1 Executive Summary

1.1 Introduction

The intent of the Executive Summary is to provide ODF managers with a truncated, stand-alone document that summarizes the most important topics from each subject area (i.e., chapter). As such, not all the issues identified in this Watershed Analysis are covered in the Executive Summary. Readers looking for a more in-depth review and discussion, as well as the presentation of other lesser-important issues are encouraged to refer to the expanded chapters in the main (full) document.

1.2 Watershed Overview

The previous OWEB assessment for the Wilson River (E&S Environmental Chemistry 2001) addressed much of the general watershed information. Therefore, only the details considered essential to a general overview of the project area are covered here.

Located in the Coast Range mountains of northwestern Oregon, the Wilson River flows off their western flank eventually emptying into Tillamook Bay, one of five major river systems to do so (refer to section 3.1 Physical Setting). The Wilson River watershed (Wilson) is comprised of eight subwatersheds (6th field HUCs; Map 2 and Table 4; refer to section 3.1.5 Waterboundaries) covering roughly 123,000 acres. The lowland alluvial plains – once forested but containing numerous hydrologically connected sloughs – are currently utilized primarily for dairy farming and rural residential housing while the forested uplands are utilized primarily for timber production and recreation (see section 3.3 Social Context).

The Wilson River watershed, part of the Coast Range Physiographic Province (Franklin and Dyrness 1973; WPN 1999) spans portions of the Coastal Lowlands, Coastal Uplands and Coastal Volcanic Uplands ecoregions (Omernik and Gallant 1986; refer to section 3.1.1 Ecoregion). The Wilson is located in the Tillamook Highlands, a geologic province of the north Coast Range and is typified by long, continuous shorelines punctuated by steep cliffs and the occasional estuarine bay containing rich lowland marshes and deep, alluvial-deposited terraces. Inland, the mountains rise up sharply to elevations greater than 3,500 feet while broad, alluvial, lowland valleys disappear into narrow, steep-sided canyons where high-gradient, cascading streams and landslides predominate (refer to section 3.1.2 Geology, Landforms and Soils).

Prevailing soil types in the Wilson River watershed (see Appendix A – Soils Data) consist of deep, well-drained, highly-productive fluvial and estuarine deposits in the lowlands with moderately deep soils covering very steep terrain in the uplands (ODF 2003, TBNEP 1998). Although much of the watershed is still forested, most of the lowlands have been cleared for agricultural production (e.g. dairy farming). Situated in the coastal temperate rainforest, the Wilson River (and its climate) is strongly influenced by the Pacific Ocean and its related weather patterns (Taylor and Hatton 1999). Typical of Pacific Northwest climate, the Wilson experiences an extended, mild, winter rainy season (November through February) followed by a moderately warm and relatively dry summer season (refer to section 3.1.3 Climate). Precipitation (generally rainfall) increases with elevation as warm, moisture-laden air rises over higher terrain, causing the air to cool and drop precipitation (orographic effect; refer to Sections 3.4.2 Flooding as an Historic Disturbance and 5.2 Flood History for detailed hydrology discussions). Average high temperatures hover around the mid-fifties (Fahrenheit) in the winter months and the high sixties during the summer months. Average low temperatures dip to the mid-thirties during the winter and the mid- to upper fifties in the summer.

State lands account for the largest proportion by land area at slightly less than 98,000 acres (~80%; Table 3; refer to section 3.1.4 Ownership). Approximately 31,330 acres are administered by the Forest Grove ODF district and the remaining 66,423 acres are administered by the Tillamook ODF district (Map 2). The remaining acreage is split between Private Industrial (~12.3%), Private Non-Industrial (~5.2%), Federally Administered Bureau of Land Management (BLM) lands (2.9%), and Miscellaneous lands administered by the City of Tillamook, Tillamook County, or the State Department of Transportation (~0.5%; Table 3).

The historical characteristics of Tillamook Bay (and the Wilson River watershed) prior to the mid-1800's are not well documented (refer to section 3.2.1 Early European Settlement). Our current understanding of the natural resources during exploration and settlement is limited to a handful of written accounts from early explorers and pioneers and to research into and accounts from Native American culture. What can be gleaned, however, is that the Tillamook Basin was rich in natural resources (e.g., fish, shellfish, crab, berries, roots, big game, etc.) and anthropological and archaeological evidence indicates that the Native Tillamook peoples relied heavily on these plentiful resources (Taylor 1974).

Similar to many of the other Native American tribes of the area, the Tillamook peoples had a custom of "burn(ing) off the whole country" late in the autumn every year to harvest grain and they were also reported to set fires in old growth spruce and fir to clear areas for their ponies and encourage verdant re-growth (Winters 1941; refer to section 3.2.1 Early European Settlement, 3.4.1 Fire as an Historic Disturbance, 3.5.2 The Tillamook Burn and Reforestation). William Clark also noted another disturbance (although not anthropogenic) around the

Tillamook Bay and surrounding coastline in the 1800's; "tremendous" landslides that were "fifty or a hundred acres" across (Bancroft 1886). While his notes pertain mostly to coastline hillslopes, they suggest that landslides were probably common in the area prior to European settlement and may have also been found further inland as hillslope gradients increased. For more detailed discussions on natural and human-influenced disturbances in the Wilson, refer to sections 3.4 (Natural Disturbances), 3.5 (Forest Management), 4.7 (Channel Modifications), 4.8 (Historic Channel Disturbances), 6.7 (Recreational Impacts on Riparian Vegetation – Direct and Indirect Effects), and Chapter 7 (Sediment Sources).

The Wilson River watershed straddles parts of both the Sitka spruce and western hemlock vegetation zones (Franklin and Dyrness 1973), both of which extend from British Columbia south to Northern California, roughly running parallel with the Eastern Pacific coastline (refer to section 3.2.2 Vegetation). Dense stands of timber included Sitka spruce, western hemlock, western red cedar, Douglas fir, grand fir, Pacific yew, red alder, bigleaf maple, black cottonwood, and Oregon ash (TBNEP 1998). Understory vegetation includes a variety of shrubs, ferns and mosses like the western sword fern, bracken fern, thistle, fireweed, wood sorrel, red and green huckleberries, salal, red elderberry, salmonberry, vine maple, Oregon grape and rhododendron (TBNEP 1998).

The structure of the vegetative communities, (i.e., successional stages and species compositions), however, has been heavily influenced by humans. In the late 1800's and early 1900's, large sections of the lowlands and tidal areas were cleared of timber, the wetlands drained, and the rivers diked for agricultural use, often resulting in profound impacts to the vegetative communities. Much of the uplands were heavily logged and/or burned over (both naturally- and human-influenced; refer to section 3.3.1 Historical Land Use, 3.3.2 Current Land Use, 3.4 Natural Disturbances and 3.5 Forest Management) and, with some exceptions, replanted primarily with one species of tree, the Douglas fir. More recently, replanted Douglas fir (many of the seedlings were from an off-site seed source; refer to section 3.5.2 The Tillamook Burn and Reforestation) have been increasingly infected with Swiss needle cast, a foliage disease resulting in defoliation and reduction in growth, which carries with it the potential for very significant forest health issues (e.g., decreased production and disease/insect resistance, increased fire danger and severity, etc.).

The dominant land use in the Wilson River watershed is forestry, accounting for roughly 95% of the watershed's total area (Map 9 and Table 5; refer to section 3.3.2 Current Land Use). The coastal lowland areas in the watershed are dominated by agricultural use, primarily for dairy pastures (~2% of the total watershed area), but development, mostly in and around the City of Tillamook, also accounts for about 2% of the total watershed area (Map 9 and Table 5).

Additionally, recreation has long been an important and valuable output of the Tillamook State Forest and the Wilson River watershed provides the majority of opportunities compared to the rest of the forest. Traditional pursuits like hunting, camping and fishing have continued to draw visitors, while new uses have rapidly increased in intensity and distribution. That trend has been fueled by population growth, change in technology and the development of road access across the forest from salvage and reforestation activities. For more detailed land use discussions, refer to section 3.3 – Social Context, 3.5 – Forest Management, 6.7 – Recreational Impacts on Riparian Vegetation – Direct and Indirect Effects, and 7.5 – Recreation-Related Issues [on sediment]).

Although a variety of non-salmonid fishes are known to occur within the basin, salmonids are of primary importance to managers as they provide substantial ecological, economic, and cultural benefits for the citizens of Oregon and are often used as indicator species of overall aquatic health (refer to section 3.2.3 Fish and Chapter 9 Fish and Fish Habitat). A variety of anadromous salmonid species are known to occur within the Wilson River watershed, including chum (*Oncorhynchus keta*; Map 5), Chinook (*O. tshawytscha*; Map 6), and coho salmon (*O. kisutch*; Map 7), steelhead trout (*O. mykiss*; Map 8), and both resident and sea-run forms of cutthroat trout (*O. clarki*, no map available). While their life histories and habitat requirements differ, all are freshwater obligate spawners and spend portions of their life in freshwater, estuarine, and marine (except for resident cutthroat trout) environments before completing their life cycle in their natal streams. For a detailed list of non-salmonid species known to occur with in Tillamook Bay and the Wilson River, see the Tillamook Bay National Estuary Project (TBNEP; 1998) and E&S Environmental Chemistry (2001) reports (also summarized in Chapter 9 Fish and Fish Habitat). For a more detailed look at historic and current salmonid abundance and distributions, refer to Chapter 9 Fish and Fish Habitat.

1.3 Stream Channel Modification

The majority of the known channel modifications within the Wilson River watershed are located off of ODF lands, primarily in the lower tidewater portion of the watershed and along the mainstem Wilson River. Log drives ended approximately 100 years ago, and a certain amount of passive recovery is expected to have occurred since then.

Only ten locations of direct channel modifications were found on ODF lands during recent road surveys, and collectively these modifications impact less than one mile of stream. Based on these findings it appears that the legacy road system is having only minor impacts on current channel function.

Current levels of stream channel modification in the Wilson River watershed were compared to the findings from nearby watersheds where ODF has performed watershed analysis. Four ODF Watershed Analyses[1] were reviewed; the Elliot State Forest, the Trask River, Miami River and the Upper Nehalem River.

Results from the Elliott State Forest Analysis were reported as lengths of road within 100 foot of channels, however, road fills within valley bottoms were not identified separately. Similarly, in the Trask Watershed Analysis, the miles of roads in "Valley" topographic positions were reported, but not road fills directly impinging on streams. Consequently, results from these two analyses are not directly comparable with the results from the Wilson River.

A total of three miles of canyon fill and four miles of channel fill were identified within the Miami Watershed Analysis area (Table 1). Canyon fill and channel fill were attributes identified as having been collected in the Upper Nehalem Watershed Analysis, however, none of the summary tables reported any mileage within these two classes. Consequently, they are not included here.

Table 1. Comparison of channel modifications on ODF within the Wilson River and adjacent watersheds. Density of disturbance is the total of canyon fill and channel fill divided by area.

Watershed	Area (mi^2) ODF lands	Canyon Fill (miles)	Channel Fill (miles)	Density of disturbance (mi / mi^2)
Miami River	24.8	3.0	4.0	0.282
Wilson River	152.7	0.3	0.4	0.005

Given these results, current conditions within the Wilson River watershed compare favorably to the Miami watershed. Road building practices have modified channels, to a slight degree, on ODF lands. Management recommendations for ODF lands include:

- Remove the few existing areas of canyon and channel fill that have been identified from the road surveys (This is a long-term strategy. There are other road-related issues that take precedent over this and are discussed later in the document)

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[1] http://www.oregon.gov/ODF/STATE_FORESTS/watershed.shtml

- Avoid future road alignments that would result in constrictions to channels and channel migration zones.

For a more detailed review of stream channels and channel modifications in the Wilson River watershed, refer to Chapter 4 Stream Channels and Channel Modification.

1.4 Hydrology and Water Use

1.4.1 Land Use Effects

The Distributed Hydrology Soil Vegetation Model (DHSVM) was used to evaluate the effects of vegetation and road conditions on peak and low flow magnitudes at the outlets of the sixth-field subwatersheds, at the location of the Wilson River stream gage, and at the outlets of ten randomly selected small headwater watersheds.

The initial model was run using only historic vegetation (no roads). The resultant values were used as the baseline against which all other model iterations were compared. The fifteen largest independent peak flow events (12 with an estimated recurrence interval [RI] of ≤ 2 years; 2 with an approximate RI of 2-5 years; and one with an approximate RI of 100 years) were used to evaluate management impacts.

Model results suggest that peak flow conditions due to 1) current vegetation conditions, 2) current road densities, and 3) road drainage conditions are not significantly different than under the baseline condition. Vegetation changes and the addition of roads appear to result in an increase of 1% or less over the baseline peak flow condition. No correlation was seen in the results between percent change in peak flow value and flood size.

In addition, we modeled streamflow for a post-fire scenario that considered the extent of historic wildfires in the Wilson River watershed that occurred in the 1940’s and 1950’s. Changes relative to historic conditions generally showed less than ten-percent increases in peak flows under post-fire conditions. There were, however, individual storm events that had modeled increases in peak flow magnitude of 40% or more.

Model results indicate that hydrologic response is not constant across all storm events (i.e., percent change varied widely by individual storm). Hydrologic response varies in response to antecedent conditions, within-storm weather patterns, and position of roads and harvest units within the landscape. For example, road location may affect the volume of water intercepted by road ditches, and the extent to which peak flow timing may be changed. LaMarche and Lettenmaier (1998) theorize that although ridgetop roads may have the greatest potential to change the timing of flows (flow that would have traveled a relatively long distance as slower subsurface flow would now travel as quicker surface flow), the volume of flow intercepted is relatively small because of the small upslope contributing area. Conversely, valley bottom roads have the ability to capture large volumes of flow, but the timing change is small because of the close proximity of these roads to streams. Midslope roads may have the biggest effect on peak streamflows because they capture moderately large volumes of water and the timing change may be significant.

Model results for the low flow period (August) also show only minor differences between the baseline and current conditions. Mean August flows increase slightly over the reference condition, probably in response to lower evapotranspirative (ET) losses from current vegetation and from roaded areas.

Given these results, management related hydrologic impacts are rated as having a low impact on proper function of aquatic systems throughout the Wilson River watershed. Furthermore, given that future harvest intensity is unlikely to exceed present practices, and that road construction and maintenance standards are likely to reduce hydrologic connectivity, it is likely that planned management activities and restoration projects will have a positive or neutral effect on hydrologic response over time.

Management recommendations for ODF lands include:

- Disconnect those road drainage segments that have been identified as being hydrologically connected to the stream network

- Design future road drainage systems in such a way as to avoid hydrologic connectivity of the road drainage structures to the channel network

- Periodically (on a 5-10 year interval) re-evaluate hydrologic conditions at the sixth-field subwatershed level using DHSVM or similar model.

Confidence in this rating is high given the existence of good road survey information and the extensive modeling exercises undertaken as part of this assessment.

For a more detailed review of land use effects in the Wilson River watershed, refer to section 5.3 Land Use Effects on Peak and Low Flows.

1.4.2 Water Uses

The majority (~70%) of water appropriated in the Wilson River watershed is used for irrigation. The majority of this is diverted in the downstream end of the watershed (below the confluence with the Little North Fork), and is used to irrigate farmland in the Lower Wilson River subwatershed and in the adjacent Trask River watershed. The second largest use for appropriated water (~30%) is for municipal and domestic water supplies, which is also withdrawn primarily in the Lower Wilson River subwatershed.

Consumptive water uses in the Wilson River watershed are relatively low (1-3% of natural flow) as compared to the total water available in any given month. Instream flow rights in the mainstem Wilson and principal tributaries, although they have a late priority date, should be adequate in maintaining ample flows needed by salmonids and other aquatic species, particularly on ODF lands, which are located upstream of the major water withdrawal points. No management changes to address water use concerns are recommended on ODF lands.

For a more detailed review of water uses in the Wilson River watershed, refer to section 5.4 DHSVM Future Modeling.

1.5 Riparian and Wetlands

The riparian analysis area is focused on the stream bank (0 - ~35 ft) and inner riparian zones (~35 – 100 ft) for ODF lands only. The ~35 foot streambank zone presented here is slightly larger than the 25 foot streambank zone buffer, as described in the Forest Management Plan (FMP). This is due to the ground-truth sampling, where variable plot radius occasionally exceeded the 25 feet from the stream edge. For practical considerations, these zones approximate the near-stream outer stream gradations for the riparian zone. Delineations and vegetation classifications followed a species-size-density code (FPS code) that was interpreted from aerial photographs; a subset of the dominant vegetation types were field sampled for this analysis. For more detailed discussions, refer to Chapter 6 Riparian and Wetlands.

1.5.1 Riparian Composition and Structure

The Wilson River watershed has ~11% land area in the 100 ft riparian buffer zones around the perennial and fish bearing streams, which is a considerable land area for potential management. The major vegetation types on ODF lands included 5,967 acres (61%) in mixed hardwood/conifer types, 2,339 acres (24%) in hardwood dominated sites, and 1,157 acres (12%) dominated by conifers. Stand structure field data were sampled for areas representing 92% of the total riparian land area on ODF lands.

At the landscape scale, stand structure and composition has been most influenced by a set of complete stand replacement events (fires and salvage logging) of the 1950's and earlier. The majority stand age is considered to be approximately 55 years since stand replacement, although recent harvest in upland areas has initiated younger stands. Overall, stands are relatively homogeneous in stand structure, though they have diverse assemblages of species.

For more detailed discussions, refer to section 6.1 Riparian Composition and Structure.

1.5.2 Riparian Vegetation Dynamics: A No Management Scenario

A 100 year growth time series is presented for the sampled riparian types for each of the subwatersheds, assuming a no management and no disturbance scenario. Within this time series, conifers do not appear to become dominant the canopy strata for any of the subwatersheds. The proportion (relative density) of conifers and hardwoods in the system are dependant upon model assumptions, though increased ("forced") regeneration in the closed canopy environment favors the establishment of slow-growing, shade tolerant species (e.g. hemlock), with differentiation allowing for conifer dominance in the second 50-year time frame. Though conifers will eventually gain dominance in numbers and proportional abundances to hardwoods, the functional components of the canopy will favor hardwoods for a period longer than 100 years.

The models suggest that conifers are not recruiting to the canopy through time. Rates of conifer tree recruitment to the ≥14 inch size class decline through time, mostly due to similar and steep declines in conifer regeneration, especially following 2036 (30 year step). This loss of conifer recruitment will potentially cause a lag in conifer recruitment to the canopy strata, which is likely to extend beyond 100 years. These observations are most likely due to the relatively early phase of succession, following the stand-replacement fire events and salvage logging following the Tillamook Burns. The observed lags in conifer recruitment to the canopy (at subwatershed scales, and for the majority of the Wilson watershed as a whole) are characteristic of this early phase of succession and will have direct implications on the *type* of wood to be recruited to the stream system over time. The current projections suggest the majority of the available wood recruiting to the stream channel will be in hardwood material, not conifer. This does not include stochastic factors (landslides, etc), but indicates a relatively low probability for direct riparian recruitment of conifer material through time (beyond 100 years).

Though no shifts in species composition are projected to occur, tree sizes are projected to increase in diameter through time. The stand-level quadratic mean diameter (QMD) of the canopy strata are increasing in size though the 100-year model run for both hardwoods and conifers. Stands are slowly becoming multi-layered, though recruitment to the canopy classes generally declines with the assumed regeneration component and shade/ competitive factors that favor slow-growing (shade tolerant) conifers. Hence, the stand structure resembles a sparse but large-diameter overstory, with higher proportions of shorter, small-diameter trees (mostly hardwoods in early phases of the run, shifting to conifers in later years) in the lowest forested strata. Mid-canopy trees (≥14 inches DBH) are notably of low density in later model years.

Mortality rates decline through time, resulting in fewer downed trees per acre. Sharp declines in mortality of the ≥14 inch size class begin after 2036. These declines persist for the remainder of the model run, and the projected rates suggest they will continue to decline at a rate of 10-20% per decade for more than 100 years. This has direct implications for large wood (LW) recruitment to the stream channel.

For more detailed discussions, refer to section 6.2 Potential Future Conditions.

1.5.3 Large Wood Recruitment and Wood Recruitment Budget

Large wood recruitment, as compared with ODFW reference reach metrics (i.e., Aquatic Inventories Project reference reaches), appear to be in the lower end of the moderate range (i.e., lower end of the middle 50% of the ODFW reference reach data) for standing conifers >20 and >35 inches DBH after 2016. However, conifer tree recruitment to these size classes sharply declines, and is projected to decline for a period extending beyond 100 years. Though large standing trees are projected to exist, there appears to be a few trees recruited to the larger size classes through time, indicating a long-term lag in large-diameter trees. As such, the standing tree ODFW metrics are not expected to improve over the 100-year timeframe.

The size of wood that can resist fluvial export and serve as a habitat-forming element (e.g., creating forced pools) increases with increasing channel size. Based on modeled tree mortality rates, wood recruitment will provide sufficient functional wood to meet regional benchmarks (e.g., exceeding median abundance values for coastal reference reaches) for small streams, those with active channel widths less than 15 meters (50 ft). Functional wood abundance modeled for larger streams, those greater than 15 m wide, although increasing over time, remains low throughout the 100-year simulation period.

Modeled wood abundances generally follow changing riparian mortality rates, with some lag reflecting the persistence of wood pieces as they decay. Abundances of smaller pieces (e.g., diameter < 24 in) peak around simulation year 2050 and decline over the remainder of the simulation. Abundances of larger pieces (> 24 in) slowly increase over time. Hardwoods account for more than half of all wood in the channel, although larger pieces (>24 in) come predominantly from conifers.

Landslides and debris flows form an important mechanism for recruitment of wood for many channel reaches in the watershed. The likelihood for landslide or debris-flow deposition varies reach-by-reach (Map 25), depending primarily on the location of tributary, debris-flow-prone headwater channels. Wood from landsliding and debris flow sources plays important geomorphic (e.g., sediment storage) and ecologic roles for all channels where these processes occur, but from a management context, these upslope sources of wood are particularly important for reaches where riparian areas lack functionally sized wood. Stand-growth and wood recruitment modeling suggest that riparian sources of functional and jam-forming wood are and will be lacking primarily along larger channels. Regional surveys indicate that piece abundances exceeding about 20 pieces per 100 m (330 feet) fall in the high range; under unmanaged conditions, riparian recruitment is expected to provide this level only for channels less than about 10 m (33ft) in width. Fewer than 8 pieces per 100 m fall in the low range, a level predicted for nearly all channels greater than about 15 m (~50ft) in width. Channels greater than 10 to 15-meters in width also provide the primary locations for high intrinsic habitat potential and current fish use (Map 37). Upslope sources of wood to these channels (Maps 38 and 39) merit particular consideration for leave areas and headwater management zones to promote future availability of large wood. Likewise, restoration efforts involving wood placement should be focused on reaches lacking potential for debris-flow recruitment.

For more detailed discussions, refer to section 6.2.2 Large Wood Recruitment and section 6.2.3 Stand Modeling of Large Wood Recruitment.

1.5.4 Wetlands, Ponds and Lakes: Condition and Location

A total of 88.8 acres of wetlands, ponds and lakes were identified. Conditions are generally good within ODF lands. Road influence and neighboring harvest may cause increased siltation in some areas, though there appears to be relatively intact riparian buffers available to slow sediment delivery. Though not directly measured, effects of recreational uses, especially OHV uses, have had a diminishing effect on some of the wetland buffer areas observed. Development of Best Management Practices (BMPs) to curtail potential uses in these buffer zones is recommended. Examples include placement of downed wood or other obstructions to discourage use at the wetland edge. A composite GIS layer of wetland, pond and lakes locations is provided in the digital appendix.

For more detailed discussions, refer to section 6.4 Wetlands, Ponds and Lakes – Condition and Location.

1.5.5 Noxious and Non-Native Weed Species

Japanese knotweed is a high priority for removal in the system. Locations near the Idiot Creek Bridge are likely to provide germplasm for infection downstream. Knotweed is well established in the lower reaches of the Wilson River, though not on ODF lands. Constant monitoring is required to track even small infestations of knotweed. Removal and location identification of upstream knotweed populations should be considered a high priority for restoration and enhancement. Other species, including garlic mustard, Scotch broom and Himalayan blackberry are of growing concern in the watershed. Garlic mustard infestations have been recorded in Gales Creek, located immediately outside the watershed boundary and are of concern for entry and establishment in the watershed. Best Management Practices (BMPs) associated with recreational uses, including washdowns of vehicles prior to trail entry, will help to mitigate weed spread. Collaborative development of BMPs with forest users should be considered to minimize the recreational impact on the native community types.

For more detailed discussions, refer to section 6.5 Noxious and Non-native Weed Species.

1.5.6 Riparian Restoration and Enhancement Opportunities

Several factors are to be considered in the enhancement and restoration of the riparian zones. The long-term outlook for species composition and structural changes, excluding stochastic factors (landslides, etc) indicate few conifers will recruit to the canopy through time. This has direct implications for wood recruitment in durable conifer material to the stream system from the immediate riparian zone, as measured from standing wood within the 100 foot buffers. In addition, a no-management scenario suggests there will be a substantial lag in canopy recruitment by both conifer and hardwoods through time, which limits the population potentials of all larger-diameter wood material (short lived and durable) in the standing stock, and ultimately for interaction with the stream channel.

This watershed analysis produced several key findings involving the riparian zone and the *ecosystem service* dynamics expected through time. The majority of these findings were based upon a map and subsequent ground-truth sampling based on aerial photography, coarse vegetation types, and relatively large stands. The current riparian vegetation map served as a very refined effort to ascertain the watershed and subwatershed level trends in species composition, structure, large wood recruitment, stream shading, and other intrinsic characteristics of the system. It is important to note that the data do not provide enough resolution to assign site-specific silvicultural treatments, nor are they sufficient to evaluate the potential effects of those treatments on large wood, shade, and other ecosystem services to the stream system. Despite this level of resolution, however, 1) the data were sufficient for developing "*general*" silvicultural prescriptions based upon the current and projected stand conditions (section 6.3.2.1.1 – Recommended (General) Silvicultural Treatments and Map 63) and 2) the acquisition and use of high resolution LiDAR data (Light Detection and Ranging; also called ALSM, Airborne Laser Swath Mapping) may help resource managers develop "site-specific" silvicultural treatments (and ODF is in process of obtaining LiDAR data for some districts). For riparian zones, LiDAR provides unique opportunities to identify riparian features, characterize, type, highlight "manageable units" to evaluate potential management options and target specific locations for riparian enhancement.

For more detailed discussions, refer to section 6.3 – Riparian Enhancement Opportunities.

1.5.7 Recreational Impacts

Recreational impacts on riparian vegetation were assessed using two different methods; one utilizing ODF's dispersed camping site inventory, the other field assessment of a subsample of ODF's dispersed camping site inventory. Sample sites were chosen to represent sites along tributaries in upper, middle and lower watersheds as well as along the main stem.

Data from ODF's dispersed inventory indicate that 33 sites (17.8%) are within 25 feet of water in the stream bank zone (SBZ). Unfortunately, ODF data were inadequate for determining how many sites are 25-100 feet from water in the inner riparian zone (IRZ). More than 62% of the sites were found to have moderate, high or very high impacts (See Map 42). The impact area in most sites was less than 1,000 square feet but there were a few sites that had very large impact areas of up to 10,000 square feet.

In contrast to ODF findings, results from our follow-up field assessment using a subsample of ODF's inventory indicate that 78% of the sites fell within the SBZ, 22% fell within the IRZ. Overall, the majority of the sites had bare soils with widespread and exposed root systems, or with trees showing visible signs of reduced vigor or mortality. In addition, the field assessment found that disturbance areas were larger than the ODF inventory data indicated. For example, less than 1% of the sites had disturbance areas less than 250 square feet, 33% had between 250-1,000 square feet, 39% had between 1,000-10,000 square feet and 22% had greater 10,000 square feet of disturbed area. The total condition class (i.e., all factors considered) at the sites ranged from 2-10 (low impact to severe impacts), and averaged 7.4 on this scale[2]. Observations of human impacts included direct erosion to the stream channel or wetlands, severe tree damage or mortality, soil compaction, and multiple user-defined OHV trails leading directly to stream channels.

Key recommendations for reducing the riparian impacts from recreation include; buffer camps from the SBZ, close and upgrade dispersed camps and removal of unrestricted OHV use from IRZ. In addition, we provide an array of potential management actions to recoup costs, collect use data, monitor impacts and modify user behaviors.

For more detailed discussions, including methodologies, results and recommendations, refer to section 6.7 Recreational Impacts on Riparian Vegetation – Direct and Indirect Effects.

1.6 Sediment Sources

1.6.1 Current and Potential Sources and Erosional Areas

Surface erosion of undisturbed soils is not an issue of concern. The soils are sufficiently permeable that surface runoff (and associated surface erosion) occur only where soils have been compacted or where drainage from road surfaces is discharged. Erosion from roads and off-highway vehicle (OHV) tracks is addressed separately, below.

1.6.2 Landslide-Prone Slopes and Debris-Flow-Prone Channels

Landslides formed by the sudden failure of water-saturated soils on steep slopes are a natural process in this watershed and provide a significant source of sediment and wood to stream channels. Steep, landslide-prone slopes are abundant (Map 44), both in headwall areas and along channel-adjacent inner gorges. Shallow-rapid landslides occur on both planar and concave (bedrock hollow) slope forms. Susceptibility to landsliding can be increased by removal of vegetation (timber harvest) and by road or skid trail rerouting and concentration of hillslope drainage. These landslides incorporate both down and standing trees; thus source areas for these landslides also serve as upslope source areas for wood to fish-bearing channels (Map 26).

Many shallow-rapid landslides deposit into small headwater (Type N) channels; these channels then form long-term storage reservoirs for sediment and wood. In some cases, shallow-rapid landslides evolve into debris flows, which can travel long distances through headwater channels, scouring the accumulated material

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[2] Adapted from Cole 1989.

for re-deposition in larger, fish-bearing channels downstream. Predominant source areas for these debris flows are identified in Map 27, and the headwater channels most likely to serve as debris-flow corridors to fish-bearing streams are identified in Map 29. Sediment from landsliding is not currently considered a limiting factor for fish productivity in this watershed; however, availability of large wood is and will continue to be limiting for many streams, so that efforts to preserve and promote availability of large wood from these upslope sources can have significant positive effects over time.

