuaries: The life support system. In: Kennedy, V. (ed.). Estuarine Comparisons. New York, NY. pp. 315-341.

Hemmingsen, A.R., R.A. Holt, and R.D. Ewing. 1986. Susceptibility of progeny from crosses among three stocks of coho salmon to infection by *Ceratomyxa shasta*. Transactions of the American Fish. Soc. 115:492-495.

Hicks, B.J. 1989. The influence of geology and timber harvest on channel morphology and salmonid populations in Oregon Coast Range streams. Ph.D. thesis, Oregon State University, Corvallis.

Hinzman, R. and S. Nelson. 1998. Tillamook Bay Environmental Characterization report

Hirsch, R.M., J.F. Walker. J.C. Day, and R. Kallio. 1990. The influence of man on hydrologic systems. In: Wolman, M.G. and H.C. Riggs (Eds). The Geology of North America. Volume O-l. Surface Water Hydrology. Geological Society of America, Boulder, Colorado. pp. 329-359.

Hjort, R.C. and C.B. Schreck. 1982. Phenotypic differences among stocks of hatchery and wild coho salmon, *Oncorhynchus kisutch*, in Oregon, Washington, and California. Fish. Bull. 80:105-119.

Iwamoto, R., and E. Salo. 1977. Estuarine survival of juvenile salmonids: A review of the literature. Report to Washington Department of Fisheries, Fisheries Research Institute., University of Washington, Seattle, WA

Johnson, R. R. and J.F. McCormick. 1979. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Gen. Tech. Report WO-12. U.S. Forest Service, Washington, DC.

Jones, J. and G.E. Grant. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. Water Resour. Res. 32:959-974.

Kauffman, J. B., R. L. Beschta, N. Ottig, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the Western United States. Fisheries 22:12-23.

Komar, P. 1997. Sediment accumulation in Tillamook Bay, Oregon, a large drowned-river estuary. Tillamook Bay National Estuary Project, Garibaldi, OR.

Lebovitz, M.E.S. 1992. Oregon estuarine conservation and restoration priority evaluation. Opportunities for salmonid habitat and wetlands functions enhancement in Oregon's estuaries. Report prepared for Oregon Trout and U.S. Fish and Wildlife Service. Yale Univ., New Haven, CT.

Light, T. 1987. Coastwide abundance of North American steelhead trout. (Document submitted to the annual meeting of the International North Pacific Fisheries Conference, 1987) Fisheries Research Institute report FRI–UW–8710. University of Washington, Seattle, WA. 18 pp.

MacDonald, J.S., C.D. Levings, C.D. McAllister, U.H.M. Fagerlund, and J.R. McBride. 1988. A field experiment to test the importance of estuaries for chinook salmon (*Oncorhynchus tshawytscha*) survival: Short-term results. Can. J. Fish. Aquat. Sci. 45:1366-1377.

McDade, M.H., F.J. Swanson, W.A. McKee, J.F. Franklin, and J. Van Sickle. 1990. Source distances for coarse woody debris entering small streams in western Oregon and Washington. Canadian Journal of Forest Research 20:326-330.

McGie, A.M. 1981. Trends in escapement and production of fall chinook and coho salmon in Oregon. Oreg. Dep. Fish. Wildl., Fish Div. Info. Rep. 81 –7, Portland. 44 p.

Mills, K. 1997. Landslides and their association to forest practices for the storm. Proceedings of the Pacific Northwest Water Issues Conference. American Institute of Hydrology. Portland, OR. 318 pp.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. 2nd ed. Van Nostrand Reinhold, New York.

Moore, K., K. Jones, and J. Dambacher. 1997. Methods for stream habitat surveys. Aquatic inventory Project. Oregon Department of Fish and Wildlife, Natural Production Program, Corvallis, OR. 45 pp.

Naiman, R.J. and R.E. Bilby, editors. 1998. River Ecology and Management. Lessons from the Pacific Coastal Ecoregion. Springer, New York.

National Research Council. 1996. "Landslides investigation and mitigation." Special report 247. Transportation Research Board, National Research Council. Washington, DC.
National Research Council 1995 in Kauffman et al. 1997

National Research Council. 1995. (U.S.) Committee on characterization of wetlands. Wetlands - characteristics and boundaries. National Academy Press, Washington, DC.