In upslope management, it is important to consider the likely effects of downstream debris-flow deposition. As discussed in Section 1.5.3 (Large Wood Recruitment and Wood Recruitment Budget), source areas to channels with high potential for fish use and low potential for riparian sources of large wood merit special consideration for leave areas and riparian management to enhance large-tree abundance. These areas are identified in Maps 38.

Mainstem channels ranging from about 15 – 20 m (50 – 66 ft) width are sufficiently large and steep that storm discharges can entrain debris flows and form debris-laden floods (Map 28). These sediment- and wood-rich floods can severely damage aquatic habitat and riparian vegetation. Unfortunately, many of the channels most susceptible to debris-laden floods are also those with high potential for fish use (Map 37). Although this is a natural process, perhaps enhanced by the lack of large trees along debris-flow corridors and in riparian zones, it is important to recognize the potential for debris-laden floods to destroy habitat gained through conservation and restoration efforts within a sub-basin. The stochastic nature of debris-flow occurrence makes it unlikely that all sub-basins would be equally affected by debris-laden floods during any major storm event. It is important, therefore, that conservation and restoration efforts be dispersed and not concentrated in any single sub-basin.

For more detailed discussions, refer to sections 7.1 – Slope Instability and 7.2 – Debris Flow-Prone Channels.

1.6.3 Deep-seated Landslides

Large, deep-seated landslides (earthflows) are present in the basin, but are generally inactive or only slow moving and are not an important source of sediment to channels. However, valley morphology associated with these landslides does affect channel profiles, with lower channel gradients found adjacent and upstream of these features. Thus large deep-seated slides could contribute to habitat formation in certain areas. For example, one or more large, ancient deep-seated landslides have created low channel gradients and wide valley floors in the lower part of the Devil's Lake Fork, creating highly rated coho habitat.

Another type of deep-seated failure occurs on relatively steep slopes and may involve tens of acres and occur at depths of 10 meters or more. Driven by highly weathered and weakened bedrock, the deep-seated slides are mostly unpredictable with the exception of mapping old landslide deposits along valley floors. A notable example of this type of deep seated landsliding occurred in the West Fork of the North Fork of the Wilson during the large storm in December 2007. Sediment volumes of tens to hundreds of thousands of cubic meters from deep-seated slides (equivalent to tens to hundreds of debris flows in headwater channels) completely overwhelmed the valley floor morphology for many kilometers downstream of the events. Because of their depth, these types of failures appear to be unrelated to timber harvests.

For more detailed discussions, refer to section 7.3 – Deep-seated Landslides.

1.6.4 Road-Related Issues

This analysis evaluated forest roads in the Wilson River watershed using a survey protocol developed by ODF to rapidly assess the risk roads pose to aquatic resources. The survey, conducted in 2006, found that culverts at stream crossings are one of the most important road features in terms of the need for ongoing inspection and repair. Severe storms in the winter of 2006 and 2007 caused failure at many crossings and illustrated the vulnerable nature of stream crossings. Based on survey data, we found many stream crossings with a high wash-out potential including many on blocked roads that are not routinely inspected. We have identified stream crossings with high washout potential and in need of servicing. These crossings are listed in Table 36 (on blocked roads) and Table 37 (on open roads). Managers need to inspect these crossings to determine if the current structure needs to be removed and replaced. Inspection of critical stream crossings should occur during high flow events. Repairs should include removing debris, constructing dips, and constructing berms in the ditch at the lower spot on the stream crossing fill.

Surveyors also rated fish passage at all stream crossings. We found 28 stream crossings that blocked fish passage. Those stream crossings are listed in Table 38 and are in need of inspection and repair.

Hydrologic connection on both open and blocked roads is relatively low. Open roads have a higher percentage of hydrologically connected segments than blocked roads. Managers should evaluate hydrologic connectivity while upgrading and repairing roads. Significant storms may change the hydrologic connectivity of a road. Therefore, monitoring roads after storms to determine hydrologic connectivity is critical.

Considering hydrologic connectivity alone does not tell the complete story of forest roads and sediment delivery to streams. We found that while hydrologic connection of blocked roads was relatively low, the majority of hydrologically connected blocked roads actively loaded sediment to streams. Segments identified as actively loading sediment to streams are identified in Appendix X – List of Priority Inspection Roads. These roads should be inspected and repaired if needed.

The proportion of open roads in higher resource risk critical locations in the Wilson River watershed is similar to other nearby watersheds. The percentage of blocked road segments determined to have cut and fill slides (i.e., high slope severity) was 10 times greater than the percentage of cut and fill slides for open road segments. Blocked roads were determined to have 3 times more of their total length that contained fill slides than did open roads (Table 30). Table 42 identifies specific road segments that may pose a long-term risk where slope severity intersects with high potential for landslide delivery to fish bearing streams. These road segments should be inspected to determine if maintenance is needed to prevent future delivery to fish-bearing streams.

Open roads in the Wilson River watershed typically have stable prisms. Blocked roads are less stable and pose a greater risk to the aquatic resource. (Table 32). Road segments that are unstable and have a high potential for landslide delivery to fish-bearing streams should be inspected in order to prevent future delivery to fish bearing streams (Section 7.4.9 Long-term Risk Analysis).

In all, the road system has been designed to limit impacts to aquatic resources. Yet, problems persist, especially at stream crossings where wash out potential is high and where fish passage is blocked. The data summarized in this analysis directs managers to road segments that are a high priority for inspection, repair or removal.

For more detailed discussions, refer to section 7.4 – Road-Related Issues (on sediment supply and delivery).

1.6.5 Recreation-Related Issues

Two field-based methods and an analysis of an existing ODF trail inventory database were used to assess the extent to which OHV trails and other recreation activities impact stream sedimentation and water quality, hydrologic connectivity, and erosion conditions, as well as the proportion of OHV trails located next to streams and their associated washout risks. The road/trail survey conducted by Duck Creek Associates in 2006 noted a variety of conditions on approximately 42 miles of trails while an additional follow-up field sample of 13 trails quantified the extent of soil loss and updated the site conditions from ODF's trail inventory database.

Field assessment results indicate that sedimentation is most acute where eroding trails intersect adjacent streams or where trails intersect road drainage systems. ODF estimates that the Wilson River watershed has approximately 150 miles of designated trails but not all undesignated trails have been systematically surveyed except where they intersect roads. Of the trails surveyed (42.7 total miles), 2.1 % had hydrologic connectivity and 2.1 % ran parallel to streams (Map 56). Data were unavailable for determining the percentage of other unsurveyed trails that were connected or parallel to streams. Data from a field assessment of hydrologically connected trails indicate a high likelihood of water quality effect on trail-stream intersections that have had no mitigating trail drainage engineering, bridging, and/or that exhibit trail grade/slope alignment in excess of trail standard maximums. The majority of hydrologically connected trails sampled at trail-road and trail stream intersections violated accepted trail design recommended maximums. An additional field assessment of erosion and site conditions along OHV trails revealed additional highly eroding hydrologically connected trails, suggesting a greater degree of erosion than previously indicated in either the ODF trail inventory database or the Duck Creek Associates road/trail survey. Many trails have steep grades, fall line trail alignment and poor drainage, and, with high use, result in active erosion conditions on most trail surfaces.

Of the designated trails surveyed during the road/trail survey (2006), approximately 3.1 miles were located parallel to streams and hydrologically connected (Map 56). Extrapolated to the entire watershed, 6.3 miles of designated trails are parallel to streams and hydrologically connected. Additionally, 47.3% of trail-stream crossings were found to have a high washout potential. Undesignated trails, however, are more likely to cross streams but no data for this type of trail is available for the Wilson River watershed. Cross sectional area (CSA) measures of soil loss and disturbance area over a combined sample trail length of 3,870 feet revealed an average soil loss of 1,157 cubic yards per mile of trail (all trail types combined). Additionally, 33 dispersed recreation sites were found to be within 25 feet of streams (See Map 43) and 62% exhibited moderate to very high water quality impacts. Sites with complete vegetation loss of greater than 1,000 square feet all occur on the Forest Grove (FG) District (road numbers FG088, FG101, FG060, FG073, FG092, and FG100 in the Duck Creek Associates road database). Two sites had greater than 10,000 square feet of vegetation loss (road numbers FG029 and FG039) and exhibited severe soil exposure and compaction.

Overall, trails in the watershed exhibit conditions that are having impacts on water quality and sedimentation rates. Of the 42 miles assessed during the road/trail survey (2006), 28% exhibited sedimentation risks. Scaled up to the watershed, this would indicate that as much as 41 miles of the 150 mile designated OHV system pose sedimentation risks. Of the hydrologically connected trail segments assessed during a field survey, extremely high levels of disturbance and erosion were recorded. Nearly half of the trails had moderate to high stream crossing washout potential and exhibited key washout risk indicators. For example, 77% of trail segments ran down the fall line and 84% had trail grades that exceeded 11 degrees. We recommend that several key washout risk indicators be included in future monitoring activities and when determining priority for corrective action on trail segments.

In general, the ODF dispersed camping inventory database provided good baseline data on site conditions but lacked quantifiable measures useful for determining specific site by site priority. We provide a range of acceptable standards and actions to guide recreation managers and recommendations for upgrading the standard ODF recreation inventory form, including the addition of numerical values based on accepted standard campsite monitoring protocols[3]. Finally, the effectiveness of recent (post-1994) upgrades to OHV sites, dispersed camping sites, and other recreational sites has been mixed. The majority of designated campgrounds, OHV sites and trails have been successfully upgraded, while other undesignated trails and dispersed sites are not within the capacity of recreation budgets to upgrade or effectively close. OHV trail upgrade and maintenance capacity is limited by heavy year-round use, too many events, and eroding trails and sites and we provide recommendations for addressing these concerns.

Key recommendations for reducing the sedimentation impacts from recreation include; removal of unrestricted OHV use from the inner riparian zone (IRZ), and relocation of trails from steep slopes and from slope alignments that produce sediment delivery to streams and road drainage systems. In addition an array of management actions to improve inventory of trail system, monitor impacts and modify user behaviors.

For more detailed discussions, refer to section 7.5 – Recreation-Related Issues (to sediment delivery and supply).

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[3] Wilderness Campsite Monitoring Methods: A Sourcebook. David N. Cole, GTR-INT-259, April 1989.

1.7 Water Quality

1.7.1 Water Quality Criteria, Limited Sections and Status

Beneficial water uses in the Wilson River watershed include maintenance of estuarine waters, support of cold-water aquatic life, and support of salmon and steelhead spawning. Current water quality limitations identified by the Oregon Department of Environmental Quality (ODEQ) in the Wilson River are due to low dissolved oxygen, probably related to high water temperatures, for the period September 1 - June 15 in the Wilson River mainstem from river mile 5.8 to 27.2 (approximately 4 miles downstream of the confluence with Little North Fork to Lee's Camp).

For more discussions, refer to section 8.2 Water Quality Criteria, Limited Sections, and Status.

1.7.2 Current and Potential Shade Levels

Stream shading was estimated as the combined function of riparian vegetation, topography, and active channel widths (i.e. effective shade) for current conditions (year 2006) and two future time periods (2056 and 2106) along the 12 principal streams within the Wilson River watershed. Future shade levels were based on riparian stand modeling, assuming no active management of riparian stands. Shade levels for all stands generally increase along the principal streams for the 0-50 year time horizon, but decrease over the 0-100 year time horizon as stands mature and canopy conditions begin to break up. Management recommendations for ODF lands include:

- Protect and allow for further passive restoration of those riparian areas currently offering high shade levels
- Evaluate areas where current shade levels are low and determine if active restoration (e.g., removal of riparian roads; planting of low-stocked stands) is warranted
- Consider more aggressive stand treatments for those riparian stands where long-term shade levels are predicted to <u>decrease</u> in the absence of active management.

For more detailed discussions, refer to section 8.3 Stream Shading.

1.7.3 Stream Temperatures, Reasonable Achievable and Compared to Potential Levels

Regression analysis was used to determine the relationship between the annual maximum seven-day moving average of the daily maximum water temperature ($\mathbf{T}_{\mathbf{max}}$) and the environmental variables most likely to affect water temperatures. Regression results were robust, explaining 81% of the observed variation. Effective shade (a combination of topographic and riparian shade) showed the strongest correlation with T_{max}.

Effective shade values for the 2056 and 2106 modeled time periods were used in the Wilson River regression model to evaluate likely future stream temperature levels along the principal streams in the Wilson River watershed. Results indicate that in the mid-term (i.e., 50-year time horizon) shade conditions, and associated stream temperatures, will experience an improving trend, as current stands mature, and riparian shade generally increases. However, over the longer term (0-100 years) we can expect to see shade conditions deteriorate, and temperatures increase, as stands break up and shade conditions decrease.

For more detailed discussions, refer to section 8.4 – Stream Temperatures, Reasonable Achievable and Compared to Potential Levels.

1.7.4 Stream Temperature Comparison with Adjacent Basins

We evaluated how water temperatures at sites in the Wilson River watershed compared to other nearby basins with similar environmental conditions. The adjacent Trask River watershed was most similar to the Wilson in terms of principal lithologies, size, and (given its adjacency to the Wilson) climate. Results of the assessment suggest that stream temperatures in the Trask are lower (by about 2 degrees Fahrenheit) than in the Wilson, at least up to ~20 miles from the drainage divide. Possible explanations for relatively lower temperatures in the Trask as compared to the Wilson include differences in riparian shading, due to more aggressive riparian harvest and/or greater riparian disturbance (e.g., flood damage); and cool-water reservoir releases (i.e., Barney Reservoir on the Middle Fork of the North Fork Trask River).

For more detailed discussions, refer to section 8.5 – Stream Temperature Comparison with Adjacent Basins.

1.7.5 Limiting Factors

We used the ODEQ "core cold water habitat use" criterion of T_{max} less than or equal to 60.8 degrees Fahrenheit (16.0 degrees Celsius)[4] as the metric to evaluate to what extent stream temperatures and/or shade conditions are limiting the achievement of properly functioning condition in the Wilson River watershed. All of the principal streams within the Wilson River watershed are designated as core cold water habitat[5]. Many of the principal streams are also designated as salmon and steelhead spawning use[6] as well, however, the seasons that this designation apply to are outside of the July and August time period considered for this analysis.

Results, presented for two time periods (0-50 years in the future, and 0-100 years), indicate that in the mid-term (i.e., 50-year time horizon) shade conditions, and associated stream temperatures, will experience an improving trend, as current stands mature, and riparian shade generally increases. However, over the longer term (0-100 years) we can expect to see shade conditions deteriorate, and temperatures increase, as stands break up and shade conditions decrease (see the discussion on lack of canopy recruitment in Chapter 6 – Riparian and Wetlands, section 6.2 – Potential Future Conditions).

For more detailed discussions, refer to section 8.6 – Limiting Factors (to water quality).

1.8 Fish and Fish Habitat

1.8.1 Species Information

As of December 2007, none of the anadromous salmonid species inhabiting the Wilson River watershed are currently listed as *Threatened* or *Endangered* under the federal Endangered Species Act (ESA; refer to Table 63 in section 9.3 Native and Introduced Salmonids). Oregon coastal coho, however, are likely to be re-listed by NOAA Fisheries in early 2008 as *Threatened*. Numerous species/stocks, however, including several non-salmonids, are listed by the State as *Sensitive/Vulnerable* or *Sensitive/Critical* (Table 63). While no introduced salmonids, except the summer steelhead stock/race, are known to occur in the Wilson River, information pertaining to the introduction and establishment of non-salmonid species is severely lacking. Additionally, information pertaining to native non-salmonid abundance and distribution is non-existent.

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[4] http://arcweb.sos.state.or.us/rules/OARs_300/OAR_340/340_041.html
[5] http://www.deq.state.or.us/wq/rules/div041/fufigures/figure230a.pdf
[6] http://www.deq.state.or.us/wq/rules/div041/fufigures/figure230b.pdf

According to a recent study by the ODFW (Kavanagh et al. 2005), historic salmonid distributions (although somewhat speculative in nature) are likely very similar to their current distributions. Additionally, current abundances, with the exception of fall Chinook salmon, are likely severely depressed compared to their historic (pre-European settlement) abundances. Indeed, resting hole and spawning counts from the past 50+ years, with few exceptions, generally indicate decreasing abundances coupled with high variability, underscoring the tenuous nature of many of these stocks/runs. Recent data (e.g., <15 years), however, may indicate that coho and Spring Chinook salmon populations are on the rebound but inter-annual variation and the short duration of the recent trend makes interpretation and conclusion problematic (refer to sections 9.7 – Historic Salmonid Abundance and 9.8 – Current Salmonid Abundance).

1.8.2 Instream Large Wood

Since European settlement, fish habitats in the Wilson River watershed have been significantly influenced by both natural and human-caused disturbances. The Tillamook Burn fires and subsequent timber harvest and road-building activities significantly altered the types and availability of high-quality aquatic habitats present in the Wilson. Perhaps the most significant effect was the removal of large wood from the system, both from the streams (“stream-cleaning”) and from the riparian (fires and subsequent harvest). The lack of instream large wood pieces (see section 9.10 Fish Habitat Condition) is likely having a detrimental effect on the overwintering abilities of juvenile salmonids and on the accumulation of gravels, especially in the Jordan Creek subwatershed where 80% of the surveyed stream reaches exhibited LOW (relative to ODFW “reference/benchmark” reach data) percent gravel, HIGH percent bedrock and LOW percent pools (Table 73 and section 9.11 – Instream Large Wood; although this may also be a relic of historic log drives).

1.8.3 Aquatic Habitat Conditions

Data for several key habitat attributes from reaches throughout the various Wilson River subwatershed often are not apportioned according to ODFW’s Aquatic Inventories Project (AIP) reference reach data. When considered collectively, however, the data may suggest that aquatic habitat conditions in the Wilson River are still exhibiting some level of functionality. For example, data for conditions within the Little North Fork of the Wilson subwatershed are fairly evenly distributed among the LOW, MODERATE and HIGH categories (28.7%, 50%, and 21.3%, respectively; see Table 73 in section 9.10.2 –Results [of Fish Habitat Condition]), indicating that aquatic habitat conditions within this subwatershed are likely functioning in a manner similar to other coastal watersheds that have experienced relatively little human disturbance (refer to section 9.10 – Fish Habitat Condition).

Key habitat attribute data from the Jordan Creek subwatershed, on the other hand, are skewed relatively heavily toward LOW categories (48% LOW, 37% moderate, 15% HIGH; see Table 73 in section 9.10.2 Results), indicating that aquatic habitat conditions in this subwatershed may be compromised compared to reference conditions (i.e., other coastal watershed that have experienced relatively little human disturbance). Indeed, three other subwatersheds exhibit similar patterns (Devils Lake Fork, Middle Wilson, and North Fork Wilson). In contrast, key habitat attribute data for the Upper Wilson/Cedar Creek and South Fork Wilson subwatersheds indicate only a moderate distributional skew away from reference conditions while still roughly approximating data from reference reaches (refer to section 9.10 – Fish Habitat Condition).

1.8.4 Fish Barriers

In order to document culvert/road barriers to fish movement, Duck Creek Associates conducted an extensive and exhaustive survey in the Wilson in 2006. Surveyors identified 926 road/stream crossings, of which 144, or 16%, were considered (likely or observed) barriers to fish-passage (see Table 77 in section 9.13 – Fish Passage Barriers; Map 58). Blockage types described by surveyors ranged from collapsed and sediment-filled culverts to blocked inlets and outlets and well as perched culverts. There are an estimated 24.6 miles (or 7.8% of the total miles [313] of designated fish habitat in the Wilson) of *potential* fish habitat that are blocked by impassable culverts (see Table 78 in section 9.13 – Fish Passage Barriers). Of the total percent blocked by culverts(7.8%), 4.6% are effective adult salmonid barriers and 3.3% are only barriers to juvenile salmonid movement. For a detailed list of the road location of these barriers, refer to Appendix Q – Fish Barriers.

1.8.5 Recommendations and Priority Stream Reaches

Although the Tillamook Bay estuary may well be the conduit for potential introduced species invasions, introductions may also occur on ODF lands. Because some invasions can have far-reaching and catastrophic effects on local, native populations, we recommend that ODF maintain a close working relationship with the ODFW and Tillamook Estuaries Partnership to identify (early) potential outbreaks of invasive species.

Due to the sensitive and precarious nature (e.g., low abundances and high variability in peak counts) of many of the watershed’s fish species, extra precaution should be employed when considering whether a species will be impacted by management actions. Additional caution is urged when considering the effects of multiple actions within relatively discrete geographic areas (e.g., individual streams).

Furthermore, because the spawning survey data indicate such a high variability in peak abundance over the last 50+ years (see sections 9.7 – Historic Salmonid Abundance and 9.8 – Current Salmonid Abundance), we recommend extreme caution when interpreting the effectiveness of restoration activities, especially over the short-term. Additionally, the effectiveness of restoration projects should be repeatedly assessed over the course of several years and even decades and the costs of long-term monitoring activities should be included when calculating future projects' costs.

Fish production is intricately tied to the availability of quality habitat and the current aquatic habitat data in the Wilson are often negatively skewed compared to ODFW's Aquatic Inventories Project (AIP) reference reach data. Furthermore, aquatic habitat complexity is intricately linked with the abundance of instream large wood. The lack of large instream wood pieces in the Wilson is having a substantial and persistent detrimental effect on the overwintering abilities of juvenile salmonids and on the accumulation of gravels and the overall number of pools present in the system. Therefore, silvicultural treatments that encourage the production and recruitment of large instream wood may well have a substantially positive impact on 1) long-term aquatic habitat conditions and 2) increased production of fish species.

Two actions that would arguably have the largest beneficial impact on aquatic wildlife and their associated habitats would be:

1. encouragement of instream large wood recruitment in both riparian and upslope areas that coincide with landslide- and debris-flow prone areas that are predicted to deliver to fish-bearing streams, and

2. placement of instream large wood in and upstream of high priority aquatic areas for the development of instream pieces of large wood.

As key pieces of large wood begin to recruit to (or are placed in) the streams, we would expect to see an increase in pool frequency, decreases in the number of habitats where bedrock dominates, increases in gravels, and increases in aquatic cover associated with wood accumulations. It is important to note, however, that the effectiveness of instream large wood depends on size of the receiving channel, size of the piece(s) of wood and the probability that large wood additions will accumulate (related to channel roughness, meander, riparian vegetation, wood size/length, etc.). Our modeling results indicate that riparian stands will be unable to provide adequate functional wood throughout the next century for streams of about 30 feet in width and greater. Streams of this width are at the upper end (and beyond) the size range generally recommended for large wood placement (e.g., ODF & ODFW 1995). Nevertheless, these are the streams with highest value for fish and the lowest potential for large wood recruitment (see Maps 31, 32, 33, and 37). It will be worthwhile, therefore, to look for opportunities for large wood placement within these general areas. The models used an estimate of average channel width, and do not capture details of spatial variability in channel configuration: some reaches within the channels identified as high priority for fish, and low potential for riparian recruitment of functional wood, will fall within the range of channel widths and slopes recommended for wood placement (page 5 in ODF & ODFW 1995). Managers ought to identify and evaluate these narrower, lower-gradient reaches as potential reaches for large wood placement.

A stream reach prioritization scheme was developed and the resulting list (detailed in section 9.14 – Priority Streams) can be used as a screening tool – when overlayed in a GIS – to identify streams and stream reaches that are of particular importance. These streams/reaches, if protected and/or restored, would provide the greatest overall beneficial impacts to aquatic resources. Priority streams/reaches were identified in every subwatershed (see Table 79 in section 9.14 – Priority Streams) and ranged in length from less than 0.1 miles to more than 60 miles with most of the reaches occurring in large, contiguous segments (as opposed to fragmented). Because of the presence of Salmon Anchor Habitats, the subwatersheds with the highest priority streams all occur in the Little North Fork Wilson, Upper Wilson/Cedar Creek (including Ben Smith Creek), and Devils Lake Fork subwatersheds. Not surprisingly, this result also corresponds with subwatersheds where aquatic habitat conditions were in MODERATE to GOOD shape (i.e., where conditions were most similar to ODFW “reference/benchmark” streams).

Aquatic habitat conditions in the Little North Fork Wilson subwatershed are in GOOD shape (relative to ODFW “benchmark/reference” reaches), indicating that aquatic habitat conditions within this subwatershed are likely functioning in a manner similar to other coastal watersheds that have experienced relatively little human disturbance. Indeed, fish numbers in this subwatershed generally reflect this. Therefore, we recommend that ODF take actions that maintain the current conditions in this subwatershed.

Key habitat attribute data from the Jordan Creek subwatershed, on the other hand, are skewed relatively heavily toward LOW categories (48% LOW, 37% moderate, 15% HIGH), indicating that aquatic habitat conditions in this subwatershed may be compromised (the aquatic habitat condition received a VERY POOR rating). Indeed, steelhead and coho numbers generally reflect this. Because this subwatershed contains high habitat intrinsic potential but low numbers of fish, ODF could consider restoration actions in this subwatershed that are geared toward steelhead and coho recovery and improvement of overall aquatic habitat complexity (e.g., increase the number of pools, percent gravel, and instream large wood).

Aquatic habitat conditions in the Upper Wilson/Cedar Creek and the Little North Fork Wilson, on the other hand were rated as being in MODERATE and GOOD condition (respectively), the subwatersheds contain high IP for coho and steelhead, areas of high core habitat for coho and steelhead, and contribute large numbers of coho, steelhead and cutthroat trout. Few restoration efforts, therefore, may be needed here and ODF should take actions that maintain the current conditions. Conversely, aquatic habitat conditions in the Devils Lake Fork and the South Fork Wilson were rated as being in POOR and MODERATE condition (respectively), yet the subwatersheds contain areas of high IP and core habitats for coho and steelhead, contribute large numbers of coho salmon and cutthroat trout but do not produce many steelhead. Therefore, restoration efforts in these subwatersheds could be focused on improving aquatic habitat conditions (e.g., increasing the number of pools, percent gravel, and large wood) for steelhead (low fish numbers) and coho (listed species).

Additionally, while apparently not a large issue in the Wilson, historic road-building activities have reduced the connectivity of stream reaches to each other, blocking the movements of fish. Although some fish blockages still exist (e.g., improperly sized culverts, steep gradients, too high steps at the mouth, etc.), current road-building and road-restoration practices have largely eliminated fish passage issues. Yet, the stream crossing washout potential and sedimentation issues identified in this assessment still have the ability to negatively impact aquatic habitats and, given the recent frequency of large storm events, should be immediately repaired or replaced. Furthermore, this assessment identified numerous recreational trails and dispersed recreation sites that were 1) hydrologically connected, 2) actively eroding, and 3) damaging riparian vegetation. To reduce sedimentation and increase riparian shade at these sites, ODF should 1) restrict their recreational use or close them altogether, 2) repair damaged areas, and 3) work to educate recreational users about the negative ecological, biological, and socio-economic effects from improper use.

In general, the Wilson River watershed's basic biological and ecological requirements are largely being met by the current conditions in the Wilson, but the lack of large wood (upslope, riparian and aquatic) is arguably having the largest impact on aquatic habitat complexity (e.g., lack of pools, deep pools, large wood accumulations, cover, low gravels, etc.) and large wood recruitment is projected to remain below target levels well into the next century. Tailoring riparian and upland silvicultural treatments for the enhancement/recruitment of large wood may help the aquatic habitat conditions recover at a faster rate.

Adhering to the management recommendations mentioned above will help to 1) ensure adequate funding for long-term monitoring activities, 2) reduce the likelihood that an exotic species invasion will go unnoticed for some time, 3) reduce sedimentation and erosion and increase riparian shade (in some areas), 4) restore fish passage to useable habitat, 5) enhance the recruitment of large wood to streams thereby improving aquatic habitat complexity, and 6) maintain (or enhance) aquatic habitat conditions throughout the Wilson.

1.9 Synthesis

1.9.1 Watershed Condition

Since European settlement, the Wilson River watershed has experienced widespread natural and human-influenced disturbance. Although current timber harvest and riparian management practices adhere to widely-accepted standards (e.g., Forest Management Practices), much of the watershed has been heavily impacted by past management practices (e.g., timber harvesting, wildland fire activities, road building, conversion of lowlands to agricultural production, stream cleaning, etc.). While the Wilson is currently in a state of intermediate recovery, the combined effects of legacy and current practices are largely evident in:

- the young, even-aged riparian forest stands,
- the low potential for near- and long-term large wood recruitment to streams
- the low amounts of instream large wood,
- the low number of pools (including deep pools),
- the lack of instream diversity,
- the relatively high number of stream crossings that
    - exhibit a high washout potential and
    - are potentially blocking fish passage,
- and the quantity of road segments, trails, and dispersed recreation sites that are actively eroding to streams.

Although recovering, these legacy effects – particularly from the Tillamook Burns and subsequent road-building and logging activities – are still having a moderate to high impact on the Wilson. Furthermore, riparian and large wood recruitment modeling exercises indicate the legacy effects will continue to impact the Wilson into the foreseeable future (e.g., >100 years). Because there are no examples on which to base the recovery of a watershed after these kinds of large-scale disturbance events, it is difficult to determine exactly how far along in the recovery process the Wilson River watershed is.

The effects from current management practices, however, range from low (e.g., hydrology) to high (e.g., recreation). Limiting recreational use and focusing restoration efforts on streamside areas will likely have a beneficial impact on the recovery of riparian areas. Fixing stream crossing with high washout potential and removing fish blockages will reduce sedimentation and open up additional areas for fish spawning, migration and rearing (although the degree to which this will aid in the recovery of a species is unclear). Additionally, tailoring riparian and upland silvicultural treatments for the enhancement/recruitment of large wood may help the aquatic habitat conditions recover at a faster rate.

Overall, while the Wilson River watershed is still largely being impacted by the legacy effects of previous land use practices, negative effects from current management practice are at relatively low level and are generally improving conditions throughout the watershed (see recreation-related topics in the text for some exceptions). In general, the Wilson River watershed appears to be in an intermediate state of recovery, given the high degree of disturbance it has experienced in the last 100+ years. While many basic biological and ecological requirements are largely being met by the current conditions in the Wilson, the lack of large wood (riparian and aquatic) is arguably having the largest impact on aquatic habitat complexity (e.g., lack of pools, deep pools, large wood accumulations, cover, low gravels, etc.) and large wood recruitment is projected to remain below target levels well into the next century.

1.9.2 Management Considerations

The Wilson River watershed is prone to periodic, large-scale disturbances. Large storm events lead to flooding and landsliding, resulting in debris-flows and torrents. Historic catastrophic fires with long fire-return intervals, combined with periodic storm events, historically recruited large wood and sediments to the system creating a rich, diverse freshwater habitat. Since European settlement, the watershed has been exposed to a variety of human-influenced events including frequent forest fires, creation of a dense network of forest roads, increasing forest recreation use and intense timber harvest.

It is important to consider that the riparian ecosystem has essentially been reset to an early-successional, even-aged, hardwood-dominated forest which modeling exercises predict, in the absence of management, is likely to persist for 100+ years. Furthermore, the Wilson has abundant steep, landslide-prone slopes and steep, mainstem channels that often confined and highly sensitive to management activities. For example, road building on steep slopes may lead to road failure and increased sedimentation to fish-bearing streams. Additionally, dispersed recreational trails on erosion-prone steep slopes that are hydrologically connected can dramatically increase sediment loading. While landsliding and debris-flows deliver sediments and large wood that is beneficial as aquatic habitat, increased fine sediments can inhibit survival of salmonid eggs and decrease the amount of available spawning gravel. Given that salmonid populations are depressed compared to historic levels and recent return rates are highly variable, it is advisable to carefully consider how management actions might influencing these areas.

While the road system in the Wilson is dense and some human-influenced barriers to fish movement exist, improvements to the existing infrastructure and well-designed new roads have largely eliminated sedimentation and fish passage issues. ODF-managed lands in the Wilson are currently being (or are attempting to be) managed to effectively address key issues influencing water quality and aquatic life. Additionally, continuation of current projects that address sedimentation and fish passage issues will help the watershed (e.g., speed up) continue its process of recovery.

Hydrologically, the Wilson has recovered from the Tillamook Burns evidenced by modeled low and peak flows that are ≤3% of baseline flows. Water quality issues (e.g., low dissolved oxygen, high stream temperatures, localized sedimentation), however, are still present during some portions of the year and streamside roads, chronic recreation-related impacts, and projected decreases in shade (under a “no management” scenario) are likely to continue to degrade water quality.

Sedimentation in the Wilson has been of considerable concern, especially after the Tillamook Burns and subsequent logging and road-building activities. However, current sediment sources from landsliding and debris flows should be considered at or near (e.g., slightly elevated) background levels as aerial and field surveys indicate that these types of disturbances were occurring in the Wilson prior to European settlement. This watershed analysis, however, has identified road segments that are actively eroding to streams that might increase sedimentation above background levels.

Riparian areas in the Wilson were essentially “reset” during the Tillamook Burns and are in an early seral stage (early recovery). This is evidenced by a general lack of large diameter trees and a relatively uniform age structure. Additionally, modeling results indicate that in the absence of active management, current riparian conditions are likely to persist into the foreseeable future (e.g., >100 years). Furthermore, few trees are projected to recruit to the larger diameter size classes, resulting in a lack of large wood recruiting to streams. Silvicultural prescriptions designed to encourage the production and recruitment of large conifers may help speed the recovery of both riparian and aquatic habitat condition.

Recreational activities in the Wilson have been occurring since settlement but large-scale activities (e.g., OHV riding and camping) are relatively recent and increasing at a rapid rate. Sedimentation and streamside shading impacts are of the greatest concern and, although relatively localized, are severe in some areas. The extent to which these activities are occurring throughout the watershed is not fully known but year-round use levels are considered chronic (as opposed to episodic) and will likely remain high.

From an aquatic habitat standpoint, the Wilson is still largely experiencing the legacy effects of past management practices evidenced by the lack of instream large wood, pools (including deep pools) and relatively low channel habitat complexity. While aquatic habitat conditions in the Wilson are recovering, three of the eight subwatersheds received a MODERATE to GOOD proper functioning condition rating, but four of the subwatersheds are in POOR to VERY POOR condition. Even though modeling exercises predict large wood will recruitment to the streams at very low levels over the next 100+ years, accumulations of wood (and gravels) from natural landsliding and debris flows may help the system recover aquatic habitat complexity faster than predicted.

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2 Introduction

2.1 Introduction

The Tillamook State Forest (Forest), covering roughly 364,000 acres, is located in the North Coast watershed basin in northwestern Oregon's coastal mountain range. The Forest, managed by the Oregon Department of Forestry (ODF), covers a vast swath of forested coastal highlands dissected by a complicated dendritic network of streams. The area is delineated into watersheds (5th Field Hydrologic Units or HUCs) including the Wilson River watershed (Map 1), the focus of this watershed analysis (hereafter, analysis). The Wilson River watershed spans approximately 123,000 acres, of which, roughly 80% (~98,000 acres) is managed by ODF's Forest Grove and Tillamook district offices (Map 2). The Wilson River watershed is managed for multiple uses (e.g. timber production and recreation) and is also home to a variety of fish and wildlife species, including chum, coho, spring and fall Chinook salmon, winter and summer steelhead, resident and searun cutthroat trout, deer, elk, and marbled murrelets.

2.2 Purpose

State laws (OAR 629-035-0020 and ORS 530.050) direct ODF to manage state lands to provide the greatest permanent social, economic and environmental value to Oregonians by managing for healthy, productive and sustainable forests. In 2001, the Northwest and Southwest State Forests adopted Forest Management Plans (FMP) to fulfill these directives. The FMPs included specific watershed assessment and analysis strategies that were compatible with, but expand upon, the existing Oregon Watershed Enhancement Board (OWEB) watershed analysis process.

The ODF watershed analysis process focuses on landscape function and process as they relate to aquatic and riparian habitat conditions on State Forest lands. The primary goal of the FMP is to manage for the "properly functioning condition" (PFC; as defined by ODF 2004) of State Forest aquatic ecosystems. The biological and ecological objective of the FMP strategies is to maintain or restore the key ecological functions of aquatic, riparian, and upland areas that directly influence the freshwater habitat of aquatic species within the context of the natural disturbance regimes that created habitat for these species. The primary objectives of the ODF watershed analysis are to identify where properly functioning habitat exists, is lacking, and what management changes can be implemented to meet the FMPs objective of maintaining or restoring PFC to aquatic systems. In addition to the OWEB watershed analysis process and requirements, the ODF process includes four explicit strategies that all watershed analysis must address: limiting factors, alternative vegetation management, slope stability, and road analyses (ODF 2004).

In 2001, E&S Environmental Chemistry completed an OWEB watershed assessment of the Wilson River project area. The purpose of the 2001 assessment was to inventory and characterize conditions in the Wilson River watershed and provide recommendations that addressed key water quality, fisheries and fish habitat, and watershed hydrology critical questions identified by OWEB (E&S Environmental Chemistry 2001; see Section 2.3). The purpose of *this* watershed analysis is to provide an updated and supplemental inventory and characterization of watershed conditions in the Wilson River drainage basin. Additionally, this watershed analysis answers questions specifically designed to determine how ODF forest practices are affecting aquatic and riparian resources. This watershed analysis was conducted by the Duck Creek Associates team of professionals. This team was comprised of a variety of specialists who analyzed existing watershed information at varying spatial scales and generated new information as it pertained to historical and current natural resource conditions within the Wilson River watershed.

2.3 Approach

This watershed analysis follows the process outlined in the ODF's State Forest Program Watershed Analysis Manual (ODF 2004) which stipulates that the methodologies be compatible with those outlined in the Oregon Watershed Assessment Manual (WPN 1999). Consistent with the process outlined therein, this document contains three distinct components (assessment, analysis, and synthesis) and each topical chapter (e.g., Stream Channels, Hydrology, Riparian, etc.) incorporates each component.

The assessment component includes both historical and current conditions. The intent of the historical assessment is NOT to define conditions at some single point in the past to use as a target for the future. Instead, the purpose is to provide a description of major historical disturbance events that occurred within the Wilson River watershed and to characterize historical management trends. Forest environments are constantly changing. Therefore, the historical conditions described herein are presented in the context of the dynamic nature of forest environments, with recurring cycles of both disturbance and recovery. For it is only through an understanding the historical conditions across the watershed that managers are able to understand the context in which the current issues have arisen.

Unlike the historical conditions assessment, the current condition assessments contained herein are a simply snapshot of the conditions as they relate to a *range* of conditions the watershed has experienced, is experiencing, and will experience. Because forest environments are continuously changing, however, the snapshot of current conditions should be considered in the context of the dynamic nature of the environment – an environment that includes recurring cycles of both disturbance and recovery. Additionally, the snapshot of current condition can be used as a measure against which future conditions can be compared to assess the relative effectiveness of differing land management scenarios.

While the current conditions are presented relative to certain “benchmarks” or “reference conditions,” it is important to note that many watershed processes cannot be characterized as either good or bad. Rather, these processes must be evaluated based on their likely influence on various resources (e.g., salmonid habitat or water quantity and quality). By updating and summarizing the existing conditions in the Wilson River watershed, the watershed can be better managed to better protect and conserve the natural resources consistent with the public values placed on them.

Similar to the previous OWEB watershed analysis (2001), this assessment is diagnostic in nature and does not prescribe specific actions for specific stream segments. Rather, it provides a decision-making framework for identifying areas of the watershed in need of protection and restoration. The assessment is conducted on a watershed level, recognizing that all parts of a watershed function as a whole and that alteration or loss of one watershed process or component can affect many other processes and components in the watershed.

Collectively, this watershed analysis evaluates dominant interactions between featured watershed processes, aquatic resources, and land use, particularly on ODF lands. The assessment component includes a narrative that describes the project area, land use patterns and various historic and current natural resource attributes. The analysis component, of primary importance to ODF, focuses on ODF administered lands within the Wilson River watershed and is intended to facilitate the management and attainment of properly functioning aquatic and riparian conditions. The synthesis section combines the results of the assessment and analysis and summarizes conclusions about the Wilson River watershed. The synthesis section also includes a determination of the overall watershed condition, a summary of the answers to OWEB and ODF questions, and provides management considerations as they relate to specific management goals and desired future conditions.

There are two general types of questions addressed in this watershed analysis: OWEB critical questions and ODF key supplemental questions. The OWEB questions are derived from the Oregon Watershed Assessment Manual (WPN 1999) while ODF questions are specific to ODF management needs and, therefore, primarily address State forest lands in the Wilson River watershed.

Critical OWEB questions were largely answered by the 2001 watershed analysis. Consequently, when addressing OWEB questions, this assessment largely references the existing OWEB assessment (E&S Environmental Chemistry 2001) but also includes additional analyses that update some of the answers from the existing assessment and answers to key supplemental ODF questions. Of particular interest to ODF is the identification of limiting factors to PFC, alternative vegetation management strategies, potential effects of landslides on streams, an information review from the road condition assessment to assist ODF in making timely road management decisions, and identification of locations where trails and dispersed camping sites are producing impacts to aquatic systems.

This watershed analysis is not intended to analyze all past and current information on all potential biological and ecological processes and natural resources in the Wilson River watershed. Rather, this analysis focuses on the issues identified in the FMP as they relate most directly to aquatic and riparian conservation and the current management strategies intended to address those issues. Consequently, upland processes are considered in the context of how they may be influencing aquatic and riparian conditions.

3 Watershed Overview

Because the previous OWEB assessment addressed much of the general watershed information, this chapter primarily addresses details considered essential to a general overview of the project area.

3.1 Physical Setting

Located in the Coast Range mountains of northwestern Oregon, the Wilson River flows off their western flank and, along the lower river, through the city of Tillamook, eventually emptying into Tillamook Bay, one of five major river systems to do so. Nestled between the Trask River to the south, the crest of the Coast range to the east, the Kilchis River to the north, and Tillamook Bay to the west, the Wilson River watershed is comprised of eight subwatersheds (6th field HUCs; Map 2). Spanning roughly 123,000 acres, the Wilson River drainage is 30+ miles long while the width varies from <1 mile to >13 miles. The lowland alluvial plains – once forested but containing numerous hydrologically connected sloughs – are currently utilized primarily for dairy farming and rural residential housing while the forested uplands are utilized primarily for timber production and recreation (see Section 3.3).

3.1.1 Ecoregion

The Wilson River watershed, part of the Coast Range Physiographic Province described by Franklin and Dyrness (1973) and WPN (1999), spans portions of the Coastal Lowlands, Coastal Uplands and Coastal Volcanic Uplands ecoregions (Omernik and Gallant 1986). Ecoregions, which are characterized based on climate, geology, physiography, vegetation type, land use, wildlife and hydrology, allow watersheds to be classified according to the patterns that shape and form the biological and ecological functions within each watershed.

Coastal Lowlands, for example, occur in valley bottoms along the Oregon and Washington coasts and are characterized by marine estuaries and terraces with low gradient meandering streams, low elevations (e.g. 0-300 feet), moderate annual rainfall (e.g. 60-85 inches) and vegetation that typically includes a mosaic of Sitka spruce, western hemlock, western red cedar, Douglas-fir, grand fir, red alder, and estuarine wetland plants (Franklin and Dyrness 1973, WPN 1999). Also found along the Oregon and Washington coasts, Coastal Uplands are associated with the upland areas that drain into the Coastal Lowlands and are characterized by terraces with medium to high gradient streams, low to moderate elevations (e.g. 0-1,000 feet), moderate to heavy annual precipitation (e.g. 70-125 inches), and, with the exception of relatively few estuarine wetland plants, vegetation similar to the Coastal Lowlands (Franklin and Dyrness 1973, WPN 1999). The Coastal Volcanic Uplands, which extends from the upper extent of the Coastal Uplands ecoregion up and over the crest of the Coast Range mountains, are characterized by steep-sided mountain slopes, high gradient, cascading streams, moderate to high elevations (e.g. 1,000-4,000 feet), moderate to high annual precipitation (e.g. 70-200 inches), and, except for the absence of estuarine wetland plants, vegetation similar to the Coastal Uplands (Franklin and Dyrness 1973, WPN 1999).

3.1.2 Geology, Landforms and Soils

The rocks and soils of the Coast Range mountains were formed through a combination of depositional, erosional and volcanic processes. The Wilson River watershed is located in the Tillamook Highlands, a geologic province of the north Coast Range that was formed in the Eocene epoch some 35 to 55 million years ago, where volcaniclastics and marine sedimentary rocks typically account for about 95% of the geology (Map 3 and Table 2; Wells et al. 1995).

Table 2. Geology of the Wilson River watershed by acreage and percentage of watershed area.

Category	Type	Description	Acres	% of Total
Surficial Deposits				
	Qf	Fluvial and Estuarine (Holocene)	3,590.8	2.9
	Qls	Landslide	2,916.8	2.4
	Qt	Fluvial and Estuarine (Pleistocene)	459.7	0.4
Volcanic/Sedimentary Rocks				
	Tbl	Lower porphyritic basalt flows	16,837.3	13.7
	Ty	Yamhill Formation (upper middle Eocene)	16,070.1	13.1
	Tbr	Submarine basalt tuff and breccia	15,376.4	12.5
	Thpb	Basalt of Hembre Ridge (lower-middle/lower Eocene)	9,414.7	7.6
	Tbpl	Lower plagioclase-porphyritic basalt	8,331.1	6.8
	Tpb	Submarine basalt	5,507.6	4.5
	Tybs	Basaltic mudstone	4,790.4	3.9
	Tbu	Upper porphyritic basalt flows	3,568.7	2.9
	Tbs	Basaltic sandstone (upper and upper middle Eocene)	3,457.2	2.8
	Tbpu	Upper plagioclase-porphyritic basalt	2,216.0	1.8
	Tet	Tyee Formation (lower middle Eocene)	1,336.1	1.1
	Tal	Alesa Formation (lower Miocene and Oligocene)	920.5	0.7
	Tn	Nestucca Formation (upper Eocene)	444.5	0.4
	Tals	Feldspathic sandstone	439.3	0.4
	Tbru	Upper submarine basalt lapilli tuff and breccia	427.7	0.3
	Tyt	Lower tuff unit mudstone	384.4	0.3
	Ths	Basaltic sandstone	270.1	0.2
	Tsf	Subaerial dacite, rhyodacite, and rhyolite	159.7	0.1
	Tba	Aphyric basalt	35.1	<0.1
	Tts	Epiclastic silicic tuff and tuff breccia	3.4	<0.1
Intrusives Rocks				
	Tidb	Diabase (middle Eocene)	25,448.3	20.7

Category	Type	Description	Acres	% of Total
	Tiab	Porphyritic basalt (late middle Eocene)	393.8	0.3
	Tib	Basalt dikes and sills (late middle Eocene)	164.0	0.1
	Tidb?	Presumed Diabase (middle Eocene)	143.4	0.1
	Teib	Basalt sills (late Eocene)	16.7	<0.1
Miscellaneous	–	Undescribed geology	3.8	<0.1
		TOTALS	**123,127.8**	**100.0**

Siltstone and sandstone deposits, along with basaltic intrusions, make up the most distinctive landforms in the watershed and the basalt formations are thought to be relic remains of an oceanic island formed during the Eocene some 40 million years ago (Wells et al. 1995). The newer siltstone and sandstone formations were formed primarily during the late Eocene but some portions were formed later in the Oligocene and lower Miocene epoch some 20 million years ago (Beaulieu 1973, Neim and Neim 1985).

The north coast is typified by long, continuous shorelines punctuated by steep cliffs and the occasional estuarine bay containing rich lowland marshes and deep, alluvial-deposited terraces. Inland, the mountains rise up sharply to elevations greater than 3,500 feet while broad, alluvial, lowland valleys disappear into narrow, steep-sided canyons where high-gradient, cascading streams and landslides predominate.

Primarily an Astoria-Hembre association, prevailing soil types in the Wilson River watershed (Appendix A) consist of deep, well-drained, highly-productive fluvial and estuarine deposits in the lowlands with moderately deep soils covering very steep terrain in the uplands (ODF 2003, TBNEP 1998). The lowland soils are collectively known as the Nehalem-Brenner-Coquille association and, with sufficient drainage, are among the most fertile soils in the surrounding area. Although much of the watershed is still forested, most of the lowlands have been cleared for agricultural production (e.g. dairy farming). The high to medium organic content soils found between the coastal lowlands and the forested uplands are known as the Quillayute-Knappa-Hebo association. Often found in extensive, broad terraces, these soils, while still fertile, are typically less fertile than the lowland soils but constitute nearly 50% of the Tillamook Basin’s tillable lands (TBNEP 1998).

3.1.3 Climate

Situated in the coastal temperate rainforest, the climate in the Wilson River watershed is strongly influenced by the Pacific Ocean and its related weather patterns (Taylor and Hatton 1999). Typical of Pacific Northwest climate, the Wilson River watershed experiences an extended, mild, winter rainy season followed by a moderately warm and relatively dry summer season. Precipitation generally falls as rain and increases with elevation as warm, moisture-laden air rises over higher terrain, causing the air to cool and drop precipitation (orographic effect). Mean annual precipitation in the city of Tillamook is just over 90 inches, increasing dramatically further up in the watershed to around 200 inches at the summit. Over 50% of the precipitation falls from November through February (average is nearly 13 inches per month) but nine months out of each year typically receive 3 inches or more of rain (refer to Sections 3.4.2 and 5.2.1 for detailed hydrology discussions). Average high temperatures hover around the mid-fifties (Fahrenheit) in the winter months and the high sixties during the summer months. Average low temperatures dip to the mid-thirties during the winter and the mid- to upper fifties in the summer.

3.1.4 Ownership

This watershed analysis recognizes five classes of land ownership: Private Industrial, Private Non-Industrial, State Administered Lands, Federally Administered Lands, and Miscellaneous city/county/state administered lands (Map 4). The Wilson River watershed covers some 123,128 acres and State lands account for the largest proportion by land area at slightly less than 98,000 acres (~80%; Table 3). Approximately 31,330 acres are administered by the Forest Grove ODF district and the remaining 66,423 acres are administered by the Tillamook ODF district (Map 2). The remaining acreage is split between Private Industrial (~12.3%), Private Non-Industrial (~5.2%), Federally Administered Bureau of Land Management (BLM) lands (2.9%), and Miscellaneous lands administered by the City of Tillamook, Tillamook County, or the State Department of Transportation (~0.5%; Table 3).

Table 3. Wilson River watershed land ownership by acreage and percentage of watershed area.

Owner Administration Class	Acres	% of Total
State-Administered Lands	97,320.3	79.0
Private Industrial	15,160.7	12.3
Private Non-Industrial	6,383.7	5.2
Federally-Administered Lands	3,703.3	3.0
Miscellaneous Administered Lands	559.8	0.5
TOTALS	**123,127.8**	**100.0**

3.1.5 Waterboundaries

This watershed analysis is organized according to a hierarchy of hydrologic unit codes (HUCs) delineated by the US Geological Survey. The Wilson River watershed, a 5th-field HUC, falls within the Wilson-Trask-Nestucca 4th-field HUC (17100203) and is further divided into eight 6th-field HUCs (subwatersheds) consisting of the Lower Wilson River, Little North Fork Wilson River, Middle Wilson River, Upper Wilson River/Cedar Creek, Jordan Creek, North Fork Wilson River, Devils Lake Fork Wilson River, and South Fork Wilson River (Map 2 and Table 4). The other prominent water feature in the watershed is Tillamook Bay, into which the Wilson River empties.

Table 4. Wilson River subwatersheds (6th field HUCs) by acreage and percentage of subwatershed area.

Subwatershed (6th field HUC) Name	Acres	% of Total
Devils Lake Fork	22,106.0	18.0
North Fork Wilson River	17,296.6	14.0
Lower Wilson River	16,893.3	13.7
Jordan Creek	16,201.0	13.2
Upper Wilson River / Cedar Creek	14,307.0	11.6
Middle Wilson River	13,486.7	11.0
Little North Fork Wilson River	12,620.5	10.2
South Fork Wilson River	10,216.7	8.3
TOTALS	**123,127.8**	**100.0**

3.2 Biological Setting

3.2.1 Early European Settlement

The historical characteristics of Tillamook Bay (and the Wilson River watershed) prior to the mid-1800’s are not well documented. Our current understanding of the natural resources during exploration and settlement is limited to a handful of written accounts from early explorers and pioneers and to research into and accounts from Native American culture.

While the Spanish Bucareli expeditions and Captain James Cook explored much of the northern Oregon Coast in the 1770’s, it wasn’t until 1788 that John Meares, a fur trader and former lieutenant in the British navy, had the opportunity to explore the Tillamook Bay region (Elliot 1928). His accounts provide the first written records of the natural resources of the area.

Mears describes the countryside (probably the southern portion of the bay) as "an open champaign country extending a considerable distance, where it was confined by a boundary of lofty mountains" (Elliot 1928), the implication being that the lowland countryside was open and had little timber blocking his view. The next written account comes from the Lewis and Clark expedition during the winter of 1805-1806 when Clark describes a river to the north of Tillamook Bay (the Necanicum; then called the Neah-Hoxie)[7] as being "entirely boarded by overhanging trees" and the mountains of the Nehalem basin, located just north of Tillamook Bay, as "covered with a verry [sic] heavy growth of pine and furr [sic], also the white cedar or arbor vita and a small proportion of the black alder, [which] grows to the height of sixty or seventy feet and from 2 to 3 feet in diamiter [sic]" (Bancroft 1886).

Distinguished explorer William Clark, through his communications with the Native Americans of the area, learned that most of the Native Tillamook peoples lived in numerous houses at the mouths of three rivers that entered the bay, they caught many salmon in the small creeks, and when salmon were scarce, "found sturgeon and a variety of other fish thrown up by the waves and left by the tide" (Bancroft 1886). While this doesn't give us an idea of how large the salmon runs were, it does suggest that salmon were plentiful enough to support a large settlement of Native Americans living in the area, at least for portions of the year. Later archaeological explorations found evidence for at least ten different Native American villages around Tillamook Bay, the earliest dating back at least 1,000 years (USACE 1975).

The Tillamook countryside supported other vast food resources (e.g., fish, shellfish, crab, berries, roots big game, etc.) and anthropological and archaeological evidence indicates that the Native Tillamook peoples were not agrarian, relying instead on these plentiful resources (Taylor 1974). While they may not have actively planted crops, Jesse Applegate, a prominent Oregon pioneer, noted that the Tillamook, similar to many of the other Native American tribes of the area, had a custom to "burn off the whole country" late in the autumn every year to harvest grain. The Native Americans were also reported to set fires in old growth spruce and fir to clear areas for their ponies and encourage verdant re-growth (Winters 1941).

William Clark also noted another disturbance around the Tillamook Bay and surrounding coastline in the 1800's, although likely not anthropogenic in nature. His journals from the winter of 1805-1806 note that tremendous landslides were visible in the coastline around the Nehalem River, located just north of

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[7] Although this translation is taken directly from Bancroft 1886, there is some confusion as to which river is actually being referenced (e.g., Necanicum versus Nehalem).

Tillamook Bay, were “fifty or a hundred acres” across (Bancroft 1886). While these notes pertain mostly to coastline hillslopes, they suggest that landslides were probably common in the area prior to European settlement and may have also been found further inland as hillslope gradients increased.

At the time of early European exploration, the Tillamook Basin was (and still is) evenly distributed between the Sitka spruce and western hemlock vegetation zones (Franklin and Dyrness 1973). The dense stands of timber the early explorers encountered (Bancroft 1886) would have included Sitka spruce, western hemlock, western red cedar, Douglas fir, grand fir, Pacific yew, red alder, bigleaf maple, black cottonwood, and Oregon ash (TBNEP 1998). The lush vegetation they encountered (Bancroft 1886) would have included a variety of shrubs, ferns and mosses like the western sword fern, bracken fern, thistle, fireweed, wood sorrel, red and green huckleberries, salal, red elderberry, salmonberry, vine maple, Oregon grape and rhododendron (TBNEP 1998).

3.2.2 Vegetation

The Wilson River watershed straddles parts of both the Sitka spruce and western hemlock vegetation zones (Franklin and Dryness 1973). Both vegetative zones extend from British Columbia south to Northern California, roughly running parallel with the Eastern Pacific coastline (Franklin and Dryness 1973). The spruce zone, typically found at elevations of less than 450 feet above sea level, covers the lower portion of the watershed and is characterized by moderate to heavy annual rainfall (e.g., 78-118 inches/year) with frequent dry season moisture coming in the form of dense fog banks. The western hemlock vegetative zone typically extends from 450 feet elevation up to the subalpine zone of the Coast Range, receives heavy annual rainfall (e.g., ~142 inches/year) but receives the summer fog moisture found at lower elevations, and frequently experiences a dry season that extends from the late spring through the fall. Both vegetative zones typically have well-developed soils that are rich in organic matter and support a myriad of lush, dense overstory and understory vegetation.

Although much of the watershed has been heavily influenced by both natural and human-caused disturbance (see sections 3.4 Natural Disturbances, 4.7 Channel Modifications, and 4.8 Historic Channel Disturbances), the current set of vegetative species is probably similar to pre-European conditions (see Chapter 6 Riparian and Wetlands). The structure of the vegetative communities, (i.e., successional stages and species compositions), however, has been heavily influenced by humans. In the late 1800’s and early 1900’s, large sections of the lowlands and tidal areas were cleared of timber, the wetlands drained, and the rivers diked for agricultural use, often resulting in profound impacts to the vegetative communities. Much of the uplands were logged and/or burned over (both naturally- and human-influenced) and, with some exceptions, replanted primarily with one species of tree, the Douglas fir. More recently, replanted Douglas fir (many of the seedlings were from an off-site seed source) have been increasingly infected with Swiss needle cast, a foliage disease resulting in defoliation and reduction in growth, which carries with it the potential for very significant forest health issues (e.g., decreased production and disease/insect resistance, increased fire danger and severity, etc.). Nonetheless, as we learn more about the ecology, natural processes, and community interactions of the area, the management of the Tillamook State Forest is continually refined to bring about more natural conditions while still providing for natural resource demands (for detailed vegetation discussions, refer to Chapter 6, Riparian and Wetlands).

3.2.3 Fish

Of particular importance to the ODF is an understanding of how watershed processes may be influencing salmonid populations and their habitats. Understanding historic and current conditions of salmonid populations allows managers to better predict how different land use practices may influence target populations. While a variety of other non-salmonid fishes are known to occur within the basin, salmonids are of primary importance to managers as they provide substantial ecological, economic, and cultural benefits for the citizens of Oregon and are often used as indicator species of overall aquatic health. For a detailed list of non-salmonid species known to occur with in Tillamook Bay and the Wilson River, see the Tillamook Bay National Estuary Project (TBNEP; 1998) and E&S Environmental Chemistry (2001) reports.

A variety of anadromous salmonid species are known to occur within the Wilson River watershed, including chum (*O. keta*; Map 5), Chinook (*Oncorhynchus tshawytscha*; Map 6), and coho salmon (*O. kisutch*; Map 7), steelhead trout (*O. mykiss*; Map 8), and both resident and sea-run forms of cutthroat trout (*O. clarki*, no map available). While their life histories and habitat requirements differ, all are freshwater obligate spawners and spend portions of their life in freshwater, estuarine, and marine (except for resident cutthroat trout) environments before completing their life cycle in their natal streams.

Salmonid bones have been found in Native American middens, the prehistoric equivalent of a trash dump, dating back at least 1,000 years (USACE 1975). In fact, some of the earliest accounts of interactions between Europeans and the Native Tillamook peoples indicate that they subsisted on the many salmon they caught in the small creeks, at least for portions of the year (Bancroft 1886). Additionally, given the historic size of many of the coastal salmon runs and their importance as a food source for many aquatic and terrestrial organisms, it is likely that large portions of the Wilson River watershed were also dependent on the salmon, relying on the large annual influx of (marine-derived) nutrients.

For a more detailed look at historic and current salmonid abundance and distributions, refer to Chapter 9 – Fish and Fish Habitat.