National Oceanic and Atmospheric Administration (NOAA). 1998. NOAA's Estuarine Eutrophication Survey. Volume 5: Pacific Coast Region. Office of Ocean Resources Conservation and Assessment, Silver Spring, MD.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 43:2443-2449.

NRCS. 1999. Draft Skipanon River Hydrologic Analysis.

Omernik, J.M. and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. U.S. Environmental Protection Agency, Corvallis, OR. EPA/600/3-86/033.

Oregon Department of Environmental Quality. 2000. Web Page. *http://www.deq.state.or.us*.

Oregon Department of Environmental Quality. 1999. Final 1998 Water Quality Limited streams- 303(d) list. *http://www.deq.state.or.us/wq/303dlist/303dpage.htm*. Accessed 8/13/00.

ODFW. 2000. Web page. *ftp://ftp.dfw.state.or.us/pub/gis*.

Oregon Department of Fish and Wildlife. 1997. Summary of January 6, 1997 ODFW Comments to National Marine Fisheries Service Concerning the Listing of Steelhead under the Endangered Species Act. ODFW, Portland, OR.

Oregon Department of Fish and Wildlife. 1997. Culvert inventory and assessment: state and county owned roads in five Oregon coastal basins, Portland, OR.

Oregon Department of Fish and Wildlife. 1997. Wild Flyer, Fall, 1997.

Oregon Department of Fish and Wildlife. 1995. Biennial Report on the Status of Wild fish in Oregon. Oregon Dept. of Fish and Wildlife, Portland, OR.

Oregon Natural Resources Council (ONRC) and others. 1994. Petition for a rule to list steelhead trout as threatened or endangered under the Endangered Species Act and to designate critical habitat. Unpublished manuscript (document submitted to the USDOC NOAA NMFS Northwest Region, Seattle, WA., February 1994). 133 pp.

Oregon Water Resources Board. 1975. Freshwater Resources of the Oregon Coastal Zone. A Natural Resource Inventory Report to the Oregon Coastal Conservation & Development Commission.

Pedone, P. 1995. Delivery of sediments to Tillamook Bay in the past: A summary of the 1978 Tillamook Bay drainage basin erosion and sedimentation study. Impacts of erosion and sedimentation in Tillamook Bay and Watershed. Summary of a TBNEP Scientific/Technical Advisory Committee forum. Tillamook Bay National Estuary Project, Garibaldi, OR.

Reisenbichler, R.R. 1988. Relation between distance transferred from natal stream and recovery rate for hatchery coho salmon. N. Amer. J. Fish. Mgmt. 8:172-174.

Reisenbichler, R. R., and S. R. Phelps. 1989. Genetic variation in steelhead (Salmo gairdneri) from the north coast of Washington. Can. J. Fish. Aquat. Sci. 46:66-73.

Reisenbichler, R. R., J. D. McIntyre, M. F. Solazzi, and S. W. Landino. 1992. Genetic variation in steelhead of Oregon and northern California. Trans. Am. Fish. Soc. 121:158-169.

Robison, E.G. 1991. Methods for Determining Streamflows and Water Availability in Oregon. Hydrology Report #2. Oregon Water Resources Dept.

Rothacher, J. 1973. Does harvest in west slope Douglas-fir increase peak flow in small streams? Res. Paper PNW-163. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 13 p.

Rothacher, J. 1971. Regimes of streamflow and their modification by logging. In: Krygier, J.T. and J.D. Hall, eds. Proceedings of the symposium on forest land use and stream environment; Oregon State University, Corvallis, OR. pp. 55-63.

Ryman, N., and L. Laikre. 1991. Effects of supportive breeding on the genetically effective population size. Conserv. Biol. 5:325-329.

Sessions, J., J.C. Balcom, and K. Boston. 1987. Road location and construction practices: effects on landslide frequency and size in the Oregon Coast Range. Western Journal of Applied Forestry 2(4):119-124.

Sheppard, D. 1972. The present status of the steelhead trout stocks along the Pacific Coast. As cited in: D. H. Rosenberg, ed., A review of the oceanography and renewable resources of the northern Gulf of Alaska. IMS Report R72-23, Sea Grant report 73–3. Institute of Marine Science, University of Alaska, Fairbanks, AK.