3.3 Social Context

3.3.1 Historical Land Use

Native Americans have inhabited the Tillamook Bay landscape for at least the last 1,000 years, living primarily at the mouths of the rivers that empty into the bay (Bancroft 1886, USACE 1975, Winters 1941). Because written accounts of the area don't start appearing with any frequency until the later half of the 19th century (after European settlement), it is difficult to assess the impacts Native Americans may have had on the landscape prior to European settlement. What is known, however, is that the Native Tillamook peoples, similar to other tribes of the area, appear to have routinely burned the lowlands and sometimes the uplands to promote rigorous plant regeneration and to clear areas for pasturage (Winters 1941). The frequency, extent and severity of these fires, however, is unknown but oft-debated. Nevertheless, mapping of 100- to 200- year old tree growth in the southern part of the Tillamook Basin watershed in 1850 indicates possible fire disturbances extending as far back as the mid 1600's (Botkin 1995) and natural stands of Douglas-fir in the watershed may also indicate a revegetation process controlled by fire (Coulton et al. 1996).

One of the earliest documented major fires in the Tillamook Basin occurred in 1845 but started in the Willamette Valley near Champoeg in Marion County and, after several weeks, crested over the coastal mountains and rapidly continued burning coastward, driving many Native Americans to Nestucca Spit and Sand Lake (Johannessen 1961). In 1851, the first European settler arrived in Tillamook, after which, fires in the area were documented in greater detail and over increasing areas up through 1874 (Coulton et al. 1996). A big fire in 1868 started in Clatsop County but quickly spread south and burned much of the Tillamook uplands, settlers and Native Americans both saying it was the largest fire they had ever seen.

As more Europeans began settling in the Tillamook region, the demands for lumber increased. The earliest logging operations, mostly clearing the lands for farming, supplied the personal needs of the settlers and occurred within close proximity to the lowland homesteads to minimize labor expenditures. By the early 1860's, however, the first commercial logging began in earnest. Three lumber mills opened in 1863, all one-man operations, to supply lumber for the growing settler population. By 1870, however, all three mills had closed.

The lowlands of the Tillamook region were highly valued as farmland and property values in the area increased rapidly through the end of the 1800's. By the late 1800's, nearly all the tidelands adjacent to the Tillamook Bay shoreline were privately owned (T.J. Murray & Associates 1982) and, with the help of an increasing network of dikes and drainage ditches, utilized primarily for agriculture. The uplands, however, largely inaccessible due to their steep topography, were still in the public domain.

By the end of the 1800's and early part of the 1900's, farmland property values in the Tillamook region began declining as large lumber companies from the Great Lakes region began purchasing many of the private lowland farms while concurrently purchasing large tracts of the public domain upland forests, the change from agriculture to forestry more pronounced in Oregon than other western states (Swift 1909). While early logging was done by hand and in close proximity to the mills, large-scale logging and the mills that processed the logs into lumber began in earnest in the 1880's, with trees felled by hand but drug by oxen teams to the mills in summer months to be milled in the wet winter months. This early industrial logging was also confined mostly to the foothills but also began to move further inland along major waterways, including the Wilson River, where large log drives to move timber to valley sawmills became commonplace (Photographic Plate 1; Farnell 1980). While splashdamming was commonplace in the Tillamook River, it was a technique apparently not utilized in the Wilson River (Sedell and Duval 1985). Instead, large log drives that occurred during high water events (Photographic Plate 1) were the norm and occurred as far upstream as the Lee's Camp area (~30 miles upstream; Sedell and Duval 1985; refer to Section 4.4 for a detailed discussion on historic channel modifications resulting from log drives).

Logging initially focused on the selective harvest of the largest Douglas fir trees along accessible waterways but by the early 1900's, oxen teams were replaced by steam donkeys and railroad access to interior portions of the watersheds made previously inaccessible timber available for clear-cut basin harvest (Coulton et al. 1996). Operators usually burned the slash in the cutover areas to protect against wildfire and then moved on to the next tract, leaving the cut areas behind with no reforestation efforts (Fick and Martin 1992). Many of the cut-over lands were allowed to go tax delinquent, a process exacerbated by the Great Depression and large wildfires that burned much of the region repeatedly from 1933 to 1951. Collectively called the Tillamook Burn, much of the remaining timber in the Wilson River watershed was burned over in the 1933, 1939, and 1945 Tillamook fires, leaving the timber companies that owned the forested land with little incentive to keep up with the taxes (refer to Sections 3.4.1 and 3.5.2 for detailed wildfire discussions).

Tax-delinquent lands were later seized for the counties by the State, creating a vast new public domain. Because the lands had been removed from tax roles, the counties were left with a crushing tax unit burden (Fick and Martin 1992). The counties, in an effort to recoup some of the lost income, turned to cattle grazing in the burned-over areas in the 1930's (clear through to the early 1950's), but thick vegetation made grazing unpractical (Fick and Martin 1992). Left with few options for recouping the lost income from tax-delinquent lands, the counties looked to other agencies to manage the lands.

The Oregon Department of Forestry, created in 1911 with the primary goal of controlling forest fires, was authorized to acquire forested lands to manage. In its early years, however, no lands were acquired but later State legislatures revised the acquisition portion of the agency to make land acquisition easier. In 1939, Oregon Governor Charles Sprague expressed a desire to create a strong Forestry Department to manage the tax foreclosed forested lands and the State Legislature responded by passing the State Forests Acquisition Act of 1939. The law directed the Board of Forestry, which oversees the Forestry Department, to acquire and consolidate forested lands and rehabilitate and manage them in perpetuity in trust for the counties (and other taxing units).

Senate Bill 261, enacted by the State Legislature in 1941, allowed the State to acquire forested county lands (as opposed to simply managing them for the counties) with the approval of the county or board of commissioners of the county, while still providing the counties with revenues generated from the sale of timber on those lands. In 1943, Tillamook County entered into a timber agreement with the Department of Forestry where title to the land was transferred to the State but 90% of the proceeds from timber sales associated with those lands would go the counties for a period of 10 years[8]. The result was that the vast majority of the watershed was transferred from County to State hands and, in 1944, the Board of Forestry adopted an official Land Policy that, with few revisions, still provides the foundation for how the State-owned portions of the Wilson River watershed is managed today.

Legal sales and court-rulings transferred a small portion of the Wilson River's forested uplands back into private hands from the 1950's through the 1970's. While the majority of the forested uplands in the Wilson River watershed are still under State control, a small portion is managed by private timber interests. Even though some of the Wilson River lowlands were sold to Great Lakes lumber companies in the late 1800's and early 1900's, the majority of the lowlands are still under private agricultural interests and are utilized primarily for raising dairy cows.

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[8] Currently, the counties receive roughly 64% and ODF receives the remainder.

3.3.2 Current Land Use

Land management practices can have significant impacts on processes operating in a watershed. For example, timber harvest can alter a watershed's hydrology by increasing road densities and clearing vegetation, resulting in increased peak flows and changes to sedimentation and erosion rates (Naiman and Bilby 1998). Due to the abundance of rich organic soils, coastal wetlands are/were often drained for agricultural use, disconnecting the floodplains from the river, resulting in habitat losses for floodplain dependent species and dramatic decreases in deposition of rich organic matter. Through a better understanding of how land management activities affect biological and landscape processes, managers can better evaluate the effects of disturbances and work to mitigate the impacts.

The dominant land use in the Wilson River watershed is forestry, accounting for roughly 95% of the watershed's total area (Map 9 and Table 5). The coastal lowland areas in the watershed are dominated by agricultural use, primarily for dairy pastures (~2% of the total watershed area), but development, mostly in and around the City of Tillamook, also accounts for about 2% of the total watershed area (Map 9 and Table 5). Forest management, agricultural use, and urban development have the potential to influence a variety of watershed processes in the Wilson River and a summary list of watershed issues, organized by major land use activity, is included in Appendix C (summarized from WPN [1999]).

Table 5. Wilson River land use by acreage and percentage of total watershed area.

Land Use Type	Acres	% of Total
Forestry	118,591.4	96.3
Agriculture	2,238.5	1.8
Rural Residential	2,111.4	1.7
Park and Recreation	85.7	0.1
Rural Industrial	59.8	<0.1
Rural Commercial	29.6	<0.1
Urban	11.5	<0.1
TOTALS	**123,127.8**	**100.0**

Additionally, recreation has long been an important and valuable output of the Tillamook State Forest and the Wilson River watershed delivers the majority of opportunities compared to the rest of the forest. Traditional pursuits like hunting, camping and fishing have continued to draw visitors, while new uses have rapidly increased in intensity and distribution. That trend has been fueled by population growth, change in technology and the development of road access across the forest from salvage and reforestation activities.

The biggest increases in recreation use is associated with OHVs, with a 50% increase in OHV ownership between 1997 and 2001. OHVs are used 1) in support of traditional recreation pursuits and 2) as a stand-alone recreational tool. The Wilson River highway provides easy access to the watershed for users from both sides of the Coast Range. Correspondingly, recreation development is more intense near the highway.

From the late 1960s to the early 1990s ODF concentrated on forestry activities while OHV recreation spread across the forest with little active management and control. The adoption of old (legacy) roads and trails for OHV use has exacerbated the impacts from heavy informal OHV use and organized events. With the passing of House Bill 2501 in 1991, ODF had the management directive, funding and technical support from the Oregon Parks and Recreation Department needed to craft a comprehensive recreation management plan. The core purpose of the plan was to address the host of resource impacts, management issues and social conflicts that had developed over time.

Since the plan was developed in 1993, considerable progress has been made in addressing the impacts, issues and conflicts through the development of regulations, staff, programs and enforcement presence in partnership with local law enforcement agencies. In addition, ODF has developed proactive programs to inform, educate and involve users in the planning, design, construction and maintenance of facilities and trails.

Several important factors contribute to the difficulty in keeping watershed impacts at a manageable level, they are:

- Extensive penetration into all corners of the forest by OHV and vehicle based recreational users.
- Extensive use of RVs and OHVs by hunters puts additional pressure on dispersed campsites and trails during the wet season.
- Intensive use of accessible riparian areas for dispersed camping and OHV recreation causing localized but chronic erosion and resource damage
- Cut bank riding and road drainage sedimentation
- Garbage, human waste, dumping and temporary campsite remains
- Uncontrolled target shooting and associated trash

- User defined trails with high resource impacts
- Vandalism to signs, structures, private property and forest resources
- Unmanaged and unrestricted minor forest products gathering

ODF has had some success in tackling these problems over the last 15 years but continue to face challenges that prevent staff from keeping up with increasing user demand, facility maintenance and preventing new impacts. Decreasing club membership and changes among recreational communities sometimes work against efforts to build partnerships, volunteerism and ownership in the facilities provided for them by ODF. Rapid population growth, a drop in club ownership (less than 10% of users) and a high degree of independence makes communicating information about recreation management more difficult.

Oregon is fortunate in having funding programs to assist clubs and agencies in developing and maintaining recreation facilities, and ODF has been very successful in securing grants for these purposes. With the completion of the Statewide Trails Plan, motorized, non-motorized and water trails have a framework and additional funding for meeting recreation demand and satisfying needs across the state. It is hoped that this report, the Second Party Recreation Assessment (Reed 2007) and ODF's past successes will help direct and leverage the necessary support for tackling resource impacts identified within the watershed.

3.3.3 Economies

Similar to many coastal towns, Tillamook County's economy was largely driven by the timber industry until the industry collapsed in the late 1980's. While the Forest accounts for over three quarters of the watershed by land area, the economies of Tillamook County are now largely farm driven. Farm jobs, however, only account for 6.5% of the jobs by occupation while 1) management, professional (and related), and 2) sales and office jobs account for nearly half of the jobs (49.1%) by occupation (US Census Bureau). From an industry perspective, agriculture, forestry, fishing, hunting and mining-related jobs provide the 4th largest number of jobs in Tillamook County and accounts for 11% of individuals older than 16 that are employed. The educational, health and social service sector accounts for the largest number of industry-related jobs in the county at 16.1% with, rounding out the top five, manufacturing second at 13%, retail trade third at 12.4%, and arts, entertainment, recreation, accommodation and food services fifth at 10.7% (US Census Bureau).

The vast majority (89.2%) of Tillamook County residents are of Anglo-American descent. There is, however, a growing population of Hispanic or Latino origin peoples immigrating to the county and, while still lower than the statewide average of 9.9%, they now account for 7% of the county residents. Similar to the statewide average, nearly 85% of the county residents age 25 and older have a high school diploma, while, slightly lower than the statewide average of 25%, nearly 20% have a Bachelor's or higher degree. Nearly 72% of the residents own their own home (the statewide average is 64.3%) but the median annual family income is $34,727, nearly 20% lower than the statewide average.

3.3.4 Population

The Wilson River drainage contains only one population center; the city of Tillamook. During the first half of the 20th century, the population in Tillamook County increased dramatically from 4,471 individuals in 1900 to 18,606 in 1950, due largely to the increases in farming and timber harvest activities. Tillamook County experienced a population decline in the 1960's, a sharp increase in the 1970's through the first part of the 1980's followed by a steady increase through 2000 (US Census Bureau). The most recent US Census (2000) counted 24,262 individuals in the county and estimated that the population would grow by just over 4% through 2005, slightly less than the projected State population growth of 6.4% (US Census Bureau).

Although the county has continued to experience population growth, data from the Center for Population Research and Census (1997) indicate that birth rates in Tillamook County have been decreasing while death rates have been increasing. According to the TBNEP (1998) report, Tillamook County's population growth can be attributed to migration/relocation of families into the county, primarily persons of Hispanic or Latino origin (US Census Bureau).

3.4 Natural Disturbances

Episodic natural and human-caused disturbances are an intrinsic property of landscapes including the northern Oregon Coast Range. Disturbances such as fires and large storms deliver the majority of sediment, and a large proportion of large wood (LW) to streams. Consequently, landslides, debris flows, and floods shape many attributes of riverine conditions, including fish habitat. It is important to consider the history and role of natural disturbance in the Wilson River watershed because it can provide an important context from which to consider how human disturbances, such as timber harvest, road construction, and river engineering projects, are changing the natural environment.

There is little information available, however, pertaining to the natural disturbance history of the Wilson River watershed and surrounding areas, particularly regarding mass wasting, wood recruitment, and channel conditions. Additionally, historical maps, aerial photographs and written accounts of historical fires provide limited information on wildfire behavior in the watershed. Yet, some information exists relating to the history of forest fires, large floods and wind storms in the watershed in the last century and it is presented below.

To supplement the limited historical information on natural disturbances, computer simulation results covering natural variability of wildfire occurrence, forest ages, landslides and debris flows, and wood recruitment from humid temperate landscapes in the Oregon Coast Range and southwest Washington are presented in Appendix E. Additionally, NOAA-Fisheries is currently conducting computer simulations of natural disturbance and its consequences to the types and abundance of aquatic habitats in the Oregon Coast Range (Earth Systems Institute - research, in progress).

3.4.1 Fire as an Historic Disturbance

Prior to Euro-American settlement, wildland fires were the dominant natural disturbance in the Coast Range (Wimberly 2002); site moisture and ignition opportunities limited the probabilities for large-scale fire events. When large-scale fires would occur, they generally occurred with high severity (~70% mortality) at large spatial scales (thousands of acres), at a relatively long fire return frequency (100 – 200 years). Fires from Native American influences would occasionally escape the Willamette Valley margin into the Coast Range, increasing the fire return frequency in the ecotonal areas along the Coast Range/ Valley interface.

Since Euro-American settlement (mid 1800's), fire frequencies increased in the region through treatment of logging slash, railroad and small engine spark scatter, and settler development (e.g. pasture establishment). Large-scale, high-severity fire events burned the majority of the analysis area in the past century, most notably the Tillamook Fire in 1933, which burned ~240,000 acres of forestland within and around Tillamook County (Map 10). The Saddle Mountain Fire in 1939 (~190,000 acres) and the Wilson/Salmonberry Fire complex in 1945 (~180,000 acres) largely occurred on the same land areas in the Wilson River watershed as the Tillamook Fire, resulting in high residual mortality, severely damaged soils, and inhibited natural regeneration for the majority of the watershed. Salvage logging, roads and subsequent (smaller scale, slash-derived) fires further shaped the overstory vegetation of the uplands and riparian zones (Photographic Plate 2), minimizing the shade, bank stability, and recruitment of large wood (LW) to the stream system.

Though no large-scale peak flow events appear to be outside of normal for the time period following the fire events[9] (between the 1930s and the 1970s), there was likely a high range of disturbances that affected the riparian zones and plant community successional dynamics, especially in lower-order (small and medium) stream channels. Channel migration and mass-wasting events, with limited LW recruitment to aid in channel stability, created a highly dynamic near-stream environment that shaped the establishment and trajectories of the riparian plant communities. These combined effects of high-severity fires, salvage logging, and stream migration/ mass wasting have contributed to shifts away from late successional, “disturbance intolerant” species (western hemlock and western red cedar) to early-successional species that are “disturbance tolerant”, or even dependent upon disturbance, such as red alder, black cottonwood, shrubs, and herbaceous species. When given enough time between disturbance events, Douglas-fir was able to establish and *resist* many smaller-scale disturbances, resulting in a mixed hardwood/conifer community that currently dominates the riparian landscape[10]. For a more detailed discussion on the Tillamook Burn, refer to Section 3.5.2.

3.4.2 Flooding as an Historic Disturbance

Periodic flooding was relatively common in the Tillamook Basin and historic summaries of past and present flooding in the region are provided in Levesque (1980), Tillamook County (1996) and Coulton and others (1996). Data on annual peak flows, extending back several decades, are available from only one gage within the Wilson River watershed (Wilson River near Tillamook, #14301500; drainage area = 161 mi^2), located at River Mile 11.4 (Figure 1). Recurrence intervals were calculated for the period of record using techniques described by the Interagency Advisory Committee on Water Data (1982).

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[9] See Hydrology Section, Peak Flows section 5.3.
[10] See Riparian Vegetation Current Conditions, section 6.1.5.

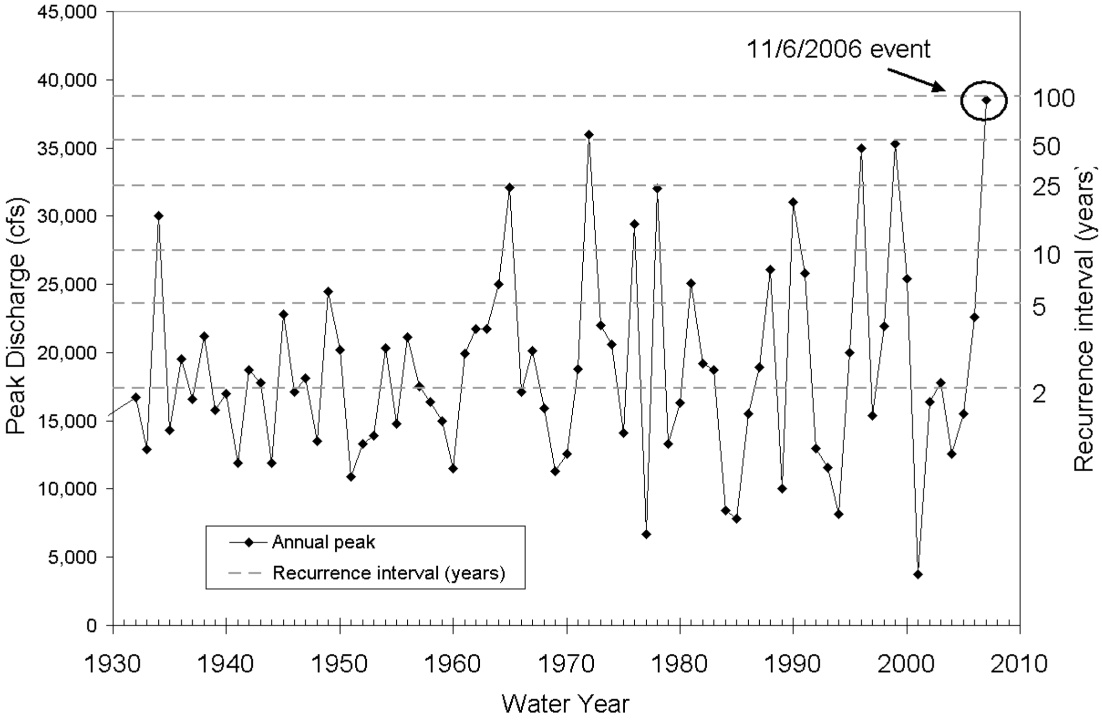

Figure 1. Recurrence interval and probability of occurrence associated with annual peak flow events at the Wilson River stream gage. Values for the 11/6/2006 event are provisional.

The largest recorded peak flow event was the flood of November 6th, 2006, having an estimated recurrence interval of ~100 years (Table 6). Seven of the nine annual events having a recurrence interval of 10 years or greater have occurred within the second half of the period of record. For a more detailed discussion on the Wilson River hydrology, refer to Chapter 5, Hydrology and Water Use.

Table 6. Wilson River stream gage annual peak flows with a recurrence interval of 10 years or more.

Date of annual peak flow	Water year	Peak flow magnitude (cfs)	Approximate recurrence interval (years)
11/6/2006	2007	38,500	94
1/20/1972	1972	36,000	55
12/27/1998	1999	35,300	47
2/8/1996	1996	35,000	44
12/22/1964	1965	32,100	24
12/13/1977	1978	32,000	24
12/4/1989	1990	31,000	20
12/21/1933	1934	30,000	17
12/4/1975	1976	29,400	15

3.4.3 Windstorms as an Historic Disturbance

Fall and winter storms are common along the northeastern Pacific coastlines and have helped shape the Oregon Coast for millennia. Information on significant wind events in the vicinity of the Wilson River watershed is available from the National Oceanic and Atmospheric Administration (NOAA)[11]. Data on windstorm events that occurred further back than about 50 years, however, become more sporadic. The largest and most damaging event on record was the Columbus Day storm of 1962, which caused wide-spread damage state-wide. The later half of the 1990's also experienced several large wind events but it is not known to what extent these storms damaged forested areas in the Wilson River Watershed.

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[11] http://www.wrh.noaa.gov/pqr/paststorms/wind.php and http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms

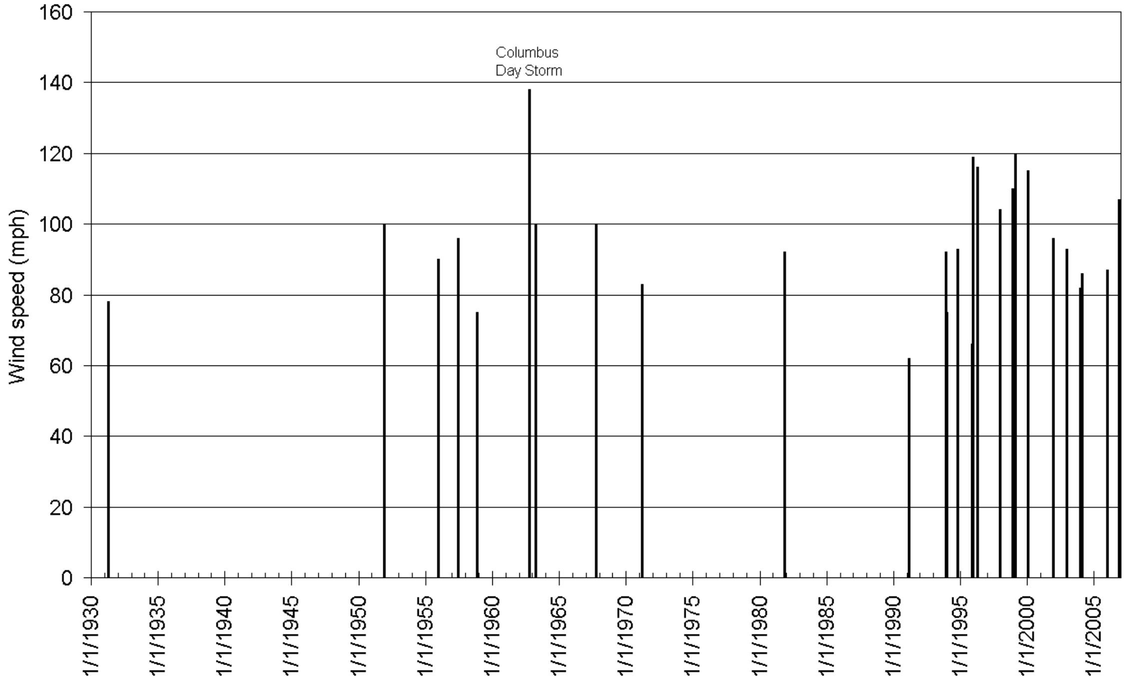

Figure 2. NOAA records for large wind events along the northern Oregon Coast.

3.4.4 Simulation Models and NetMap Analyses

The geomorphic component pertaining to natural disturbances in this analysis consists of (1) simulation modeling of fires, storms, landslides and debris flows, channel sedimentation, and large in-stream wood that was conducted in a landscape similar to north coastal Oregon (located in Appendix D), (2) predictions of inherent channel disturbance potential in the Wilson River watershed using the software program NetMap (refer to Benda et al. 2007 for an overview of NetMap or the Technical Support section of ODF's NetMap tools), and (3) predictions of frequency and magnitude of sedimentation using NetMap. The channel disturbance index and the frequency-magnitude analysis can be used to understand which channel reaches are most prone to natural disturbances such as landslides, debris flows, sedimentation, and flooding impacts. Thus, a high channel disturbance index can identify reaches where habitat restoration or in-stream monitoring may be infeasible while a low channel disturbance index can be used to identify areas appropriate for long term monitoring or restoration projects.

A "channel disturbance" index was created using the Channel Disturbance Tool in NetMap and three watershed attributes were used in the calculation: 1) debris flow susceptibility at tributary junctions of headwater streams with larger channels; 2) segment scale annual sediment yield, and 3) confluence probabilities[12]. The model predicts that numerous discrete areas within the Wilson River watershed are naturally prone to disturbances involving the input and routing of sediment and large wood (LW; Map 11). It is likely that these areas would also be responsive to a human modified disturbance regime (e.g., accelerated debris flow activity), such as at tributary confluences.

A key relationship between river networks and sediment related watershed disturbance regimes are the frequency and magnitude of channel sedimentation. Reaches in the Wilson River watershed that are predicted to have a high to moderate magnitude and low to moderate frequency may be more prone to natural disturbance compared to areas with a high frequency of low to moderate sedimentation. In NetMap, the skew of the probability distribution function (PDF) of sediment yield is used to predict how sediment supply frequency and magnitude vary down the network. It predicts that the highest magnitude and the lowest frequency of sediment fluctuations due to debris flows should occur at the confluences of first- and second-order streams with higher order channels (Map 12). A sediment yield analysis, using a headwater skew of 20 as defined by Benda 1994, reveals that areas of highest natural disturbance are concentrated within the upper watersheds, where numerous first- and second-order channels intersect larger, fish bearing streams at a high spatial frequency (Map 12). Maps 11 and 12 can be used in conjunction with one another to identify channel segments prone to natural disturbance and thus could be used to help inform restoration planning and in-stream monitoring.

3.5 Forest Management

3.5.1 Early European Land Uses

The forested lands in the Wilson River watershed occur from the lowlands through the uplands, the majority extending upward from the foothills. Prior to European settlement, the Native Americans of the Tillamook area would frequently burn the forested lowlands and surrounding areas to clear the areas of brush, stimulating vigorous, tender, vegetative regrowth for ponies to feed on and to allow them to harvest various seeds and other resources (Winters 1941). As settlers moved into the Tillamook area, they began clearing some of the forested lowlands to create farmlands suitable for plowing. As more settlers arrived and worked to clear the lands, fires in the area were documented in greater detail and over increasing areas up through 1874 (Coulton et al. 1996). Additionally, much

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[12] For definitions, refer to Appendix D – Natural Disturbance Theory and Simulation, Appendix E – Detailed Methodologies, Appendix R – NetMap Analysis of Critical Road Locations and Appendix T – Slope Stability Assessment.

of the land adjacent to the tidewaters was diked and drained to allow the fertile soils to be turned into farmlands. Settlers ignored the uplands, however, because they were too steep for farming so they remained largely in the public domain until the end of the 1800's.

As farming interest took hold in the valley through the end of the 1800's, large Great Lakes timber companies, realizing the profits that could be made from harvesting the large old-growth Douglas-fir trees of the region, began buying up some of the forested lowlands and laying claim to much of the timbered uplands (Fick and Martin 1992). Early efforts to log the area occurred primarily in the lowlands and were often one-man operations. As technologies improved and roads and railroads pushed further into the watersheds and up the mountains, the size and extent of the timber harvest increased.

Toward the end of the 19th century, logging operations moved from one man hand operations to oxen pulled multi-man operations. Shortly after the turn of the 20th century, the use of steam-donkeys ushered in a new era of logging, allowing dozens of men to harvest entire hillsides, something almost entirely unheard of up to that point. Steam donkeys, followed by chainsaws around the middle-half of the 1900's, remained the primary pieces of logging equipment until after the Second World War. After the war, diesel equipment began to be utilized with increasing frequency, allowing even larger portions of lands to be harvested in an even more efficient manner.

3.5.2 The Tillamook Burn and Reforestation

Forest fires were relatively commonplace in the Coastal Mountains but a series of catastrophic burns, ignited in 1933 and following every six years until 1951, drastically changed the landscape from one of dense forests to one of barren and denuded wasteland. Collectively called the Tillamook Burn (refer to Map 10)), this series of wildfires prompted land managers to completely rethink the way in which timber harvest occurred. Up to that point, logging operations would often simply cut over large tracts of land, often harvesting only the largest of the old growth trees and leaving the others behind, burn the slash, and move to the next tract. Reforestation efforts were nearly unheard of and, after repeated burns that made much of the timber unfit for harvest, private timber companies often stopped paying taxes on the lands, allowing them to go tax-delinquent.

As the embers from the first Tillamook Burn (1933) faded, public outcry over the loss of timber (and the revenue it generated, both in timber sales and in taxes) prompted the Department of Forestry to formulate a plan to rehabilitate and reforest the burned areas. The plan that followed was unprecedented both in its goals and scope of the work. The US Forest Service, at the request of the counties and with permission from the Department of Forestry, undertook two natural reproduction studies (1935 and 1937) with the purpose of studying the natural regeneration of Douglas-fir and associated species following catastrophic fires. Results from these studies were largely responsible for shaping future rehabilitation efforts.

Additionally, to reduce the hazardous conditions in the Tillamook Burn, the Forest Service recommended 1) that roads be constructed to salvage log the area, 2) firebreaks be developed along the railroads and roads by felling snags, cleaning debris and forced burning, and 3) continue to close the area to the public during severe weather conditions. To reforest the area, the Forest Service recommended 1) protecting the remaining seed trees in the area from logging and slash burning and 2) seeding and planting of areas lacking seed trees after salvage logging had occurred.

Although the Forest Service provided these recommendations to the State, the Forest Service felt that it would be the best equipped, indeed, the only entity that could carry out a plan of this magnitude. The State, however, disagreed but continued to work cooperatively with the Forest Service from 1941 through 1947 on rehabilitation and reforestation efforts. In 1947, the Forest Service agreed that it did not have the money to undertake such a large project, leaving the State and counties to finish the rehabilitation and reforestation efforts.

Early reforestation efforts, carried out by both the Department of Forestry and volunteer organizations, got underway in January 1941 when the initial hand plantings (Port Orford cedar seedlings) took place along the trail from the Wilson River Highway to Cedar Butte Lookout. The Second World War, however, sequestered most of the manual labor needed for tree planting and little reforestation occurred until after the end of the war. Removal of snags and the construction of logging roads, part of the original Forest Service recommendations, decreased reforestation costs when large-scale reforestation efforts again resumed in 1949, the official start of the rehabilitation and reforestation program. Prior to 1949, however, the State had already begun sporadic snag-falling and tree planting, especially around the Owl Camp area and the upper Wilson River watershed. Additionally, they had undertaken an experimental aerial seeding program on a 600 acre burned plot in Tillamook County (1945-1946).

Reforestation efforts began in earnest with the official kick-off in 1949 and continued through 1973 with initial plantings peaking in 1963 and replanting peaking in 1970 (Fick and Martin 1992). Unfortunately, the fire had consumed much of the fertile topsoil, creating difficult growing conditions for plant/tree growth. As a result, many animals switched to foraging on the tender shoots of the newly planted trees, creating a serious obstacle to successful reforestation. Early in the 1940's the State initiated a rodent control program that could be carried out while hand planting the trees. As aerial seeding became the preferred method of reforestation, aerial rodent control also gained attention and, by 1946, was in full production.

By the end of the 1940’s, rodent damage to seedling had decreased considerably but another seedling damage problem was rapidly raising alarms and, by the mid 1950’s, surveys of replanted areas found nearly 80% of the replanted seedlings had been damaged by foraging from deer and elk. The Oregon Game Commission responded to calls from the State to control deer and elk populations and, starting in the fall of 1956, controlled either-sex deer hunts in the burned regions began thinning out cervid populations. These controlled either-sex hunts continued, with moderate success, until the early 1960’s when it was determined that the damage to seedlings was within acceptable levels.

Reforestation efforts were also hampered by faster growing plant species that shaded out the young seedlings (e.g., ferns, salmonberry, thimbleberry, vine maple, alder, cherry, hazelnut, etc.). By 1958, the Department of Forestry recognized that they could no longer ignore the rapidly spreading hardwood thickets that had taken over much of the burned areas. Of particular concern were the stands of alder that had rapidly moved up the hillslopes from the stream bottoms. Thickets of salmonberry and thimbleberry were also creating shade problems for seedling growth and survival. Early manual efforts to control these stands/thickets met with limited success and, in 1958, aerial applications of herbicides became relatively commonplace and continued until 1973 (Fick and Martin 1992).

Early in the 1960’s, however, it became clear that another problem was hampering the growth of the new forests. Early reforestation efforts had planted trees at relatively thick densities and overcrowding by other seedlings resulted in competition for limited nutrients. Starting in 1962, aerial application of herbicides targeting young hardwood species was initiated and carried out with relative success until 1973 (Fick and Martin 1992). Additional manual thinning of overcrowded tracts was started in 1965 and continued through until 1973 (Fick and Martin 1992).

In July of 1973, an official ceremony marking the end of the Tillamook Burn rehabilitation effort was held, 40 years after the first Tillamook Burn and just 24 years after the official rehabilitation kick-off ceremony. Tree planting, however, continued in some of the burned areas that had still not been replanted while stands continued to be actively thinned to prevent overcrowding. Even though the rehabilitation efforts had been officially concluded, the effects from the fires would be evident for generations and are still being actively addressed today.

3.5.3 Recent Forest Management and Associated Policies/Regulations

Large-scale, stand-replacement fires shaped early (organized) riparian management. Following the fires, a public/private conglomerate enterprise called the Consolidated Timber Company was created to conduct salvage operations (West Consulting 2000), with the intent to increase fire control, intensively harvest salvaged trees, fall snags, and construct a vast network of fire roads to increase fire control and facilitate the planting (and eventual harvest) of even-aged Douglas-fir.

Following the salvage logging period (early 1950s), organized management goals became official with standards enacted by the Oregon Forest Practices Act in 1972. Part of this legislation involved guidelines for the establishment of streamside buffer strips. In 1987, a comprehensive revision to harvesting and road construction rules was made, with additional rules to protect riparian zones. The revision specifically required set numbers and sizes of conifer trees to be retained in riparian management areas in western Oregon. Other aspects included site-specific protections for endangered and threatened species and ecologically significant areas, including wetlands.

Over the last few decades, a new forest management concept has emerged; the concept of managing riparian zones for *ecosystem services*. Beginning in 1988 and adopted in 1991, rules were established to provide specific numbers and sizes of residual conifer tree species in riparian zones, within 100 feet of all Class I streams, and within 300 feet of ecologically sensitive areas, including wetlands. Incentive programs were developed in the mid-1990s to provide for stream enhancement, and an initial designation of a *desired future condition* was established to manage classes of riparian stands for “mature forest” and to provide for conversion management options to revert hardwood-dominated stands to conifer dominance in areas where conifers were historically dominant.

The Forest Management Plan (FMP), approved in 2001[13], provided management standards designed to produce riparian zones in mature forest condition. These riparian areas, conceptually, would provide *ecosystem services* to the stream channel, including stream shading, large wood (LW) recruitment, and other less quantifiable functions, such as sediment retention. The major goals of the Forest Management Plan are to provide for:

- Sustainable timber production, and

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[13] ODF 2000. Northwest Oregon State Forests Management Plan, Final Draft. http://www.odf.state.or.us/DIVISIONS/management/state_forests/sfplan/nwfmp01-final/31-J-Aqua-Rip.prn.pdf

- Properly functioning aquatic habitat; habitat for native species, protect soil, air and water, and to provide recreation.

3.5.4 Forest Recreation

Recreation has also long been an important use of the Tillamook Basin and Wilson River. The Wilson River has been a hunting, fishing and camping destination since the pioneering era when those traditions were established. However, the series of fires known as the "Tillamook Burn" interrupted those activities and changed the face of the forest completely. In the four to five decades since the fires, salvage and replanting program era, the forest has seen a steady increase in the level and range of recreational pursuits. Traditional pursuits like hunting, fishing and camping have gradually been overtaken or extended by fast growing technology. Off-highway vehicle (OHV) use has increased by 50% during the 1997 to 2001 period.[14] Nationally, the number of OHV users climbed sevenfold in the last 30 years--from five million in 1972 (1 in 42 persons) to 36 million in 2000 (1 in 8 persons).[15]

Off road motorcycle riding and four-wheel driving have long been commonplace in the Tillamook State Forest. Some clubs representing these users have been in existence for 50+ years and have third generation members being recruited into the sport as soon as they are big enough to handle a mini-bike.

From 1945 to 1975 the ODF established 12 campgrounds primarily focused on concentrating campers into stream side campgrounds to reduce fire risk. The program was cut back in 1980 leading to campground closures, loss of recreation staff and halting of fee collection for designated campsites. From 1980 until the new Recreation Management Plan came into effect in 1993, camping became dispersed and unmanaged leading to resource impacts, social conflicts and long term occupancy (homeless camps). Motorized recreation impacts worsened and users had free reign to ride anywhere and any season. OHV impacts on riparian zones were especially pronounced because vehicles and motorcycles were routinely using the streams and campsites as motocross and obstacle courses. OHV events were being routed down streams in the middle of spawning seasons. Clubs held events with little oversight or restriction except in fire closure periods.

The legacy of firebreaks, logging roads, and skid trails from railroad logging, firefighting, salvage operations and reforestation became the network OHV users

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[14] In an October 30, 2003 letter from the NM Tourism Department to The Consumer Products Safety Commission (CPSC) using CPSC April 23, 2003 data to present OHV legislative initiative in New Mexico

[15] In a July 7, 2004 press release issued by Forest Service announcing their release of proposed OHV rule available at
http://www.fs.fed.us/news/2004/releases/07/off-highway-vehicle.shtml.

explored and reestablished. Many of these roads and skid trails were not built or intended for long term use. Steep grades, poor or non-existent drainage, and placement in riparian areas have all resulted in failures of the road structure and failure of puncheon bridges. OHV pressure continues on these roads and stream crossings until made impassable, or the site of multiple ad hoc alternatives.

Until the mid-1990s there were no geographic or seasonal restrictions on OHV use across the watershed. Events were largely unmanaged and routes not assessed before or after the activity. Problems with resource damage, productivity loss and public safety mounted over time. Tree damage from target shooting has been a long standing problem across the forest with little to no restrictions on where or when shooting can occur. Regulations were not fully developed for state forests, seldom posted, rarely enforced and widely ignored resulting in an array of disturbance patterns, which include;

- Extensive penetration into all corners of the forest by OHV and vehicle based recreational users.
- Extensive use of RVs and OHVs by hunters puts additional pressure on dispersed campsites and trails during the wet season.
- Intensive use of accessible riparian areas for dispersed camping and OHV recreation
- Chronic erosion and resource damage
- Cut bank riding and road drainage sedimentation
- Garbage, human waste, dumping and temporary campsite remains
- Uncontrolled target shooting and associated trash (skeet fragments, lead, shells, man-made targets, appliances and tree damage)
- User defined trails with high resource impacts
- Vandalism to signs, structures, private property and forest resources
- Unmanaged and unrestricted minor forest products gathering
- Little or no restriction on OHV event course location.

The 1993 Tillamook State Forest Recreation Management Plan (RMP) was developed to address these issues and an array of user education, experience and management goals. Steady progress has been made implementing the RMP to the extent that staff estimate more than 90% of action items have been accomplished.

However, user demands and especially OHV event management pressures continue to outstrip staff capacity and mitigation efforts. Resource damage continues to be a serious issue, particularly erosion from the OHV trail system and riparian vegetation impacts from dispersed camping, although stream crossings on the designated trail system have been gradually replaced by bridges, culverts or reroutes. For more detailed recreation-related forest issue discussions, see section 6.7 – Recreational Impacts on Riparian Vegetation – Direct and Indirect Effects and section 7.5 – Recreation-Related Issues.

3.5.5 Stream-Road Crossings

Over time, the ODF has changed the way it manages stream crossings at culverts. Originally, culverts were designed to allow water to flow freely and to prevent debris from collecting inside. A successfully designed culvert was one that moved water quickly through the smallest diameter pipe possible (Paul et al. 2002.) With the passing of the Endangered Species Act, managers began considering culverts in terms of barriers to fish passage. In 1995, ODF released the first document about constructing stream crossings at Type F streams (Mills and Stone 1995) with emphasis on juvenile fish passage. After the flood producing storm in February 1996, ODF accelerated culvert replacement using money allocated to the State by the Federal Emergency Management Agency (Mills personal communication). Within this time frame ODF forest practice rules changed regarding culverts. In 1994, culvert volume requirements went from a 25 year flow with unspecified headwater to a 50 year flow with headwater at the top of the culvert. Since 1996, ODF has, when dealing with all stream crossings, designed culverts with fish use in mind and has followed ODFW Fish Passage statutes and criteria since their adoption in 2001. Today culverts are designed to optimize fish passage, and cross-drains are designed to filter road run-off sediment away streams. For more detailed stream-culvert crossing discussions, see section 7.4.6 Stream Crossings and section 9.13 Fish Passage Barriers.

4 Stream Channels and Channel Modification

4.1 Methods/Background

This stream channel analysis was conducted using NetMap software (Benda et al. 2007). Using NetMap's functions to calculate habitat intrinsic potential (HIP) for coho salmon and steelhead trout (e.g., Burnett et al. 2003), habitat core areas (using HIP for coho and steelhead), and predicted biological hotspots, we can better understand how channel habitat types have been modified. Habitat intrinsic potential is based on a simple empirical model developed for the Oregon Coast Range that ranks habitats according to channel gradient, valley confinement, and flow. Habitat core areas are defined by connected habitat having a defined critical HIP score and size (length). Rankings of biological hotspots is based on biologically relevant physical characteristics such as gradient, confluence effects, and wood accumulation types. For detailed descriptions of the methodology used to complete this section, see Appendix E – Detailed Methodologies. While the results for coho and steelhead HIP, biological hotspots, and channel classification are found below, additional analyses are located in Appendix D – Natural Disturbance Theory and Simulation and Appendix F – Classification of Stream Channel Habitat Types. Additionally, to ensure accuracy, several NetMap watershed parameters were field validated. Results from the field validation analysis are found in Appendix S – Field Validation of Some NetMap Parameters.

4.2 Channel Habitat Types

A classification of stream channel habitat types was performed to lay the foundation for the Habitat Intrinsic Potential (IP), habitat core areas and biological hotspot and channel disturbance analyses. The different types of habitat classification can be used in different ways in the watershed analysis and in forest management. 'Habitat intrinsic potential' for coho and steelhead juvenile rearing (e.g., Burnett et al. 2003) provides a broad brush classification of general habitat potential in a watershed. The addition of large wood accumulation types and confluence effects creates more specificity to HIP values that might be useful in site specific projects or on-the-ground habitat evaluation. 'Habitat core areas' identifies concentrations of the best potential habitats that in effect sews together somewhat disparate pieces of habitat (HIP for coho and steelhead in this case). This information could be used to inform subbasin-scale plans for resource use and even habitat restoration measures. In other words, basins with the most core areas may be of the most concern. Finally, 'Biological hotspots" includes other more site specific habitat attributes known to be important to fish habitat like woody debris accumulation types and confluence environments. This finer scale rendering of habitat potential could be used to plan more site specific projects, like stream reach scale restoration measures or habitat monitoring projects. Thus the selection of one habitat classification over another is somewhat dependent on the scale of application and interest. Because the channel habitat type classifications were not of primary interest, however, results from the analysis are presented in Appendix F – Classification of Stream Channel Habitat Types.

4.3 Habitat Intrinsic Potential

NetMap's analyses of habitat intrinsic potential (HIP) for coho and steelhead trout are shown in Maps 13 through 15. Generally, a high HIP value is considered to be greater than 0.7 (Burnett et al. 2003). High HIP values for coho would apply to low gradient (<2%) and unconfined channels. In the Wilson watershed, HIP for coho juvenile rearing habitat greater than 0.7 encompasses approximately 10% of the fish-bearing network (ODF fish bearing) and concentrated in the eastern most portion of the basin and in the western most portion nearest the estuary (Map 13). Overall, the Wilson basin appears to provide fair to poor habitat for coho salmon, particularly across the upper steeper portions of the basin, the exception being the lower gradient portions of the Devils Lake Fork. For juvenile steelhead trout, approximately 46% of the fish-bearing network (ODF fish bearing) has a predicted HIP of greater than 0.7 (Map 14). The predicted HIP for coho with the addition of tributary confluence effects and jam-partial jam wood accumulation type is shown in Map 15.[16]

4.4 Habitat Core Areas

NetMap was used to create habitat core areas for coho and steelhead juvenile salmonids. The critical habitat factors for the core areas for both species were a HIP greater than or equal to 0.7 (a threshold recommended in Burnett et al. 2003), a maximum habitat proximity distance of 500 meters, and a minimum habitat core area persistence length of 1,000 meters. The resulting predicted core habitats for coho (Map 16) are limited to the far eastern and far western (estuary) portions of the networks and comprise a total of approximately 12% of the fish-bearing network.

The predicted area of core habitats for steelhead is distributed throughout the Wilson watershed (Map 17) and comprises approximately 45% of the fish-bearing network. Thus, based on habitat intrinsic potential predictions (e.g., Maps 15 and 16) and estimated core habitat areas (e.g., Maps 18 and 19), the

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[16] For definitions, refer to Appendix D – Natural Disturbance Theory and Simulation, Appendix E – Detailed Methodologies, Appendix R – NetMap Analysis of Critical Road Locations and Appendix T – Slope Stability Assessment.

Wilson watershed is dominantly a steelhead fishery system. However, there are patchy but significant areas of coho habitat, particularly in the far eastern and western portions of the basin.

4.5 Biological Hotspots

The map of potential biological hotspots for the Wilson watershed is shown in Map 18 (refer to section 4.2, above, for a definition). Approximately 14% of the fish-bearing network was classified as having a biological hotspot index of > 0.7 and only about 5% of the network was classified as having a biological hotspot index of> 0.8. The parameter used to create biological hotspots includes 1) tributary confluence effects, 2) channel gradient, and 3) valley confinement.[17]

4.6 Sensitive Areas

Channel sensitive areas are those that are most likely to have a change in morphology given the addition or removal of sediment from natural watershed processes (landslides and floods) or from land use related events, including landslides, etc.

4.6.1 Background/Methods

A habitat sensitivity index was created using the parameters of 1) gradient, 2) confinement, and 3) local channel segment-scale sediment supply (t/km^2/yr). The most sensitive channel segments are those classified as meandering in gravel beds and typically have a gradient less than 2%. In addition, unconfined channels are generally those with a valley width to channel width ratio of greater than 5. Local sediment supply was calculated in NetMap using an average basin erosion rate of 100 t/ km^2/yr. Based on that average, a channel-segment-scale threshold erosion rate of 130 t/ km^2/yr was used (e.g., 30 t/ km^2/yr > than the average) based on NetMap's predicted sediment supply associated with high landslide and debris flow terrain in the Wilson River watershed.

4.6.2 Results

The resultant "habitat sensitivity index" map created by the "Habitat Index" tool in NetMap differentiates the fish-bearing channel network into classes of habitat sensitivity that varies from 0 to 1 (Map 19). For example, approximately 15% of the fish-bearing network is classified as having a relatively high sensitivity (> 0.7). The highest sensitivity channels (> 0.7) are scattered across the Wilson River basin with the highest concentrations located in upper subwatersheds that

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[17] For details of the model parameterization using NetMap's habitat creator tool, see the NetMap datafile "Wilson_hot".

have combinations of lower gradient habitats and high erosion potential. The Little North Fork Wilson river subwatershed exhibits the highest overall sensitivity and the Devils Lake Fork, Lower Wilson and Middle Wilson subwatersheds exhibit the lowest overall channel sensitivity.

4.7 Channel Modifications

4.7.1 Methods

We reviewed existing material relevant to the locations and significance of channel modifications and disturbances within the Wilson River watershed, and compared these to channel sensitivities. Materials reviewed included:

- ODFW aquatic habitat inventory GIS data and survey reports (supplied for this assessment by ODF)
- Wilson River Watershed Assessment (E&S Environmental Chemistry 2001)
- Development of an Integrated River Management Strategy, Final Report (Philip Williams & Associates et al. 2002).
- 2006 road survey data collected by DCA
- 2005 color digital orthoquads of the Wilson River watershed
- Additional ODF watershed analyses from adjacent basins[18]
- GIS coverages showing State Highways and Railroads[19]
- Federal Emergency Management Agency (FEMA), National Flood Insurance Program's floodplain maps[20].

The ODFW aquatic habitat inventory GIS data and survey reports reviewed for this assessment identified no areas of channel modification along any of the streams surveyed[21]. Channel modifications were mapped in GIS to the extent possible given available information. Materials from this and other sections of the assessment were synthesized to evaluate:

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[18] http://www.oregon.gov/ODF/STATE_FORESTS/watershed.shtml

[19] http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml

[20] http://libweb.uoregon.edu/map/gis_data/fema.html

[21] As part of the RFP for this assessment, ODF specifically asked about modifications in the vicinity of South Fork Camp. Although ODFW surveys covered this area, no significant modifications were identified.

- The extent to which historic modifications and disturbances are impacting current conditions,
- The distribution of modifications and disturbances by channel sensitivity,
- The relative magnitude of modifications and disturbances among the sixth-field subwatersheds within the Wilson River, and between the Wilson River and adjacent similar watersheds that have available data on channel modification and disturbance.

4.7.2 Results

Known channel modifications within the Wilson River watershed are shown on Map 20. Six types of channel modifications were identified in this assessment, and are discussed in the following paragraphs. Dredging and gravel extraction within the lower river are additional modifications that historically occurred but current operations are extremely limited in scope and volume of material extracted and are not discussed in this section. The majority of channel modifications occurred on non-ODF lands (only "Canyon Fill" and "Channel Fill" occurred on ODF lands), and are beyond ODF's power to change.

Dikes occur exclusively within the Lower Wilson River subwatershed (Map 20) where there are approximately 2.5 miles of them (Table 7). Dikes within the Lower Wilson River were likely constructed to reduce saltwater intrusion in farm fields, as well as to constrain the location of the river in its existing location.

Table 7. Summary of channel modifications. Miles of each feature are summarized by subwatershed.

Subwatershed	Dikes	Highway fill	Railroad fill	Canyon Fill	Channel Fill	Log drives
Devils Lake Fork	-	2.5	-	-	-	-
Jordan Creek	-	-	-	-	0.1	-
Little North Fork Wilson River	-	-	-	0.2	-	-
Lower Wilson River	2.5	2.6	0.5	-	0.1	17.3
Middle Wilson River	-	-	-	-	-	8.5
North Fork Wilson River	-	-	-	0.0	0.1	-
South Fork Of Wilson River	-	-	-	-	-	-
Upper Wilson River / Cedar Creek	-	3.0	-	0.1	0.0	5.3
Grand Total	**2.5**	**8.1**	**0.5**	**0.3**	**0.4**	**31.1**

Over eight miles of highway fill have been identified as limiting channel migration and flood flows along the Wilson River (Map 20; Table 7). Sections of highway fill along US Route 101 north of Tillamook are located within the floodplain of the Wilson River (Map 20). State Highway 6 follows the mainstem of the Wilson River from Tillamook to the crest of the coast range in the Devils Lake Fork subwatershed. Portions of Highway 6 impinge on the river in the Lower Wilson and Upper Wilson/Cedar Creek subwatersheds. In the Devils Lake Fork subwatershed, several sections of fill slope impinge on the river as the highway climbs in elevation towards the pass (Table 7; Map 20).

The Port of Tillamook Bay Railroad crosses the Wilson River floodplain east of US Route 101 (Map 20). Approximately one half mile of fill associated with the railroad is located within the 100 year floodplain (Table 7).

The 2006 road survey conducted by Duck Creek Associates identified two types of channel modifications associated with roads on ODF land. Segments identified as “canyon fill” consist of roads in steep, narrow canyons, with high cuts and fills crowding the stream in places. Segments identified as “channel fill” consist of roads next to and sometimes crowding stream, though in a generally stable location. Very few road segments were identified as either canyon or channel fill (Table 7; Map 20). The five segments identified as canyon fill total 0.3 miles, and the five channel fill segments total 0.4 miles.

4.8 Historic Channel Disturbances

4.8.1 Methods

We reviewed existing materials relevant to the locations and significance of channel modifications and disturbances within the Wilson River watershed, and compared these to channel sensitivities. Materials reviewed included:

- Wilson River Watershed Assessment (E&S Environmental Chemistry 2001)
- Environmental History of the Tillamook Bay Estuary and Watershed (Coulton et al. 1996)
- Development of an Integrated River Management Strategy, Final Report (Philip Williams & Associates et al. 2002).
- Additional ODF watershed analyses from adjacent basins[22]

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[22] http://www.oregon.gov/ODF/STATE_FORESTS/watershed.shtml

- Federal Emergency Management Agency (FEMA), National Flood Insurance Program's floodplain maps[23].
- Regional- and local-scale assessments of splash-damming and log drives (Sedell and Duval 1985, Coulton et al. 1996).
- Historic ODF stream survey and cleaning reports from the 1940's to 1970's.

Channel modifications were mapped in a GIS to the extent possible given available information. Materials from this and other sections of the assessment were synthesized to evaluate:

- The extent to which historic modifications and disturbances are impacting current conditions,
- The distribution of modifications and disturbances by channel sensitivity,
- The relative magnitude of modifications and disturbances among the sixth-field subwatersheds within the Wilson River, and between the Wilson River and adjacent similar watersheds that have available data on channel modification and disturbance.

4.8.2 Results

Information on historic log drives and splash damming was taken from Sedell and Duval (1985) and Coulton and others (1996). Coulton and others (1996) summarize information from a navigability study of the rivers of Tillamook Bay (Farnell 1980) that suggest that log drives occurred along the mainstem Wilson River from the mouth upstream to river mile 22.5. Sedell and Duval (1985) indicated that the log drives extended upstream of Lee's Camp to approximately river mile 31 (Map 20; Table 7). Log drives on the Wilson River ended by 1908. No splash dams were identified to have occurred within the Wilson River watershed, although there are records of dams on other Tillamook Bay tributaries.

No information is available on persistent impacts from splash damming within the Wilson River watershed. However, given that approximately 100 years have passed since the end of log drives it is likely that impacts to stream banks and riparian vegetation have recovered to a large extent. Impacts due to removal and loss of large wood accumulations/jams likely persist to the present day.

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[23] http://libweb.uoregon.edu/map/gis_data/fema.html

ODF supplied over 200 pages of historic stream survey reports for the Wilson River watershed conducted primarily in the 1950's, but spanning the period from the late 1940's to the early 1970's. These reports described observations made by aquatic biologists during field reconnaissance of the mainstem Wilson River and tributaries. These surveys were extensive, appearing to have covered at least portions of most major streams and tributaries. The primary focus of these surveys was observations of spawning gravel size and quality, observations of fish and fish carcasses, notes on possible stock-supplementation sites, and identification of potential barriers to fish passage. Areas of recent stream cleaning were also noted. Numerous large log jams were noted as part of these surveys, and most were rated as being barriers to fish migration. It is assumed that many of these jams were targeted for subsequent removal. Given that these surveys occurred following the major fires in the area it is not surprising that many large jams were identified; most likely as a result of fire-killed instream large wood (LW) recruitment. Although no quantitative conclusions can be derived from these records, it is clear that extensive stream cleaning occurred throughout the watershed (heaviest in the areas of greatest fire impacts), which most likely resulted in habitat simplification and release of large quantities of stored sediments that may have otherwise been stored in stream banks and streamside terraces.

4.9 Channel Habitat Types Impacted By Channel Modification

4.9.1 Methods

As discussed in section 4.1 Methods/Background and Appendix F – Classification of Stream Channel Habitat Types, a channel classification system was developed for the Wilson River watershed based on channel gradient and channel confinement. Channel confinement consisted of two categories; streams whose ratio of valley width (Vw) to channel width (Cw) was less then or greater than five. Channel sensitivity to modifications generally decreases with increasing gradient and confinement.

4.9.2 Results

Channel modifications are summarized by channel class in Table 8. The majority of modifications are located off of ODF lands and are beyond the control of ODF managers. Disturbances on ODF lands (i.e., channel fill and canyon fill segments) occur primarily in less responsive steep and/or confined segments (Table 8). The three areas of channel fill that are identified along channel type 1A occur along the North Fork Wilson River in the North Fork Wilson subwatershed and along two distinct sections of Jordan Creek in the Jordan Creek subwatershed. These three segments should be the highest priority areas for remediation on ODF lands.

Table 8. Summary of channel modifications by channel class. Miles of each feature are summarized by channel class. Channel sensitivity generally decreases with increasing gradient and confinement (i.e., from left to right across the table).

	Gradient <2%		**Gradient 2-4%**		**Gradient 4-8%**	**Gradient >8%**	**Unknown gradient and Confine-ment**
	Vw/Cw <5	**Vw/Cw >5**	**Vw/Cw <5**	**Vw/Cw >5**	**Vw/Cw <5**	**Vw/Cw >5**	
Channel modification	**1A**	**1B**	**2A**	**2B**	**3A**	**4B**	**n/a**
Canyon Fill	-	-	-	-	0.1	-	0.2
Channel Fill	0.2	-	-	-	0.0	0.1	-
Dikes	-	2.5	-	-	-	-	-
Highway fill	4.8	1.8	1.3	0.1	0.1	-	-
Log drives	19.7	10.6	0.3	-	0.5	-	-
Railroad fill	-	0.5	-	-	-	-	-
Grand Total	**24.8**	**15.3**	**1.6**	**0.1**	**0.7**	**0.1**	**0.2**

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5 Hydrology and Water Use

5.1 Introduction

The Hydrology / Water Use assessment consists of several separate sections. Flood History is discussed in section 5.2. Land use effects on peak and low flows (section 5.3) form the bulk of the discussions, and rely on new data and analyses completed as part of this assessment. Water use is discussed in section 5.4 – DHSVM Future Modeling of the report, and is largely summarized from the *Wilson River Watershed Assessment* (E&S Environmental Chemistry, Inc. 2001), with supplemental data (where appropriate) from the Oregon Department of Water Resources (OWRD). Methodologies are discussed within each subsection. Note: Land Use is usually presented in this portion of the analysis when following the OWEB protocol, however, in this assessment land use is presented in sections 3.3.1, 3.3.2 and 3.5.1, above.

5.2 Flood History

5.2.1 Methods

The flood history of the Wilson River watershed is based on long term records available for a single USGS stream gage (#14301500, Wilson River near Tillamook), located within the Lower Wilson River subwatershed. Flood history at the gage is summarized in Figure 1 and Table 6 located in section 3.4.2 of this report. The purpose for assessing the flood history was to evaluate temporal trends in annual peak flows at the Wilson River stream gage. Trends were investigated in the residual variation after accounting for the influence of precipitation.

Regression analysis was used to examine the relative significance of precipitation on stream flow, following which time trends were evaluated in the residual variation. The residual variation was plotted against time to determine if there was a time trend in the unexplained variation. Kendall’s rank-order correlation (Kendall and Gibbons 1990) was used to test for trends over time in the residual variation. Kendall’s test is a non-parametric method of determining an increasing or decreasing trend in a paired data set. Values of the trend coefficient range from –1.0, which indicates a perfect inverse correlation, to 1.0, which indicates a perfect positive correlation. For this analysis, significance was defined at the $p < 0.05$ level.