Shields, F. and C. Cooper. 1994. Riparian wetlands and flood stages. Proceedings of the conference Hydraulic Engineering ‘94 Volume 1, G. Cotroneo and R. Rumer, eds, American Society of Civil Engineers, Buffalo, NY, August 1–5, pp. 351–355.

Shreffler, D.K., C.A. Simenstad, and R.M. Thom. 1992. Foraging by juvenile salmon in a restored estuarine wetland. Estuaries 15(2):204-213.

Sidle, R., A. Pearce, and C. O'Loughlin. 1985. “Hillslope stability and land use.” American Geophysical Union, Water resources monograph 11. Washington, D.C.

Simenstad, C., and E. Salo. 1982. Foraging success as a determinant of estuarine and nearshore carrying capacity of juvenile chum salmon, *Oncorhynchus keta*, in Hood Canal, Washington. As cited in: B. R. Miteff and R. A. Nevè, ed., Proc. North Pacific Aquaculture Symposium Report 82–2. Alaska Sea Grant Program, University of Alaska, Fairbanks, AK.

Simenstad, C., D. Jay, C. McIntire, W. Nehlsen, C. Sherwood, and L. Small. 1984. The dynamics of the Columbia River estuarine ecosystem Volume II. Columbia River Estuary Data Development Program.

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: An unappreciated function. In: Kennedy, V. (ed.). Estuarine Comparisons. New York, NY. pp. 343-364.

Snohomish County Public Works. 1996. Skykomish River floodplain management plan, public review draft, August.

Stottlemyer. R. 1992. Nitrogen mineralization and streamwater chemistry, Rock Creek Watershed, Denali National Park, Alaska, USA. Artic and Alpine Research 24:291- 303.

Sulllivan, T.J., J.M. Bischoff, K.B. Vaché, M. Wustenberg, and J. Moore. 1998. Water Quality Monitoring in the Tillamook Watershed. E&S Environmental Chemistry, Inc., Corvallis, OR

Taylor, G.H. and R.R. Hatton. 1999. The Oregon Weather Book - A State of Extremes. Oregon State Univ. Press, Corvallis. 242 pp.

Tillamook Bay National Estuary Project. 1998. Tillamook Bay Environmental Characterization. A Scientific and Technical Summary. Final report prepared under Cooperative Agreement #CE990292–1 with the U.S. Environmental Protection Agency. Garibaldi, OR.

Tuchmann, E., K.P. Cannaughton, L.E. Freedman, and C.B. Moriwaki. 1996. The Northwest Forest Plan: A Report to the President and Congress. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 253 pp.

U.S. Department of Agriculture. 1978. Tillamook Bay drainage basin erosion and sediment study. Cooperative study by The Tillamook Bay Task Force, Oregon State Water Resources Department, USDA Soil Conservation Service Forest Service-Economics, Statistics and Cooperative Service.

U.S. Department of Agriculture. 1964. Soil Survey, Tillamook County. Series 1957. No. 18.

U.S. EPA. 2000. STORET. *http://www.epa.gov/storet*.

U.S. Environmental Protection Agency, Coastal Ecology Branch (USEPA). 1998. The effects of habitat alteration

U.S. Fish and Wildlife Service and Canadian Wildlife Service. 1990. North American Waterfowl Management Plan: Pacific Coast Joint Venture; Pacific coast habitat: a prospectus. USFWS, Portland, OR.

Washington Forest Practices Board. 1995. Washington Forest Practices Board manual: standard methodology for conducting watershed analysis under 222-22 WAC Version 3.0. Washington Department of Natural Resources, Forest Practices Division, Olympia, WA.

Watershed Professionals Network. 1999. Oregon Watershed Assessment Manual. June 1999. Prepared for the Governor's Watershed Enhancement Board, Salem, OR.

Weber, W. and J. Sheahan. 1995. Status of Naturally Producing Stocks. Columbia Region - Fish Division Annual Meeting. Oregon Department of Fish and Wildlife.

Wissmar, R. 1986. Carbon, nitrogen and phosphorus cycling in Pacific Northwest estuaries. As cited in: Wetland functions, rehabilitation, and creation in the Pacific Northwest: The state of our understanding: Proceedings of a conference. Olympia, WA.

Wissmar, R., and C. Simenstad. 1984. Surface foam chemistry and productivity in the Duckabush River Estuary, Puget Sound, Washington. As cited in: V.S. Kennedy, ed., The estuary as a filter. Academic Press, Inc., New York, NY.