Precipitation records from the Seaside climate station[24] were used for this portion of the analysis. The Seaside station was chosen because it was the only climate station in the vicinity of the watershed whose period of record coincides with the period of record for the Wilson River gage. The Seaside station is located approximately 33 miles NNW of the center of the watershed. Missing values in the Seaside record were estimated from records from the Tillamook 1W and Newport climate stations using regression analysis.

The effect of precipitation on annual peak flow was evaluated using an antecedent wetness index as the precipitation variable. The antecedent wetness index was derived using daily precipitation values from the Seaside climate station following the approach used by Lewis and others (2001). The underlying assumption of the antecedent wetness index is that precipitation occurring prior to time “t” influences the runoff efficiency at time “t”, and that this influence decays over time. Put another way, the runoff associated with today’s precipitation will be strongly influenced by yesterday’s precipitation, slightly less by precipitation from the day before yesterday, and so on. The antecedent wetness index was calculated as follows:

$$\mathbf{W_i = C*W_{i-1} + P_i}$$

Where: C = wetness constant
W_i = antecedent wetness index on day i (inches)
W_{i-1} = antecedent wetness index on day i-1 (inches)
P_i = precipitation on day i (inches)

The value of the wetness constant is the value that satisfies the relationship $C^{\text{half-life}} = 0.5$, where half-life is in days. The value of C used was arrived at iteratively by trying several values for C, and finding the value that gave the best solution (i.e., highest r^2 value) for the equation:

$$\mathbf{Q_p = f(W_i)}$$

Where: Q_p = Annual peak flow
W_i = Wetness index on day of the peak flow

A final C value of 0.7000 was chosen, which resulted in a half-life of approximately 2 days, which makes intuitive sense for a watershed of the size and location of the area upstream of the Wilson River stream gage.

Additionally, we qualitatively evaluated how the effects of major storms of the past ten years impacted the various subwatersheds of the Wilson River by

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[24] http://www.ocs.oregonstate.edu/page_links/climate_data_zones/daily_precip/precip_filesz1.html

evaluating changes in channel area for eight reference stream reaches. The eight reaches were located at or near the downstream end of each subwatershed, and were ½ mile in length[25]. All reaches were in areas mapped as low-gradient with valley widths five or more times wider than active channel widths. Channel areas in the reference reaches was measured on aerial photos taken during summer 1994. The 1994 values were used as the reference for comparison with later years. Ideally, a reference condition from the 1950's would have been used, as this would have represented a period of relative quiet with respect to large flood events (Figure 1). However, the 1994 photos were the earliest geo-referenced photos available for the project area. Furthermore, the 1994 photos represent conditions prior to the large flood events of 2/8/1996, and 12/27/1998 (Figure 1). Active channel area was measured on photos taken in Summer 2000, and Fall 2005.

5.2.2 Results

The relationship between annual peak flow and wetness index at the Wilson River stream gage is shown in Figure 3. Residual variability in the relationship is plotted over time in Figure 4. No statistical trend was detected in the residual variability ($p = 0.0842$). Based on these results there is no statistical time-related trend in peak flow magnitude at the Wilson River stream gage.

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[25] With the exception of the reach along the Wilson River in the Lower Wilson subwatershed, which was located upstream of the confluence with the Little North Fork, and was one mile in length.

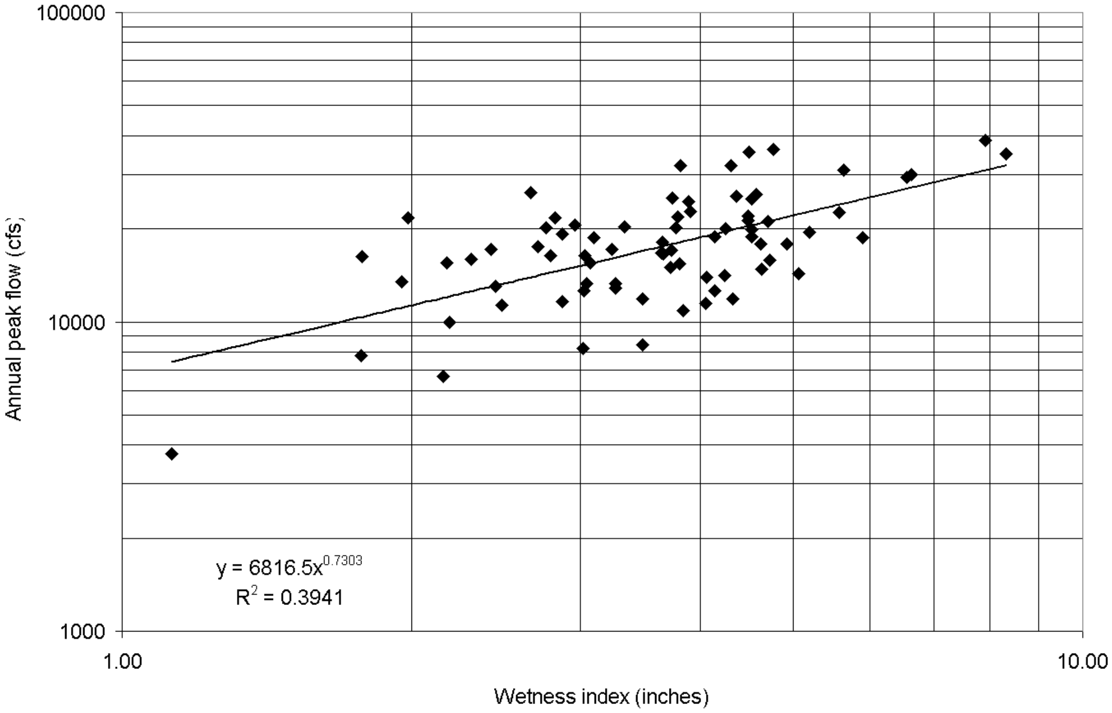

Figure 3. Relationship between annual peak flow and wetness index at the Wilson River stream gage.

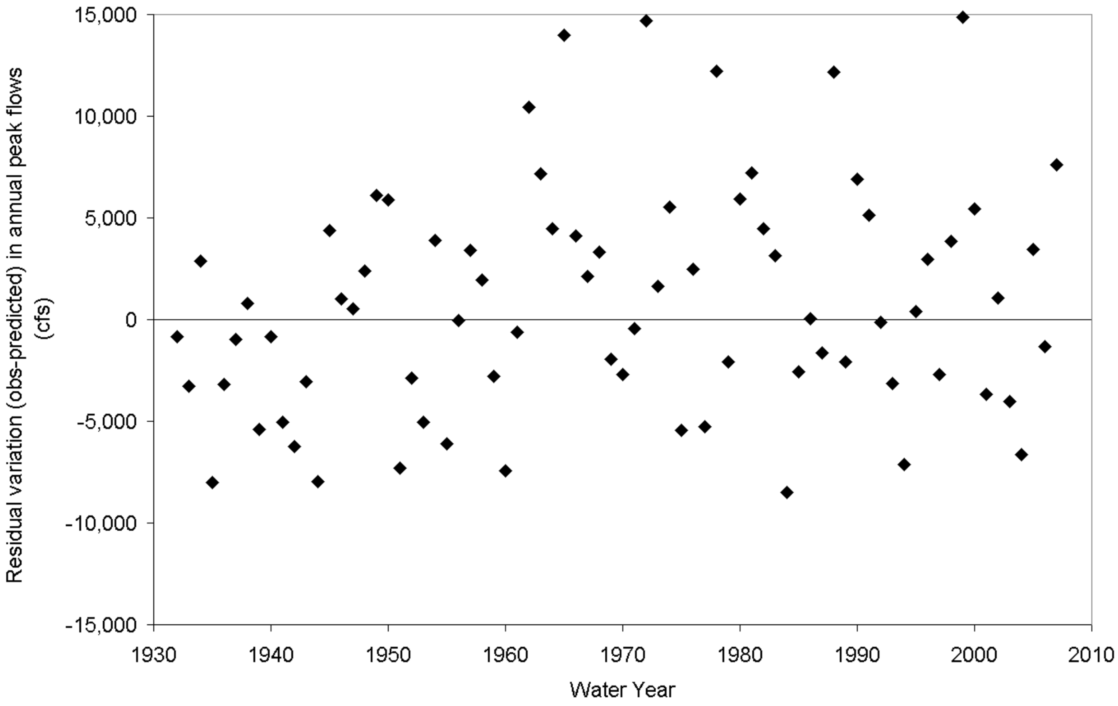

Figure 4. Residual variability in the relationship between annual peak flow and wetness index at the Wilson River stream gage.

We would expect that a long-term trend in channel narrowing is occurring in the Wilson River mainstem, as the channel recovers from past log drives. However, this is not visible over the eleven year period represented by this assessment. The ratio of active channel area in 2000 and 2005 to area in 1996 are shown in Figure 5. Higher-elevation subwatersheds (Jordan Creek, Devils Lake Fork, Upper Wilson/Cedar Creek, and North Fork Wilson) showed the greatest relative channel widening in the 1994 to 2000 period, while the lower elevation showed relatively minor changes (Figure 5). Widening in reference reaches over the 1994-2000 period was probably a result of the 1996 flooding. Annual peak flows were relatively small in the period from 2000 to 2005 (Figure 1), and most reference reaches showed a decrease in width over this period, or remained relatively constant. The Little North Fork stands out as an exception in that it increased dramatically in area from 2000 to 2005. Increases in channel width in the North Fork Wilson reference reach may be due to elevated sediment inputs due to mass wasting or other disturbances.

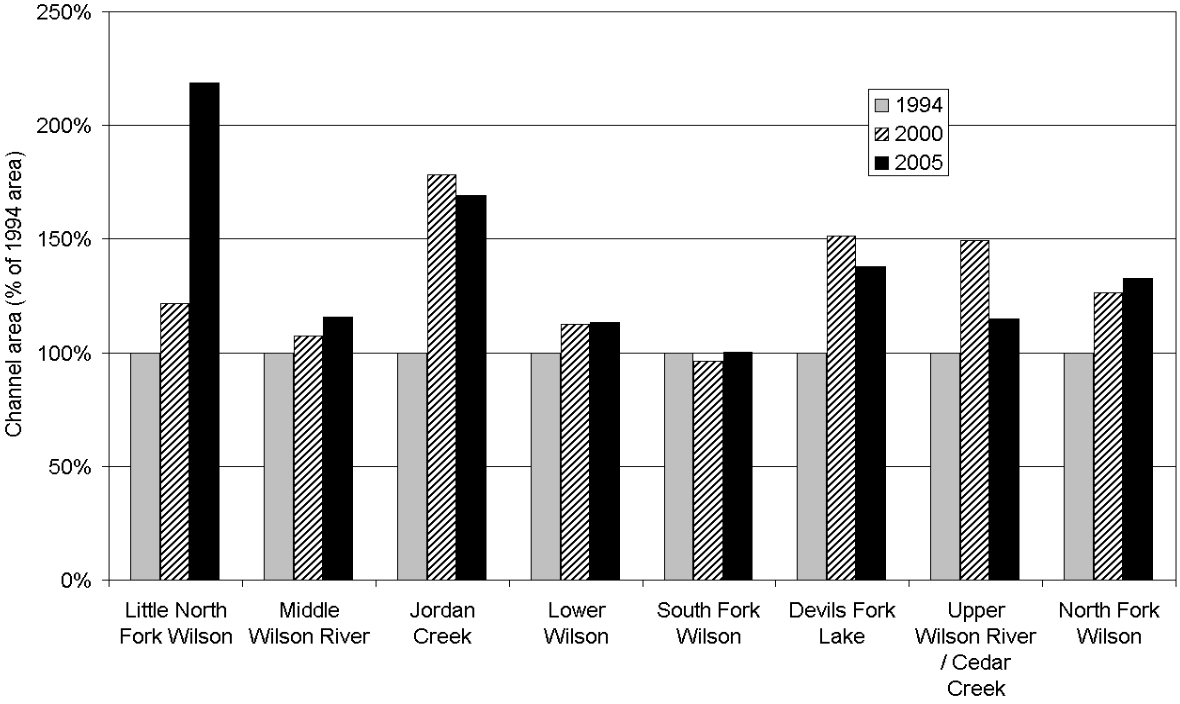

Figure 5. Change in channel area in reference reaches. As measured from 1994, 2000, and 2005 aerial photographs. Changes are relative to the 1994 condition.

5.3 Land Use Effects on Peak and Low Flows

5.3.1 Overview

The Distributed Hydrology Soil Vegetation Model[26] (DHSVM) was developed to evaluate the effects of topography and vegetation on water movement through a watershed (Wigmosta et al. 1994). Spatially distributed models such as DHSVM provide a dynamic representation of the spatial distribution of soil moisture, snow cover, evapotranspiration, and runoff production, at the scale of digital elevation model (DEM) pixel (Figure 6). DHSVM has been used to assess changes in flood peaks due to enhanced rain-on-snow and spring radiation melt response (e.g., Thyer et al. 2004), effects of forest roads and road drainage (e.g., Lamarche and Lettenmaier 2001), and the prediction of sediment erosion and transport (Doten and Lettenmaier 2004).

5.3.2 Methods

We used the DHSVM model to assess management- and wildfire-related impacts on stream flows at the outlets of the eight sixth-field subwatersheds within the Wilson River watershed. In addition, flows at the outlets of ten randomly selected small catchments were also evaluated. For the purpose of this assessment, however, the portion of the Lower Wilson subwatershed below the confluence of the Little North Fork Wilson River was not included (Figure 7) because the topographic relief was too low to accurately capture the location in the mainstem Wilson River with the DEM used[27]. This area that was omitted is approximately 10 mi^2 in size and represents ~5% of the entire assessment area. The assessment area includes USGS stream gage #14301500, the Wilson River near Tillamook, OR (drainage area = 161 mi^2; period of continuous record = 1931-present; Figure 7).

The DHSVM was first constructed for current conditions (i.e., current vegetation and current road network), and calibrated using the Wilson River stream gage record. We then evaluated management-related impacts on stream flows by selectively removing each management impact (e.g., replacing areas currently occupied by roads and harvest units with the potential land cover appropriate for the area), and re-running the model. Results from these allowed us to compare peak flow magnitudes for selected storm events under four scenarios:

- Current conditions (i.e., existing vegetation and road conditions)

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[26] An overview of the DHSVM model, source code, and details of the model application, can be found at http://www.hydro.washington.edu/SurfaceWaterGroup/Models/DHSVM/index.shtml
[27] The digital elevation model used is discussed further in subsequent sections.

- Current vegetation conditions with road effects removed
- Potential vegetation conditions (no management) and no roads
- Post wildfire (1939 and 1945 fires)

The DHSVM model requires several types of spatial and temporal data inputs. Detailed discussions on how the spatial and temporal data were derived can be found in Appendix E – Detailed Methodologies.

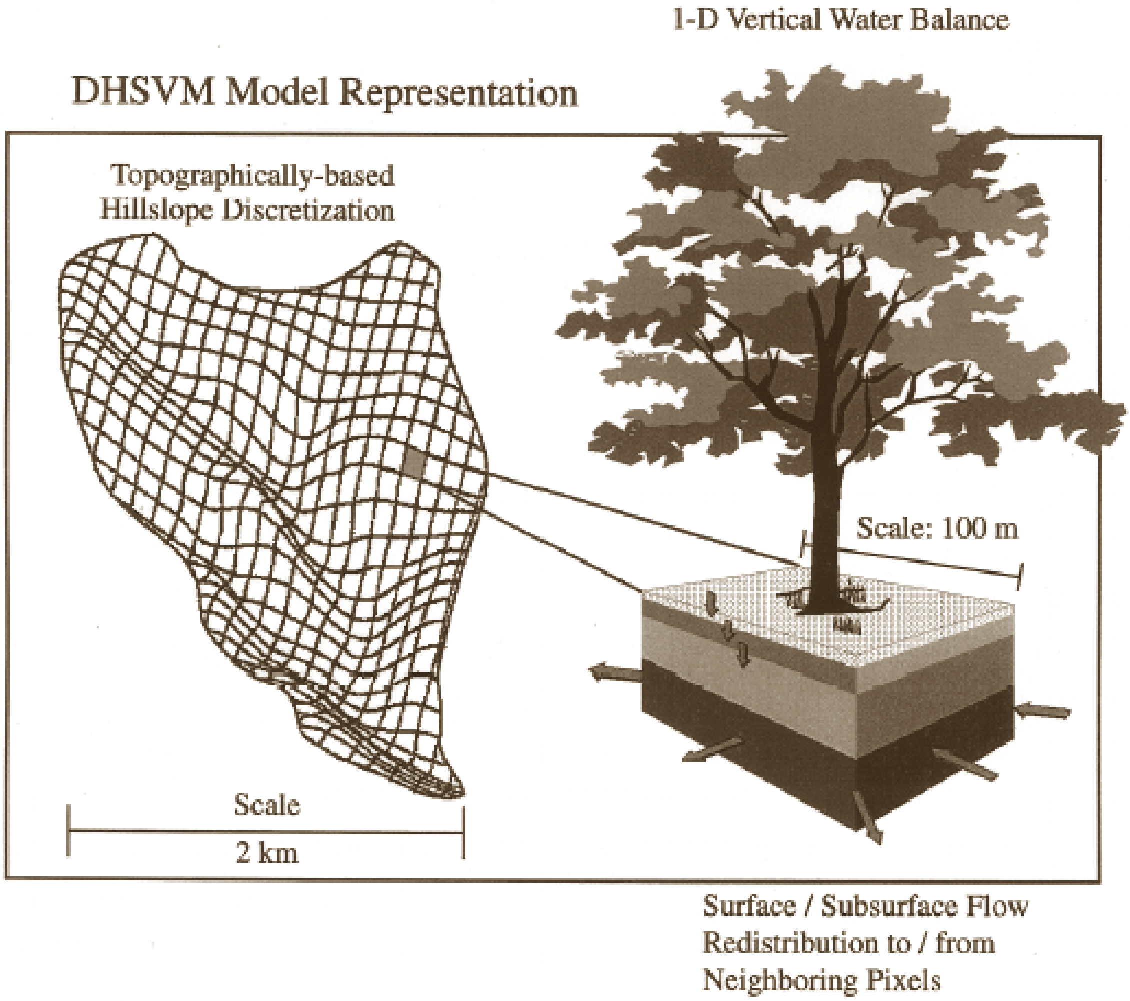

Figure 6. Schematic of the DHSVM model. Model representation of watershed soil, vegetation and topography as discrete pixels (from Vanshaar and Lettenmaier 2001).

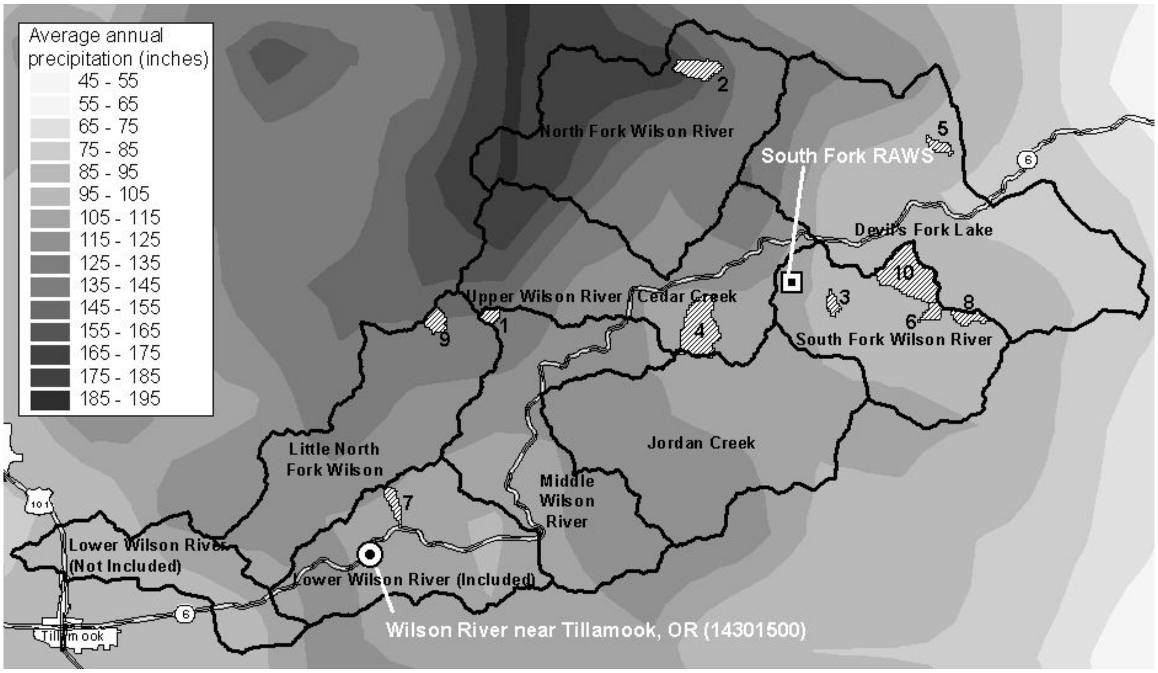

Figure 7. Ten randomly selected small catchments (cross-hatched), the South Fork RAWS climate station, USGS stream gage 14301500 (Wilson River near Tillamook), and average annual precipitation[28].

5.3.3 Results

The DHSVM model was run using data for the period 10/1/2004 to 5/1/2007[29]; the longest continuous time period with available climate data. Results were evaluated by comparing the fifteen largest peak flow events[30] over the modeling period across the range of modeled scenarios. The potential vegetation model that did NOT include roads was used as the baseline model against which all other model iterations were compared.

The fifteen events chosen for analysis all occurred within one or two days of each other at the outlets of the eight sixth-field subwatersheds, and within 5 days of each across all analysis locations (i.e., at the outlet of each subwatershed, at the

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[28] http://www.ocs.oregonstate.edu/prism/state_products/maps.phtml?id=West

[29] The climate record used was applied to all modeling scenarios. Given that our question is how will the watersheds respond to the same climatic conditions given varying vegetation, roads, and soil conditions. It does not matter from what time period the climatic data is from, as long as it is representative of conditions experienced in the watershed.

[30] This was the largest number of independent events that could be extracted from the modeled period. Each event was separated from the next by a minimum of two weeks.

gage location, and at the outlets of the ten small subwatersheds; Figure 7). At the gage location modeled peak flows were all within one or two days of observed events. The corresponding observed peak flows at the gage location were equivalent in magnitude to an annual recurrence interval of 2 years or less for twelve of the events, between 2 and 5 years for two of the events, and approximately a 100-year recurrence interval for one event (i.e., the November 2006 event). A summary of results for all analysis locations are provided in Table 9, and output for all fifteen storms at each location are provided in Appendix I, DHSVM Peak Flow Output.

Table 9. Summary of DHSVM results. Values are averages for fifteen storm events (values in parentheses represent the range of observations). Refer to Figure 7 for analysis locations. Refer to Appendix I – DHSVM Peak Flow **Output** for full results.

	Location	**% ∆ due to vegetation changes**	**% ∆ due to vegetation & roads**	**% ∆ due to historic fires**
	USGS Gage	0.2% (-0.4% to 1.2%)	0.3% (-0.4% to 1.3%)	-0.9% (-10.8% to 6.6%)
6th-field HUCs	Devils Lake Fork	0.1% (-0.1% to 0.7%)	0.0% (-0.2% to 0.7%)	-1.4% (-11.5% to 4.6%)
	South Fork Wilson	0.1% (0.% to 0.7%)	0.0% (-0.1% to 0.5%)	-2.2% (-14.7% to 4.2%)
	North Fork Wilson	0.1% (-0.5% to 0.8%)	0.1% (-0.5% to 0.8%)	-1.6% (-10.3% to 3.6%)
	Upper Wilson/Cedar Creek	0.1% (-0.3% to 1.%)	0.2% (-0.3% to 1.1%)	-1.3% (-10.8% to 5.1%)
	Jordan Creek	0.2% (-0.5% to 1.3%)	0.3% (-0.4% to 1.4%)	-0.9% (-11.4% to 7.6%)
	Middle Wilson	0.2% (-0.4% to 1.1%)	0.2% (-0.4% to 1.1%)	-1.% (-10.9% to 5.7%)
	Little NF Wilson	0.9% (0.1% to 5.6%)	1.1% (0.1% to 6.%)	6.3% (-2.7% to 40.3%)
	Lower Wilson Below Little NF	0.2% (-0.4% to 1.2%)	0.3% (-0.3% to 1.3%)	-0.8% (-10.5% to 7.2%)
Small catchments	Small Shed 01	0.3% (-0.1% to 1.3%)	0.3% (0.% to 1.3%)	-0.2% (-8.7% to 5.7%)
	Small Shed 02	0.0% (0.% to 0.%)	0.0% (0.% to 0.%)	-3.5% (-9.% to 0.9%)
	Small Shed 03	0.3% (-0.4% to 2.2%)	0.3% (-0.3% to 2.2%)	1.4% (-27.3% to 11.3%)
	Small Shed 04	0.6% (-0.4% to 3.%)	0.3% (-0.7% to 3.2%)	6.3% (-3.1% to 44.2%)
	Small Shed 05	0.1% (-0.1% to 0.9%)	0.1% (-0.1% to 1.%)	-2.1% (-11.1% to 2.2%)
	Small Shed 06	0.2% (-0.7% to 2.2%)	1.0% (-0.2% to 3.6%)	-1.0% (-11.5% to 8.6%)
	Small Shed 07	0.5% (-0.3% to 2.6%)	0.5% (-0.3% to 2.6%)	4.7% (-2.9% to 16.5%)
	Small Shed 08	0.2% (-0.2% to 2.2%)	0.2% (-0.2% to 2.2%)	-1.1% (-10.% to 7.6%)
	Small Shed 09	0.1% (0.% to 1.3%)	0.2% (0.% to 1.4%)	2.6% (-3.1% to 11.%)
	Small Shed 10	0.2% (-0.1% to 0.7%)	-1.6% (-2.1% to -0.1%)	1.0% (-11.7% to 8.9%)

Neither changes in vegetation or roads appear to have a significant effect on modeled changes in peak flows at the outlets of any of the eight 6th-field subwatersheds, or the ten small catchments. Modeled changes for individual storm events ranged from -0.5% to 5.6%, with an average value of 0.2%, due to differences in vegetation conditions alone. Modeled changes due to vegetation and roads combined ranged from -0.5% to 6.0% for individual storm events, with an overall average value of 0.3%. The largest changes in peak flow magnitude were in the mainstem Wilson below the confluence of the Little North Fork, where modeled peak flow increases due to vegetation changes alone were 140 cfs during one storm, and 150 cfs for the current condition scenario (i.e., current vegetation and roads). These modeled changes were associated with the tenth largest event out of the 15 storm events that were analyzed.

Results for the post-fire modeling scenario indicate a wide range of variation across the 15 modeled storm events. Modeled changes for individual events ranged from a 15% decrease in peak flow magnitudes to a 40% increase. In terms of the absolute magnitude of modeled change, the largest decrease in peak magnitude was 1,699 cfs at the outlet of the Middle Wilson subwatershed (6th-largest event out of the 15), which equated to a 10.9% decrease in the size of the peak. The largest increase was 767 cfs in the mainstem Wilson below the confluence of the Little North Fork Wilson (10th ranked event out of 15), which represented a 6.8% increase in the size of the peak.

Total modeled volume of discharge at the USGS gage location is given in Table 10. The total volume for the baseline condition were compared to the other three modeling scenarios. The post-fire scenario showed a large increase (6.4%) associated with the loss of forest cover, and reduced evapotranspiration losses.

Table 10. Modeled increases in total volume of discharge over the modeling period (10/1/2004 to 5/1/2007) at the USGS gage location on the Wilson River.

Scenario	Modeled discharge (cubic feet) over modeling period	Percent increase over baseline
[Baseline] Historic vegetation, no roads	1.06E+11	-
Current vegetation, no roads	1.07E+11	1.3%
Current vegetation, current roads	1.08E+11	0.7%
Post fire	1.15E+11	6.4%

Mean low flow values for the month of August are given in Table 11. As with peak flows the modeled flows for the lowest-flow month of the year appear to be little affected by current vegetation conditions or roads. Minor increases are probably due to lower modeled ET losses from existing vegetation as compared to the potential future condition, and the lack of ET losses in roaded areas. Many of the smaller drainages show large percent increases (e.g., the Little North Fork); however, the magnitude of change is very small (hundredths of a cfs).

Table 11. Modeled mean monthly flows for the month of August. Values are given by subwatershed.

Location	[Baseline] Historic vegetation - no roads	Current vegetation - no roads	Current vegetation - current roads	Post fire	% Δ due to vegetation changes	% Δ due to vegetation & roads	% Δ due to fire
Devils Lk Fk	43	46	46	59	5.0%	5.5%	35.5%
Jordan Ck	17	18	18	24	2.9%	3.9%	35.9%
Little N Fk Wilson	0.006	0.006	0.011	0.021	9.6%	81.4%	260.2%
Lower Wilson below Little N Fk	101	105	106	131	3.7%	4.5%	28.8%
Middle Wilson	98	102	103	126	3.7%	4.5%	28.8%
N Fk Wilson	33	33	34	38	2.5%	3.4%	16.8%
S Fk Wilson	15	17	17	24	7.3%	8.1%	55.5%
Upper Wilson/Cedar Ck	78	81	82	99	4.0%	4.6%	27.2%
USGS Gage	100	104	105	129	3.7%	4.5%	28.7%
Small Shed 01	0.0002	0.0003	0.0003	0.0004	11.3%	11.3%	73.8%
Small Shed 02	1.8217	1.8217	1.8217	2.5692	0.0%	0.0%	41.0%
Small Shed 03	0.0001	0.0001	0.0002	0.0003	7.1%	50.4%	145.4%
Small Shed 04	0.0005	0.0005	0.0007	0.0017	9.0%	44.4%	242.7%
Small Shed 05	0.1083	0.1219	0.1299	0.0562	12.6%	20.0%	-48.1%
Small Shed 06	0.0003	0.0003	0.0005	0.0006	6.7%	50.2%	97.8%
Small Shed 07	0.0001	0.0001	0.0001	0.0002	11.8%	11.8%	205.7%
Small Shed 08	0.0005	0.0005	0.0007	0.0008	4.2%	43.7%	57.6%
Small Shed 09	0.0002	0.0002	0.0012	0.0004	4.0%	524.9%	124.6%
Small Shed 10	0.0019	0.0020	0.0029	0.0040	7.2%	54.9%	111.4%

5.4 DHSVM Future Modeling

The current vegetation types and stand-level field data were used to model the future, reference, or *desired* conditions within the watershed. The primary watershed-scale categorical basis in assessing the potential future conditions was the *structural range of variability*, or the SRV.

5.4.1 Structural Range of Variability

As part of the evolution of the *desired future condition* (DFC) for riparian zones, a series of watershed-level conditions were developed for the Elliot State Forest Habitat Conservation Plan (HCP; refer to Appendix J – Desired Future Conditions) that included a range of stand structures that provide structural diversity and continuity for achieving *ecosystem services* for the aquatic system. Specifically, these ranges of structures were presented in terms of *early, intermediate and advanced* structures.

Structural classifications for this assessment were made on the basis of the FPS size class determinations (1-5; refer to Appendix G – Current and Potential Future DHSVM Vegetation Types) found in the photo-interpreted riparian coverages for ODF lands and the watershed as a whole. These structural classes included the following diameter ranges:

- **Early Structure.** Representing size classes 1 and 2, or where the largest 40 trees (L40) had a mean diameter of <14 inches DBH.
- **Intermediate Structure.** Includes size class 3, with an L40 size range of 14 – 20 inches DBH.
- **Advanced Structure.** Includes size classes 4 and 5, where L40 exceeds 20 inches DBH.

The range of structural conditions, expressed as a percentage of land area, is referred to here as the "*Structural Range of Variability*" (SRV) to describe the current and desired ranges of stand structures on the landscape. These ranges and the current structural distribution are presented in Table 12 and Map 21.

Table 12. Current and Desired Structural Distribution. The acres and percentage of riparian zone acres on ODF and the watershed as a whole exhibiting each broad-scale structural characteristics. Target ranges are also presented.

SRV	Structural Description	Desired Range	ODF Acres	% ODF Lands	Watershed Acres	% Watershed
ES	Early Structure	5 - 15%	7,062	73%	8,738	67%
IS	Intermediate Structure	15 - 45%	2,356	24%	3,351	26%
AS	Advanced Structure	45 - 70%	45	<1%	90	1%
NF	Non-Forest	Non-forested	241	2%	859	7%
	Total		**9,704**		**13,037**	

As was the case with stand composition, the structural trends of the riparian zones do not differ markedly between ODF managed lands and the distribution of the watershed as a whole. In both cases, the riparian zones are dominated by early forest structures (73% and 67%, Table 12) that are well outside the desired range (5 - 15%).

Stand metrics data were examined to evaluate if there are ranges of measurable benchmarks (i.e., basal area, large trees, etc.) that could be developed for determining the transitioning of early and intermediate to advanced structure in the Wilson watershed. Because the majority of the land area is within size classes 2 and 3 (early/intermediate structure[31]), and the stand metrics data were collected to capture current conditions, the available stand metrics reflect the variable range of early stand structure. In addition, there are few advanced structure areas (45 acres) available in the watershed to calibrate and validate against growth modeling using FPS.

Stands in current early, intermediate and advanced structures were assigned a potential *future* classification based upon the logical growth patterns of the dominant and co-dominant species. Specifically, data within the growth-modeled stand metrics dataset were used to evaluate the potential trajectories of vegetation types. For example, stands in a current (early structure) condition of mixed conifer, early seral (L40 DBH 8-14 inches) would progress to an advanced stage structure (L40 DBH, 20-30 inches) over the course of the ~100 year model period.

The current condition of riparian stands (ODF and watershed-level) was analyzed to create a “target distribution”, following the SRV proportions of early, intermediate and advanced structural types. This was done by creating a random matrix of stands and reclassifying structural types based upon the likely shift in L40 size over time. Target acres were set to “grow” the early stages to intermediate structures, and intermediate structures to advanced structures following the distribution described in the Elliot HCP (Table 12). Stands were selected at random to provide a landscape-level view (at the watershed- and ODF-scales) for a potential future distribution of structures. This method allowed for a coarse-scale view to alter FPS codes on the basis of size only, and not composition. For example, this assumes a selected HX2H coded stand would eventually become a HX3H or HX4H and would assume attributes of changing heights and diameter classes. This second set of “target distribution” conditions (“future conditions”) was applied to all riparian stands, and this set provides the

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[31] No statistical differences were found between size class 2 and 3 from the field data. This is likely due to the 14 inch diameter cutoff between the classifications; the QMD values for all sampled stands was within 1-2 inches of the 14 inch diameter cutoff.

basis for comparison with DHSVM modeling (as discussed in section 5.3 and Appendix E), and stream shading (as discussed in section 8.4), and other landscape-level analyses.

5.5 Water Uses

5.5.1 Methods

Information from the 2001 Wilson River Watershed Assessment (E&S Environmental Chemistry 2001) was used to answer the general questions about water use in the Wilson River watershed. Current Oregon Water Resources Department (OWRD) records were reviewed, and changes from the 2001 assessment are noted. Additional analysis on the effects of consumptive water uses on water availability is discussed at the end of this section.

5.5.2 Results

5.5.2.1 Beneficial Uses

A review of water rights records from the OWRD[32] indicate that only four new water rights have been applied for in the Wilson River watershed since publication of the 2001 Wilson River Watershed Assessment. Three are for manufacturing-related use of water, and the fourth (from a well) is for irrigation. Collectively these new application are for less than 0.01% of the total instantaneous withdrawal rate already allocated. Consequently, the values reported in the 2001 Wilson River Watershed Assessment, and summarized below, will not be modified from what was originally reported.

The majority (~70%) of water appropriated in the Wilson River watershed is used for irrigation. The majority of this is diverted in the downstream end of the watershed (below the confluence with the Little North Fork), and is used to irrigate farmland in the Lower Wilson River subwatershed and in the adjacent Trask River watershed (Map 22). The second largest use for appropriated water (~30%) is for municipal and domestic water supplies, which is also withdrawn primarily in the Lower Wilson River subwatershed. The City of Tillamook receives the majority of its water from the Tillamook River watershed, from Fawcett and Killam Creeks, and several small individual withdrawals occur as well. Remaining uses (fish ponds, industrial uses, power generation) account for only a minor amount of the total withdrawals. The majority (> 90%) of appropriated waters are from surface, rather than groundwater, sources.

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[32] http://apps2.wrd.state.or.us/apps/wr/wrinfo/wr_summary_pod.aspx

5.5.2.2 Storage, Withdrawals and Transfers

No significant water storage has been constructed in the watershed, and no inter-basin transfer occurs, beyond the application of water withdrawn from the Wilson River to irrigated lands in the adjacent Trask River watershed. It is not known to what extent (if at all) un-permitted uses of water are occurring in the basin.

The OWRD also approves instream water rights for fish protection, minimizing the effects of pollution or maintaining recreational uses. Instream water rights set flow levels to stay in a stream reach on a monthly basis, have a priority date, and are regulated the same as other water rights. Instream water rights do not guarantee that a certain quantity of water will be present in the stream; under Oregon law, an instream water right cannot affect a use of water with a senior priority date. Nine locations within the Wilson River watershed have designated instream water rights for "supporting aquatic life" and "anadromous and resident fish rearing" (Table 13). All instream water rights have priority dates of 1973 or 1991, and are junior to most other water rights in the watershed.

Table 13. In-stream water rights in the Wilson River watershed. Table taken from E&S Environmental Chemistry (2001); data originally obtained from the Oregon Water Resources Department. See Map 22 for locations of water availability basins.

Water Availability Basin	Priority date	Purpose
Wilson River @ mouth	1991 1973	Anadromous and resident fish rearing; Supporting Aquatic Life
Little N. FK. Wilson @ mouth	1991 1973	Anadromous and resident fish rearing; Supporting Aquatic Life
Fall Cr. @ mouth	1991	Anadromous and resident fish rearing
S. Fk. Wilson @ mouth	1991	Anadromous and resident fish rearing
Cedar Creek @ mouth	1991	Anadromous and resident fish rearing
N. Fk. Wilson River @ mouth	1991 1973	Anadromous and resident fish rearing; Supporting Aquatic Life
Elk Cr. @ mouth	1991	Anadromous and resident fish rearing
Devil Lake Fork @ mouth	1991	Anadromous and resident fish rearing
Jordan Cr. @ mouth	1991	Anadromous and resident fish rearing

5.5.2.3 Effects on Peak and Low Flows

Two pieces of information are needed to estimate the net effects of water use on stream flows at any given location; 1) an estimate of the natural stream flow volume, and 2) an estimate of the consumptive portion of all upstream water withdrawals. Unfortunately, only one gage is located within the Wilson River watershed, and it is located upstream of most points of diversion. The OWRD has estimated natural monthly stream flows at the mouths of several water availability basins (WABs) within the Wilson River Watershed (Map 22). The natural streamflow estimates available from the OWRD are the monthly 50% and 80% exceedance flows. The 50% exceedance stream flow is the stream flow that occurs at least 50% of the time in a given month. Conversely, the stream flow is also less than the 50% exceedance flow half the time. The 50% exceedance flow can be thought of as representing a “normal” stream flow for that month. The 80% exceedance stream flow is exceeded 80% of the time. The 80% flow is smaller than the 50% flow, and can be thought of as the stream flow that occurs in a dry month[33]. These exceedance stream flow statistics are used by the OWRD to set the standard for over-appropriation: the 50% exceedance flow for storage and the 80% exceedance flow for other appropriations. These estimates of natural monthly stream flows were made by the OWRD using statistical models derived from multiple linear regressions.

A consumptive use is defined as any water use that causes a net reduction in stream flow. These uses are usually associated with an evaporative or transpirative loss. The OWRD recognizes four major categories of consumptive use: irrigation, municipal, storage, and all others (e.g., domestic, livestock). Uses are not estimated to be 100 percent consumptive, and are estimated by multiplying a consumptive use coefficient (e.g., for domestic use, the coefficient is 0.20) by the maximum diversion rate allowed for the water right. The OWRD assumes that all of the non-consumed part of a diversion is returned to the stream from which it was diverted. The exception is when diversions are from one watershed to another, in which case the use is considered to be 100 % (i.e., the consumptive use equals the diversion rate). Consumptive use estimates available from the OWRD through the Water Availability Reporting System (WARS) [34] were used in this assessment. The net effect of water withdrawals on monthly stream flows were estimated in the following manner:

- The estimated monthly natural stream flows for average and dry years (represented by the 50% and 80% exceedance flow respectively) were first plotted for each location.

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[33] For example, the 50% exceedance flow at the mouth of the Wilson River in the month of December is estimated to be 2,050 cfs, while the 80% exceedance flow for the same month is estimated as 1,050 cfs. The 50% and 80% exceedance flows at the same location for the month of August are 104 and 78.7 cfs

[34] telnet://wars.wrd.state.or.us/

- The portion of all water withdrawals that does not return to the stream (i.e., the consumptive uses) was added to water diverted for storage for each month and plotted on the same graph.

- Instream water rights for the watershed were also shown on the graph

- Finally, the sum of instream water rights and consumptive uses was plotted on the graph.

The estimated net effect of water withdrawals on monthly stream flow is shown for the mouth the Wilson River watershed in Figure 8. These estimates indicate that consumptive water use does not exceed the estimated volume of natural stream flow in any month, either in average (50% exceedance flows) or dry (80% exceedance flows) years. Consumptive use of water is far below the amount available in all months. However, when the instream water right is added to consumptive uses there is insufficient flow to meet all uses in the months of August – October in average years, and in May, July – October in dry years.

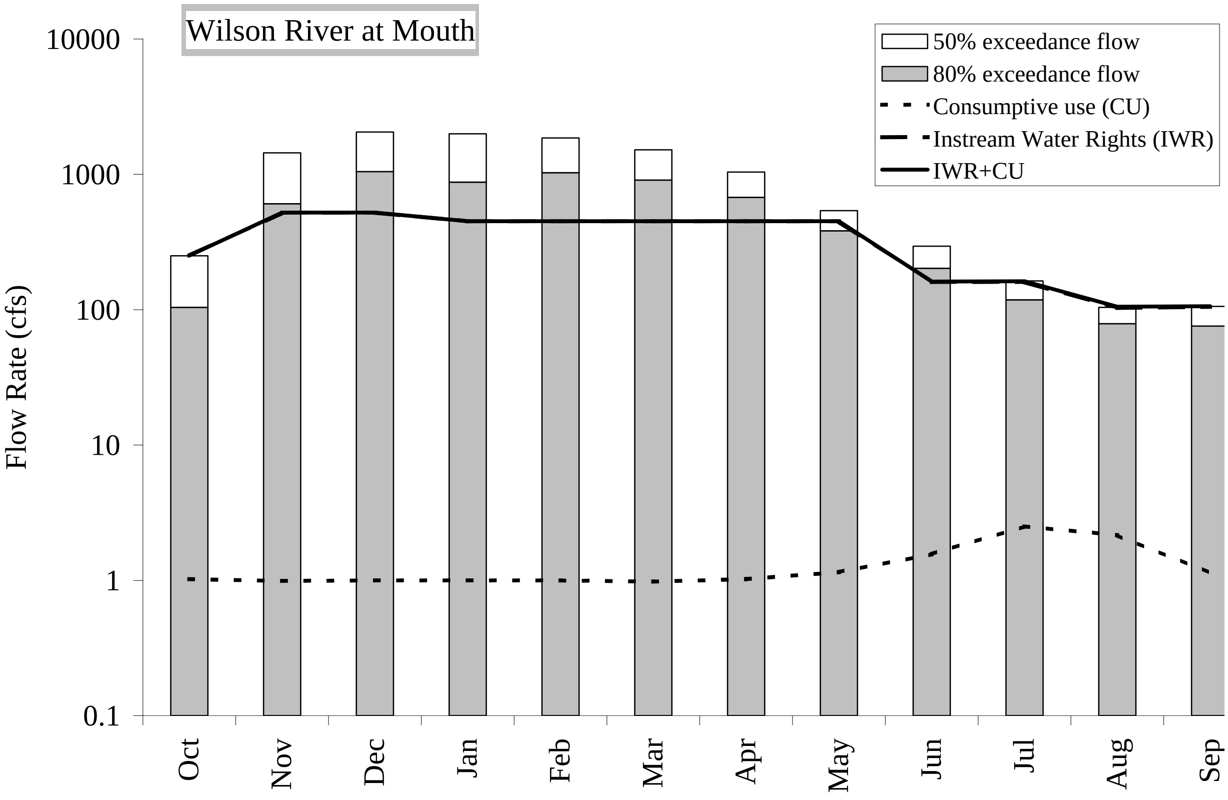

Figure 8. Estimated net effect of water withdrawals on monthly stream flows at the mouths of Water Availability Basins. Shown are estimated natural stream flows for average and dry years (50% and 80% exceedance flows); the sum of consumptive uses (CU); instream water rights; and the sum of instream water rights (IWR) and consumptive uses (CU). Data source: OWRD.

The pattern shown in Figure 8 is the "worst case" scenario among the WABs in the Wilson River watershed. Consumptive uses in the watershed are relatively low as compared to the total water available in any given month. Instream flow rights, although they have a late priority date, should be adequate in maintaining ample flows needed by salmonids and other aquatic species.

5.6 Limiting Factors

The Distributed Hydrology Soil Vegetation Model (DHSVM) was used to evaluate the effects of vegetation and road conditions on peak and low flow magnitudes at the outlets of the eight sixth-field subwatersheds, at the location of the Wilson River stream gage, and at the outlets of ten randomly selected small headwater watersheds.

Model results suggest that peak flow conditions due to current vegetation conditions and current road densities and road drainage conditions are not significantly different than under the baseline condition. Vegetation changes and roads appear to result in an increase of 1% or less over the baseline condition. There was no correlation between percent change in peak flow value and flood size.

These results are consistent with other Northwest forest published results pertaining to peak flow responses after forest harvest that indicate that forest-harvest and road-drainage related peak flow changes are negligible in rain-dominated areas similar to the Oregon Coast Range (e.g., Duncan, 1986; Golding, 1987; Harr, 1979; Wright et al., 1990; Storck et al., 1995; Ziemer, 1996). Aquatic resource degradation associated with peak flow increases must be evaluated on a site-specific basis. However, it is generally not considered to be a concern until peak flow increases are in the magnitude of 10% or greater (Washington Forest Practices Board, 1997). Furthermore, hydrologic connectivity of the road drainage system is generally low within the Wilson River watershed, and DHSVM results indicate that road drainage effects on peak flows are negligible.

Given these results, management related hydrologic impacts are rated as currently having a low impact on proper function of aquatic systems throughout the Wilson River watershed. Furthermore, given that future harvest intensity is unlikely to exceed present practices, and that road construction and maintenance standards are likely to reduce hydrologic connectivity, it is likely that planned management activities and restoration projects will have a positive or neutral effect on hydrologic response over time.

5.7 Confidence in the Assessment/Analysis

Confidence in the Hydrology / Water Use assessment and analysis is high. Water availability estimates from the OWRD were used to evaluate the extent to which consumptive water use (and resultant diminished base flows) are limiting in the Wilson River watershed. The OWRD results indicate that water use is relatively low as compared to the total water available in any given month, and that instream flow rights should be adequate in maintaining ample flows needed by salmonids and other aquatic species. The relative abundance of water adds to the confidence in the results; given that minor to moderate errors in calculations are unlikely to change the overall interpretation.

Confidence is also high in the peak and base flow modeling done as part of this assessment. Data on vegetation and road drainage is recent and appears to adequately represent current condition. Output from the hydrologic modeling matched observed gage records fairly well, further increasing our overall confidence in the results.

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6 Riparian and Wetlands

The purpose of this section is to provide an assessment of the current conditions for the riparian and wetland areas within the Wilson River watershed and to establish a range of potential future conditions (~50-100 year timeframe) for use in management direction. This section presents findings following a series of Critical Questions from the OWEB watershed assessment manual (WPN 1999) and a suite of ODF Key Supplemental Questions to address specific management needs and to enhance the understanding and knowledgebase of the watershed. While the entire Wilson analysis area will be considered, the majority of the available data and management focus will be placed on ODF lands.

This section presents the following:

- Riparian Composition and Structure,
- Riparian Restoration and Enhancement Opportunities, including the development of the Desired Future Condition (DFC),
- Large Wood Recruitment,
- Wood Budget,
- Wetlands, Ponds and Lakes Conditions,
- Noxious and Non-native Weed Species, and
- Recreational Impacts on Riparian Vegetation.

6.1 Riparian Composition and Structure

6.1.1 Riparian Management Areas

The Riparian Management Area(s) (RMA) can be coarsely divided into four zones, each contributing unique ecological values to the stream system at progressively increasing distances from the stream channel. The four zones are:

Aquatic Zone: This zone contains the stream channel, the Channel Migration Zone[35], side channels, in-stream wetland components, and features such as beaver ponds. Vegetation components are present, though many riparian functions are served immediately outside of this zone.

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[35] The Channel Migration Zone is the area adjacent to an unconfined stream channel, where channel migration is likely to occur during high flow events. Often, these areas are associated with side channels, stream-associated wetlands, and low terraces.

Stream Bank Zone: This area is interactive with the stream channel, originating at the stream banks to approximately 25 feet from the stream channel. This area serves many ecological functions to the stream channel, including direct influence on stream shading, coarse particulate organic matter (CPOM) inputs such as tree/shrub litterfall, large wood, bank stability, and in-stream habitat features such as submerged branches and root wads.

Inner Riparian Zone: This zone is immediately adjacent to the Stream Bank Zone, originating at approximately 25 feet and extending to ~100 feet from the stream channel. This area highly contributes to riparian ecological functions, including stream shading (both vegetative and topographic influences), large wood delivery, and associated coarse particulate organic matter inputs. The majority of ecological functions (and the magnitude of how they function) occur within this zone. As such, the Inner Riparian Zone is a *high priority* zone for implementation constraints as they relate to management actions.

Outer Riparian Zone: This area extends outside of the ~100 feet outer stream buffer to ~170 feet, and is usually dominated by upland vegetation. The primary ecological function for this zone is to provide a buffer to protect microclimates within the inner and stream bank zones (e.g., windthrow). Other functions may be contributed to the riparian ecosystem (vegetative/topographic shade and LW), though to a lesser extent than the inner and stream bank zones.

Though the entire riparian zone will be considered in this watershed analysis, the focus of the analysis and available data occur on ODF lands, with quantitative emphasis on the Stream Bank Zone and the Inner Riparian Zone.

6.1.2 Vegetation Classifications

All fish-bearing (Type F) and perennial streams in the Wilson River watershed were selected for a riparian vegetation classification mapping effort in 2006[36]. Stream segments were buffered to a 100 foot width on both sides of the stream to approximate the combined widths of the Stream Bank Zones and Inner Riparian Zones which constitute the key RMAs within the watershed. We determined that 13,037 acres of riparian management area (RMA) exist along fish-bearing streams (Type F streams). Of this, 124 acres are lost due to road prism width (for a more detailed discussion of roads and road widths, refer to Chapter 7 Sediment Sources, section 7.4 Road-Related Issues).

Color stereo-pair aerial photographs (taken in 2006; 1:12,000 scale) and digital orthoquad imagery were used to delineate and interpret the 100 foot buffer areas

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[36] Conducted by Duck Creek Associates in 2006.

for the entire watershed. Delineations were made in a GIS on the basis of homogenous vegetation structure (tree size and densities) and major species dominance (e.g., conifer, hardwood, mixed). The hierarchical classification scheme followed the coding system that is compatible with the Forest Projection and Planning System (FPS)[37] vegetation labels used in stand compilation and growth modeling. This system involved a four-digit code that describes the species, size and relative density of forested polygons, and provided a suite of non-forest classifications (water, shrub, administrative, etc.). The classification hierarchy is presented in Table 80 in Appendix E – Detailed Methodologies.

Following classifications of the 100 foot riparian buffers, the riparian vegetation coverage was analyzed for the entire watershed with greater intensity on lands under ODF management (see section 6.1.3, Field Reconnaissance, below).

The size classifications following the FPS codes (1-5) were further classified to denote stands of *Early Structure* (ES; sizes 1 and 2), *Intermediate Structure* (IS; size 3) and *Advanced Structure* (AS; sizes 4 and 5). These size classifications were used to group the current and potential future distribution of stand types in categorical classes that follow the Elliot State Forest Habitat Conservation Plan (refer to Appendix J – Desired Future Conditions). These structural classifications were also used to determine the desired future condition, assuming a range of structural types (see Potential Future Conditions, section 6.2).

6.1.3 Field Reconnaissance

While the aerial photo classifications provide qualitative groupings based on major species, size and density, the interpretive classifications did not provide adequate stand metrics to meet the supplemental questions for this analysis. In efforts to meet these goals, a field reconnaissance of the riparian zones was conducted on ODF-managed lands with the objective to collect stand-level inventory data (species, size, height) within the most dominant riparian classifications in the watershed.

Of the 45 different vegetation codes found on ODF lands, approximately 92% of the riparian area was represented by 10 forested vegetation codes. The field sampling protocol was designed to capture a proportional number of acres of each type (representing between 8 and 10%) to better describe the major vegetation types currently on the landscape. A total of 71 stands[38] in 775 riparian acres were selected within the 6 major mixed forest types, 2 pure conifer types, and 2 pure hardwood types (Table 14). Stands were selected from a GIS to

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[37] Forest Projection and Planning System (FPS). 2006. Version 6.50. Forest Biometrics Research Institute, Corvallis, Oregon.

[38] 68 stands in the Stream Bank Zone.

maximize field efficiencies and were selected in groups to avoid excessive access times between individually sampled stands.

Each selected riparian stand was subdivided into two zones to approximate the stream bank zone (0 – 35 ft) and the inner riparian zone (~50 ft). In each of these areas of each stand, a variable radius plot was established and sampled, in the stream bank zone, every 5-10 acres[39]. The variable radius plot was conducted in a semi-circle away from the stream and plot counts were doubled. The field sampling protocol followed the standard ODF Stand Level Inventory (SLI) protocol for upland inventories[40] for trees ≥5 inches DBH. Empirical data collected included tree species, diameter, and a sample of tree heights. Species, size and density values for trees 0-5 inches DBH (including seedlings) was obtained from existing SLI plot data, where plots fell within the measured riparian stands.

In addition to the SLI protocol, conifer stumps were tallied in a 1/10th acre circular plot (37.5 ft radius). The purpose of these data were to identify a sub-sample of stands in the watershed that have been altered by human disturbance – the primary goal was to determine the proportion of hardwood mixed or dominated stands that may have been converted from an historically conifer dominance.

Stream connectivity metrics were also collected, including visual bankfull width estimates, vertical elevation at the stream edge (stream bank zone plots), vertical elevation at the stream bank/ inner riparian zone interface, and the horizontal and vertical distance to plot center from the stream edge. These data provide a spatial context of landform and connectivity to the stream channel for measured plots.

Following data collection, the riparian SLI data were incorporated into an FPS database, with the FPS code classification as the basis for the expansion. Stands were compiled and weighted averages for stand metrics were calculated. Stands with like FPS codes (vegetation classes) were expanded with the weighted average stand metrics. Stands were populated to provide a stand table summary and a summary by species and DBH class. No stand metric data were assigned to unsampled FPS codes (Ranks 11-45, or ~8% of the ODF riparian area).

Using FPS, the expanded riparian SLI dataset was modeled for future conditions assuming no future management. The datasets for the stream bank zone and inner riparian zone were treated separately in the future growth modeling. Data were modeled in five 20-year increments to provide *midpoint* stand metrics for

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[39] 1-4 plots were installed in the stream bank zone and the inner riparian zone for each stand.

[40] Reference SLI Protocol, ODF.

2006 (current growth year), 2016, 2036, 2056, 2076 and 2096. Hence, the values represent each of the 20-year time periods: 2006-2026, 2026-2046, 2046-2066, 2066-2086 and 2086-2106 (100 year timeframe).

Table 14. Riparian Vegetation Sampling Intensity. The sampling intensity of the ten-most represented FPS Vegetation classes on ODF lands.

Major Type	FPS Code	Rank[41]	Sampled Stands	Sampled Acres	Total Stands	Total Acres	% Acres Sampled
Conifer	1D2H	5	5	64	165	628	10%
Conifer	1D3H	7	4	34	122	370	9%
Hardwood	1H2H	2	10	165	364	1,773	9%
Hardwood	1H3H	8	4	45	82	321	14%
Mixed	HX2H	1	10	159	428	2,101	8%
Mixed	DX2H	3	14	144	398	1,675	9%
Mixed	DX3H	4	12	75	254	863	9%
Mixed	HX3H	6	4	44	127	517	8%
Mixed	HX2M	9	3	23	65	240	10%
Mixed	DX2M	10	3	22	52	235	10%
	Totals		**69**	**775**	**2,057**	**8,722**	**9%**

Though the streambank zone is defined as 0-25 feet from the stream channel, the variable plot sampling used as part of this analysis incorporated approximately 0-35 feet of the near-stream riparian zone (a legacy of the variable plot sampling). At the 50 ft point away from the stream channel, the inner riparian zone was sampled to capture the 25 – 100 ft buffer areas. Though not exactly in line with the riparian zone management area designations, the data reflect a sampling of these two zones.

6.1.4 Field Validation and Final Classification Scheme

Photo-interpreted data were analyzed and evaluated for appropriate use in further analyses by determining the extent of statistical differences between the it and the FPS classification data. Structural data were compiled and analyzed based upon a range of compositional, structural, and spatial classifications. Classifications were made as variations upon the FPS codes originally described, and the physical location of the installed plots in both the inner riparian zone and stream bank zone) to capture a range of classification complexity (i.e. simple to complex). The following hierarchical classifications ("Classification Factors")

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[41] Rank refers to the highest to lowest (1-45) of forested classifications by acre found on ODF lands. Mixed hardwood/conifer type HX2H was the most common on ODF lands, representing 2,101 acres.

were made to evaluate sensitivities in the structural data, in increasing order of complexity:

- **Riparian Zone Classification:** Streambank zone and inner riparian zone, pooled for all measured FPS codes. This category offers the lowest level of classification resolution and complexity (spatial distribution only).
- **Major Vegetation Types:** Pooled FPS Codes for Conifer, Hardwood and Mixed dominance, also pooled for inner and stream bank zone (compositional distribution only)
- **FPS Codes:** Pooled for inner riparian zone and stream bank zone (composition and structure).
- **Major Vegetation Type and Riparian Zone:** Combined classifications of Conifer, Hardwood and Mixed Dominance, separated by inner and stream bank zone (compositional and spatial considerations).
- **Combined FPS Code and Riparian Zone:** Combined classifications of FPS Codes, separated by inner riparian zone and stream bank zone. This category offers the highest level of classification, and was the resolution sampled in the field (compositional, structural and spatial considerations).

Measured structural stand data were compiled and analyzed at the stand level. Large trees (≥20 inches DBH) were calculated as separate variables to describe absolute trees per acre and basal area (ft^2 per acre) and relative densities (i.e., the percentage of large trees compared to total trees per acre and basal area). Other attributes included total stems per acre, total basal area, and quadratic mean diameter (QMD). Table 11 displays the Analysis of Variance (ANOVA) results for determining differences of structural attributes among Classification Factors.

Overall, no robust statistical differences that provided for clear delineations among increasing levels of classification hierarchies were detected. The proportion and nominal values of large trees (≥20 inches DBH) served as statistically significant and strong indicators for determining differences between conifer and hardwood types (mixed types were not significantly different). The measured trends suggest that hardwoods had approximately one-half of the large trees (by density and basal area size) of conifer stands (Table 16).

Perhaps the strongest observation was the difference in stand structure relative to the proximity to the stream channel. Mixed- and hardwood-dominated types within the stream bank zone had higher total basal areas (average 212 and 231 ft^2/ac) than the same types in the inner riparian zone (167 and 141 ft^2/ac). This was mostly due to the higher prevalence for large-diameter trees (i.e., higher basal area and relative densities) near the stream bank.

Table 15. Classification Significance Matrix. Significant differences detected of structural attributes among grouping factors of FPS codes, riparian zones sampled, and both factors. Values are probability values (P) with an alpha value of 0.05, measured by ANOVA. *Statistically Significant (P< 0.05) and ‡ Strong biological significance (P<0.10).

	Classification Factor				
	Lowest Complexity →				**Highest Complexity**
Structural Attribute	**Riparian Zone Class**	**Major Vegetation Type**	**FPS Code**	**Major Veg. Type & Riparian Zone**	**FPS Code & Riparian Zone**
Large Tree TPA	0.16	0.01*	0.06‡	0.05‡	0.28
Large Tree RD (TPA%)	0.83	0.11	0.08‡	0.47	0.06‡
Large Tree BA	0.30	0.01*	0.02*	0.08‡	0.27
Large Tree RD (BA%)	0.91	0.04*	0.05‡	0.26	0.16
Total Stems	0.06	0.50	0.62	0.33	0.41
Total BA	<0.01*	0.82	0.56	0.03*	0.24
QMD	0.87	0.07‡	0.16	0.39	0.23
Total Score[42]	**1**	**3**	**2.5**	**2**	**0.5**

A “Total Significance Score” was developed to rate the associations of the stand metrics with each Classification Factor. This simply identifies the number of statistically and potentially biologically significant relationships with increasing classification complexity. The intent is to provide a basis for balancing important and discrete stand metrics with ecological functions in an appropriate classification scheme.

While the FPS codes by themselves demonstrated reasonable differentiation in stand metrics, the pooling of FPS codes into Major Vegetation Types (conifer, hardwood and mixed) provided the highest levels of differentiation for classification purposes. However, considering the ecological importance of

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[42] Total Significance Score was determined by a score of 1 point for each statistically significant relationship and a score of 0.5 points for relationships of strong biological significance (i.e. P<0.10).

stream proximity to riparian functions, and considering the strong relationships in large tree basal area between the stream bank and the inner riparian zone, a hybridized classification scheme involving Major Vegetation Types and Riparian Zones is considered for this analysis. A summary of stand metrics and sampled sites is presented in Table 16.

Table 16. Stand Metrics by Major Type and Riparian Zone. The average stand metrics for sampled stands using the most robust classification scheme (Riparian Zone and Major Vegetation Type).

Riparian Zone	Major Type	Large Trees (TPA)	Large Trees (% TPA)	Large Trees (BA, ft^2/ac)	Large Trees (% BA)	Stem Density (TPA)	Basal Area (ft^2/ac)	QMD
Inner RMZ	Conifer	28	23%	74	40%	151	199	16.1
Inner RMZ	Hardwood	10	9%	29	23%	158	141	13.9
Inner RMZ	Mixed	20	22%	65	38%	134	167	16.4
Stream Bank Zone	Conifer	29	27%	85	44%	155	194	16.5
Stream Bank Zone	Hardwood	19	11%	47	23%	220	231	14.4
Stream Bank Zone	Mixed	23	22%	70	37%	172	212	16.3

It is important to note that the field sampling was biased toward the current conditions (i.e., intent was to capture the most abundant FPS codes, Table 14), and the majority of the land area is within FPS size class codes of "2" and "3" (≥8 – 20 inches in diameter). As a result, the measured stands reflected this condition, with average QMDs between ~14 and 16 inches in diameter (Table 16). To capture future conditions and a range of size classes within the sampling regime, current stands were compiled by riparian zone and FPS code, and stand metric data were expanded to the larger population. These data were modeled for growth and structure in 10-year increments using the Forest Vegetation Simulator (FVS; assuming normal mortality patterns) and no management from 2006 until 2106. Diameter classes from the FPS codes (1-5) were assigned to the modeled FVS stand metric data for ease with interpretation.

Two analytical scales and datasets are used for the riparian portion of this watershed analysis. For local scales where stand metrics are important factors in evaluating ecosystem functioning (stream shade modeling, large wood recruitment, etc.), riparian stands will be evaluated on the basis of location (inner and stream bank zone) and major vegetation type (conifer, hardwood and mixed species); diameter measures were summarized as diameter classes that have been derived from the FVS modeled database. At landscape scales, the original FVS codes are presented throughout this report using a consolidated system of major vegetation type, size class and density[43].

6.1.5 Riparian Vegetation Current Conditions

6.1.5.1 Distribution of Riparian Zones

Riparian zones typically do not constitute a large percentage of land area, though they perform many key ecological functions for the landscape. In the ~123,000 acre analysis area, approximately 11% of the land area is represented by the combined stream bank and inner riparian zones (0 - 100 ft) riparian zones (Table 17), which is at the upper end of a range that is typical for other watersheds of this size, and underscores the importance of riparian zone management in the dynamics of the Wilson River system.

The distribution of the riparian zones under ODF management is similar to that of the watershed as a whole, with the exceptions of the Little North Fork Wilson River, Lower Wilson River and Devils Lake Fork subwatersheds. These areas have higher proportions of lower gradient stream systems, which contribute to higher proportions of riparian area on non-ODF managed lands (Table 17 and Map 23).

Table 17. Riparian Land Area Summary. The distribution of key riparian zones (100 ft buffer area) by subwatershed (6th field HUC) and the watershed as a whole for ODF management and all riparian zones.

	ODF Lands		Watershed-Level		Subwatershed Acres	
Subwatershed Name	**Acres**	**% Riparian Zone**	**Acres**	**% Riparian Zone**	**Acres**	**% of Watershed**
NF Wilson River	1,146	7%	1,625	9%	17,297	14%
Upper Wilson/ Cedar Creek	1,314	9%	1,527	11%	14,307	12%
SF Wilson River	1,283	13%	1,284	13%	10,217	8%
Little NF Wilson River	1,155	9%	1,457	12%	12,621	10%
M Wilson River	999	7%	1,138	8%	13,487	11%
Jordan Creek	1,010	6%	1,224	8%	16,201	13%
L Wilson River	796	5%	2,236	13%	16,893	14%
Devils Lake Fork	2,002	9%	2,547	12%	22,106	18%
Totals	**9,704**	**8%**	**13,037**	**11%**	**123,128**	**100%**

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[43] For a complete list of the major vegetation classifications used for the landscape-level vegetation analysis, see Appendix U.

6.1.5.2 Major Vegetation Types

The distribution of major species dominance (conifer, hardwood, mixed and non-forest), as measured from photo-interpretation (FPS codes) is notably similar in proportion between ODF-managed lands and the watershed as a whole (Table 18, Map 23). Approximately two-thirds of the watershed riparian zones are dominated by mixed conifer-hardwood species. This “Mixed” forest type is characterized as a stand having ≤80% of the observed basal area in a single species, and is typified by the Douglas-fir and red alder community type in shifting proportions of co-dominance.

It is important to note that “dominance” from aerial photo interpretation is less reliable than stand-level data, especially for the mixed types. Stand samples (see Appendix K) indicate that mixed types could contain higher than 80% of basal area or trees per acre in a single-type. Aerial photo interpretation involves the estimate of canopy cover, not basal area, and hence the canopy-level view may suggest a mixed type when the inventory data suggest dominance by a single type. Despite these shortcomings, the major dominance types are useful for a landscape-level view of major vegetation types in the watershed.

Hardwood-dominated sites occur throughout the watershed, representing ~22% of all riparian acres, and 24% of ODF riparian zones. Conifer-dominated stands were less prevalent, representing only 13% of the riparian land area in the watershed.

Table 18. Coarse Riparian Vegetation Types. The distribution of the major vegetation types within ODF managed areas and the watershed as a whole.

Forested	Forest Type	ODF Acres	% of ODF Lands	Total Acres	% of Watershed
Forested	Conifer	1,157	12%	1,697	13%
Forested	Hardwood	2,339	24%	2,833	22%
Forested	Mixed	5,967	61%	7,637	59%
Non Forest	Other	241	2%	871	7%
	Totals	**9,704**		**13,037**	

At the subwatershed scale (Figure 9 and Table 19), the distribution of ODF-managed riparian zones is highly biased toward mixed conifer/ hardwood types; mixed types ranged between ~48% and 73% of each subwatershed riparian areas. Hardwood dominated types were abundant (~20 – 49%) in all subwatersheds except Devils Lake Fork (7%) and the SF Wilson (16%) subwatersheds, where conifers were more prevalent (28 and 22% conifers, respectively).

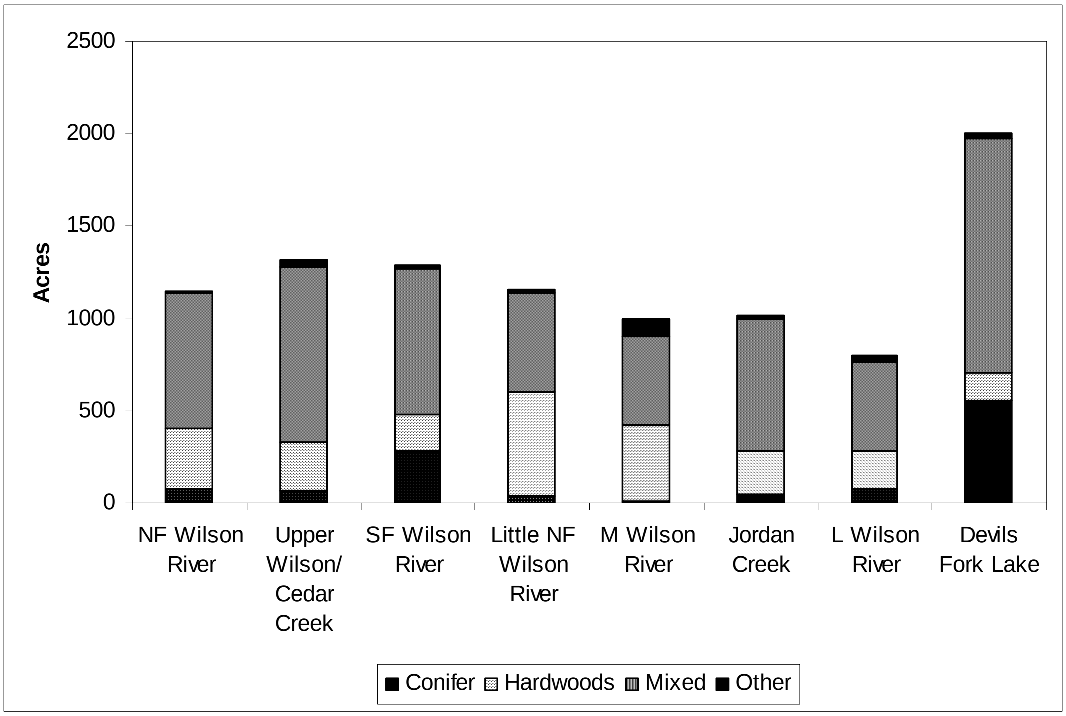

Figure 9. Major Vegetation Types (ODF Lands). The distribution of forest dominance for the 9,704 acres under ODF management.

The dominance of hardwood and mixed conifer/hardwood types in context with the fire and management history suggests that the majority of ODF lands have undergone a near-complete conversion from historic vegetative patterns to, at a minimum, a current condition of early- and mid-seral vegetative structures.

Compositionally, the stump presence data collected as part of the field campaign suggest that, while stumps were found in 52 of the 72 measured stands, without exception the stumps appeared to be formed soon after the fire and salvage logging events of the 1950s. Given the apparent widespread homogeneity of stand ages due to fire and intensive salvage logging, and the relative uniformity of stand metrics among types measured (Table 16), the data strongly suggest the current condition of the forested riparian zones represents a uniformly-aged stand structure, with divergence in species compositional dominance throughout ODF lands.

Table 19. Major species classes by subwatershed. The distribution of major species on ODF lands. Note hardwood and mixed types represent ~85% of ODF lands.

	Conifer		Hardwood		Mixed		Other		
Subwatershed Name	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Totals**
N. Fk. Wilson River	73	6%	328	29%	741	65%	4	<1%	**1,147**
Upper Wilson/ Cedar Creek	70	5%	257	20%	955	73%	33	3%	**1,315**
S. Fk. Wilson River	282	22%	200	16%	789	62%	12	1%	**1,284**
Little N. Fk. Wilson River	39	3%	564	49%	532	46%	19	2%	**1,156**
Middle Wilson River	10	1%	410	41%	481	48%	97	10%	**1,000**
Jordan Creek	47	5%	235	23%	718	71%	11	1%	**1,011**
Lower Wilson River	79	10%	203	26%	478	60%	36	4%	**797**
Devils Lake Fork	557	28%	143	7%	1,272	64%	29	1%	**2,003**
Totals	**1,157**	**12%**	**2,339**	**24%**	**5,967**	**61%**	**241**	**2%**	**9,705**

6.1.6 Vegetation Type Descriptions

This section describes the dominant conifer, hardwood and mixed forest types (including the riparian characteristics), connectivity with the stream channel, and forest health concerns for ODF lands. In addition, the subsequent sections report the current mean, range and distributions of species, size and density values collected during the field reconnaissance.

A stand-level summary of all measured stands is presented in Table 20. A full species table is included in Appendix K – Riparian Stand Information. A distribution of the conifer, hardwood and mixed stands as well as size classifications is displayed on Map 24.

6.1.6.1 Conifer Dominated Stands

Conifer-dominated stands were the least common forested riparian type and comprise 1,157 acres of ODF riparian zones, or 12% of the ownership in the Wilson watershed (Table 19); approximately one-half of the land area in conifer-dominated types is within the South Fork and Devils Lake Fork subwatersheds. A total of 9 sampled stands (out of 139) were conifer dominated; five stands were in size class 2 (8-14 inch L40 DBH) and four stands in size class 3 (14-20 inch L40 DBH) (Table 20).

As was the case with all stands measured, the stand table information is highly variable among sites (see Appendix K – Riparian Stand Information), though these stands averaged 67-92% of the basal area and ranged between 36% and 90% of the stem density in Douglas-fir dominance in both the inner riparian zone and the stream bank zone. Most of these sites had regenerating western hemlock in the understory, with occasional pockets of red alder in the mid-story strata (range 8-14 inches DBH). Approximately 14-18% of the stems and 29-40% of the basal area were in large trees (≥20 inches), almost exclusively in Douglas-fir, with a very minor contingent (1%) in western hemlock. A typical image of these conifer stands is displayed in Photographic Plate 3.

Conifer stands represent an early to intermediate stage of succession; the presence of western hemlock in the seedling and small tree categories indicates a gradual shift to shade-tolerant establishment. These zones are relegated to the upper reaches of the stream systems transitioning to hardwood co-dominance fairly rapidly with progression downstream.

Table 20. Summary of Field Data. The stand-level mean and range for basal area, stem density and quadratic mean diameter (QMD) for the71 stands sampled within the Inner Riparian Zone (IRZ) and the 68 stands sampled within the Stream Bank Zone.

Riparian Zone	Major Type	Major Class	FPS Code	N of Stands	Mean BA (ft^2/ac)	Min BA (ft^2/ac)	Max BA (ft^2/ac)	Mean Density (TPA)	Min Density (TPA)	Max Density (TPA)	Mean QMD (Inches)	Min QMD (Inches)	Max QMD (Inches)
IRZ	Conifer	FC2H	1D2H	5	203	126	286	172	62	277	15.5	12.9	19.3
IRZ	Conifer	FC3H	1D3H	4	193	151	235	125	91	169	16.9	16.0	17.4
IRZ	Hardwood	FH2H	1H2H	10	140	80	218	153	79	334	13.3	11.0	15.2
IRZ	Hardwood	FH3H	1H3H	4	135	60	201	200	30	305	12.8	10.1	19.2
IRZ	Mixed	FM2H	DX2H	14	176	120	302	142	31	276	16.6	10.4	28.0
IRZ	Mixed	FM2H	HX2H	11	145	38	226	156	35	370	13.7	10.6	18.3
IRZ	Mixed	FM2M	DX2M	3	164	88	235	73	46	89	20.0	18.6	22.7
IRZ	Mixed	FM2M	HX2M	3	108	50	138	90	59	151	15.3	12.5	20.4
IRZ	Mixed	FM3H	DX3H	12	199	101	336	182	38	473	16.0	10.8	22.2
IRZ	Mixed	FM3H	HX3H	5	105	25	160	105	14	208	15.3	11.1	18.8
SBZ	Conifer	FC2H	1D2H	5	190	151	226	117	57	182	18.1	15.1	23.3
SBZ	Conifer	FC3H	1D3H	4	208	126	302	209	112	386	14.1	12.0	16.4
SBZ	Hardwood	FH2H	1H2H	10	230	80	347	339	149	565	11.5	8.5	15.5
SBZ	Hardwood	FH3H	1H3H	4	188	80	269	247	48	595	13.9	8.8	17.4
SBZ	Mixed	FM2H	DX2H	14	206	101	440	172	49	371	15.6	11.5	19.5
SBZ	Mixed	FM2H	HX2H	9	185	120	218	192	73	395	14.5	8.4	20.6
SBZ	Mixed	FM2M	DX2M	3	218	151	269	153	53	265	18.1	12.8	22.8
SBZ	Mixed	FM2M	HX2M	3	190	67	252	208	23	341	16.0	11.6	23.0
SBZ	Mixed	FM3H	DX3H	12	226	101	520	202	46	486	15.4	11.3	19.9
SBZ	Mixed	FM3H	HX3H	4	218	100	280	302	86	765	13.7	8.2	16.6

6.1.6.2 Hardwood Dominated Stands

Hardwood dominated stands were the second-most dominant stand type for ODF riparian zones (2,339 acres, 24% of all ODF riparian zones, Table 19), though these types were co-dominant with mixed hardwood/conifer types in the Little NF Wilson River and Middle Wilson River subwatersheds (~49 and 41%, respectively). To capture the dominant structural classes on the landscape (L$) sizes 2 and 3), fourteen stands were field sampled in both the inner and stream bank zones.

In all measured cases, red alder was the dominant tree species, contributing >92% of the basal area and stems in the stream bank zone, with the balance found in bigleaf maple. Red alder ranged between 83-96% of the basal area and stem density in the inner riparian zone, with contributing components of bigleaf maple (3-7%) and midstory Douglas-fir. The size class distribution for both “size 3” and “size 4” stands showed an even distribution of basal area in trees 8-14 and 14-20 inches in DBH; ~40% of the basal area were in each of these size classes. Trees ≥20 inches were present throughout, mostly red alder and bigleaf maple, with minor components of Douglas-fir (inner zone only). A typical image of these stand types is presented in Photographic Plate 4.

As is the case elsewhere, these stands are in a relatively early stage of succession. Few regenerating conifers were found in this stand type, though some evidence of legacy conifers were found in the stream bank portions of the stands (Photographic Plate 5), suggesting some minor historic conifer co-dominance in some areas. Of the hardwood-dominated stands, 7 of the 14 sampled stands had ranged between 1 and 3 total legacy conifer stumps per acre for all plots sampled. Hence, legacy conifers were present, though their overstory dominance appeared to have been intermittent in this vegetation type.

One potential large-structured hardwood stand was found as part of the aerial photo interpretation (L40 size class 4). This stand was found on non-ODF lands at the confluence of Tillson Creek, on the right bank of the Wilson River. Though this stand appeared to have large-diameter trees, it is within a large strip of managed areas, pastures, and other disturbed features. Hence, the stand had large-diameter trees, but not old-growth structure. Though the photo-typed “mature” levels corresponded to the diameter classes, the majority of the watershed contained elements of mature hardwoods, where successional dynamics appeared to show regenerating cohorts of hardwoods with older (~50 year old) hardwood overstories. Though these may be considered “mature hardwood stands”, the likelihood is this is a legacy of the extreme stand-replacement fire activity from the Tillamook Burns. Hence, the current structure of hardwoods is possibly transient, though in later sections, the “transient” nature may exceed 100 years before conifer establishment may increase the conifer/ hardwood mix. For practical purposes, the current status of the majority of the hardwood stands is in an element of stem exclusion status, where older hardwoods are (or soon will) undergo self-thinning and regeneration. This status is probably not the “mature” status considered for hardwoods, though it is indicative that the near-term trend will favor a hardwood-dominated environment for the majority of the watershed. The hardwood dominated stands are found throughout all gradients and are associated with the range of stream sizes and types.

6.1.6.3 Mixed Dominance Stands (Hardwood and Conifer)

The most abundant stand type on ODF lands (and the watershed as a whole) is found in the “mixed” type, containing at least 20% conifer or hardwood. Two mixed forest types are identified in the FPS coding system: Hardwood-Conifer and Conifer-Hardwood (HX and DX, Table 14). These stands are best described as highly diverse in composition and structure; abrupt changes in topography or aspect favors one species group over the other (conifer vs. hardwood). Field data and walk-through exams suggest the FPS code system at the photo-interpreted scale (~1,500 ft stream lengths) does not provide sufficient detail to distinguish subtle and patch mosaic differences in co-dominance. Photographic Plate 6 provides an example of similarly coded stands with markedly different patch compositions and structures.

The heterogeneity among (and within) mixed types favors a diverse mix of species from black cottonwood to western hemlock. The hardwood to conifer ratio in trees per acre and basal area were highly variable; generally stands that were indicated to have more conifer cover than hardwood did have average higher relative densities than stands indicated to have hardwoods more dominant, though trends were not strong enough to support discrete stand classes.

Douglas-fir, red alder and bigleaf maple were the principle species for these stands, with few stands having regenerating western hemlock and western red cedar (steeper draws). Large trees were common among all sites; stand types had ~10 to 40% of the trees per acre in trees ≥20 inches DBH (~20% total basal area) and up to 5% of the trees per acre in trees ≥30 inches DBH (~5% total basal area).

The diversity of these stands provides important features for the stream system. As with other stands in the watershed, the Mixed stand types are in an early stage of development, with lower gradient communities transitioning to hardwood dominance (red alder, bigleaf maple and black cottonwood, Photographic Plate 7) and upslope riparian communities—both in the inner and the stream bank zones in steep gradient systems – differentiating away from hardwood co-dominance to include regenerating shade-tolerant species (western hemlock and western red cedar, following Photographic Plate 6, left image). These vegetation types offer the best opportunities for restoration and enhancement, discussed in greater detail in section 6.3 Riparian Enhancement Opportunities.

6.2 Potential Future Conditions

6.2.1 Riparian Vegetation Dynamics: "No Management" Scenario

Estimates of stand successional dynamics and the potential for instream large wood recruitment from riparian vegetation was generated from the riparian dataset with expanded stand metrics (ODF lands only). The expanded dataset was modeled for growth and tree mortality using the Pacific Coast variant of the Forest Vegetation Simulator (FVS). Species, size and density projections were modeled in 10-year increments, from 2006 (growth year of field measurement) to 2106. Regeneration and 0-5 inch size class components were obtained from SLI plot data in measured and expanded stands. Regeneration components were considered in different ways, and the model results presented here involve the growth model to "force" seedling establishment every other time step (20 years)[44].

The primary purpose of this analysis is to quantify and describe the expected ranges of principle riparian functions and attributes (e.g., large wood recruitment, stream shading, and compositional dynamics) under the assumptions of no management and no disturbances. This is important, as this analysis does not include stochastic factors that often influence stand structure and composition (e.g. landslides, debris torrents, gap mortality, etc.) – some of these factors are described elsewhere in this analysis and typically are beyond the normal range of forest management options or the capacity of the model utility. Ultimately, this analysis serves to evaluate if projected ranges meet the desired ranges of conditions without active management. In addition, this tool provides a basis to determine the range of limiting factors that may be present, by which active management options could be considered. As a modeling tool, the no-management option provides the basis to compare the effects of potential vegetation treatments on the benchmarked ranges (see section 6.3 Riparian Enhancement Opportunities).

It is of critical importance to note that the collected data and base riparian vegetation map have utility at the subwatershed scale and larger. The limiting

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[44] Further discussion and model evaluations are presented in Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

factors affecting the resolution of the data are primarily the coarse-level vegetation codes (FPS codes) and the unit delineation size for riparian stands (~1,500 ft). At the subwatershed scale, these data provide insight as to the fundamental patterns in species composition, tree growth and mortality. Site-level prescriptions based on these data are not advised, as the data do not have the resolution needed to prescribe a practical or valid active management scenario. The reason for these limitations and pathways for solutions are described in detail below (refer to section 6.3 Riparian Enhancement Opportunities).

This section describing the non-managed scenario is arranged to quantify the successional dynamics of the following riparian ecosystem aspects for the 100-year time period[45]:

- Species composition, specifically the ratios of conifers and hardwoods contributing to total tree densities,
- Stand structural characteristics, including trees per acre by size class, rate of recruitment of trees to the forest canopy, and quadratic mean diameter changes,
- Species compositional dynamics of the forest strata, or the distribution of conifer and hardwood species in context of forest structure and succession, and
- Canopy tree mortality, and the number and rate of hardwoods and conifers that die within each time period.

Following this section, further discussion associated with riparian forest dynamics is explored with stream temperature modeling (vegetative shade effects) and estimating the fate and interaction of dying trees with the stream channel. Potentials for management options and utility and confidence of this dataset are also explained. A "general" silvicultural prescription and an Action Plan Pathway are presented to provide guidance for increasing the utility and management design of a riparian base map using LiDAR available in early 2008.

6.2.1.1 Species Composition: Shifts in Conifer Abundance

Riparian tree species were grouped on the basis of their conifer or hardwood classification and the relative abundance of conifers was calculated as a

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[45] For additional information on how assumptions change these characteristics, see Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

percentage of stand-level trees per acre for all modeled years. This value provided an evenly scaled system to evaluate the relative abundance of conifers within the riparian zones, despite stand-to-stand and year-over-year changes in trees per acre. Specifically, this attempts to describe the relative shifts in species dominance between conifers and hardwoods through time. Stand-level relative abundances were weighted on the basis of acres, and reported at the subwatershed scale (Figure 10).

A caveat associated with this particular analysis is that standardized growth models have difficulty in quantifying the shifts in species composition through time, especially in longer time periods. Species shifts are often controlled by microclimate, opportunity (seed dispersal and germination), disturbance patterns, and other factors at play at the site level that are difficult to measure and predict. The deterministic growth models are designed to provide opportunity for cohort advancement on the basis of model thresholds (stand density indices, canopy cover, percent survival, etc.). As such, the compositional changes observed are a function, in part, of the model input assumptions and thresholds, showing how trees respond to the mortality thresholds set in the models.

With a full understanding of this potential limitation, the model is useful in generalizing trends in species composition at the landscape-level to evaluate the establishment and abundances of potential seed trees, and to quantify the dynamics of recruitment into the different levels of the forest strata. Conifer and hardwood abundances are examined here to evaluate the ranges of co-dominance, and to predict if any marked or notable changes are predicted to occur under a non-managed/ no disturbance scenario at the sub-watershed scales for the 100-year time period.

The model run shows a clear increase in conifer proportions through time, with a shift from hardwood dominance in the first 50 years to a reversal by the end of the model run (Figure 10). Two major factors contribute to the observed trend. The first is the presence of the 0-5 inch cohort, which contained an element of conifers that are allowed to compete and eventually recruit or persist to later periods of the model run (i.e. when hardwood abundances decline beyond ~50 years). The second and most significant factor is the regeneration component, and the use of this component during the model run. As stated and explained elsewhere in this document[46], the regeneration feature in the FVS model utilized “forced” natural regeneration, meaning time steps and not stand density thresholds dictated when seedlings were to be established. This is evidenced by the “stair-step” curves in Figure 10, where establishment of seedlings occurred

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[46] For a discussion of different model runs and assumptions, see Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

and were subsequently adjusted by mortality triggers relating to stem density, shading, etc. As such, the most persistent species will be projected to survive, favoring conifer species over hardwoods (e.g. hemlock, cedar). Hence, the projection of conifer dominance is mostly dependant upon the assumptions made in regeneration and stand density indices for mortality, and this becomes more important at later periods in the time series. Disturbance events (which are not modeled here) are more significant contributors to compositional dynamics.

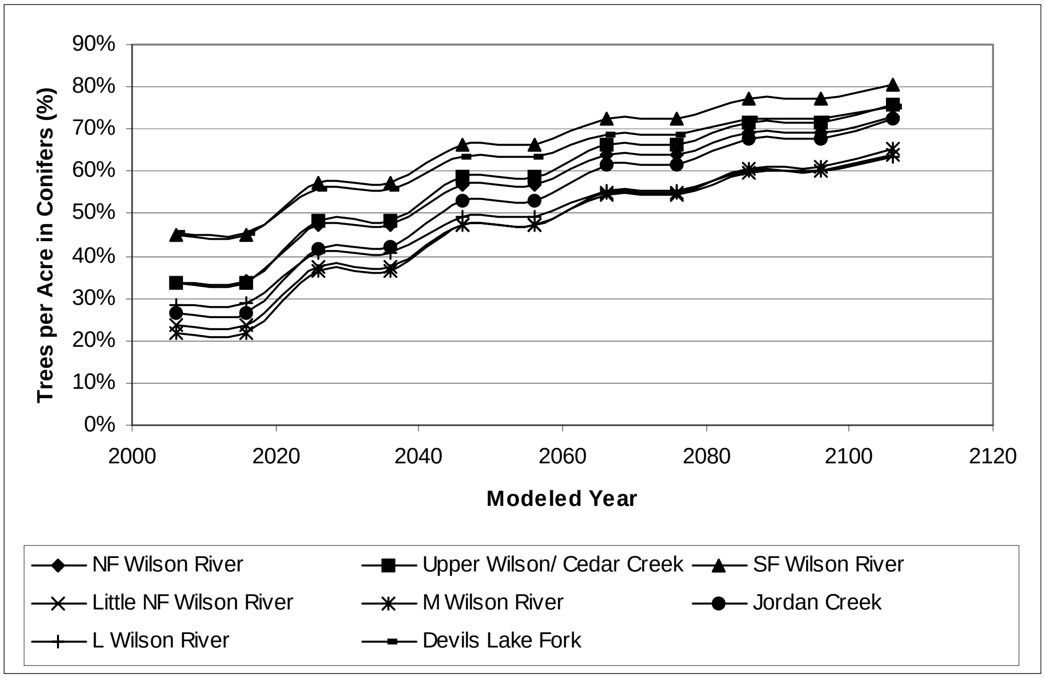

Figure 10. Relative Abundance of Conifers. Stand-level averages of conifer proportions of trees per acre, weighted at the subwatershed scale.

With the understanding of the caveats associated with modeling compositional dynamics, the landscape-level view shows the potential for conifer establishment in these stands (from a relative abundance standpoint), though as described in subsequent sections, the conifer component is very slow in gaining dominance in the overstory component of the system (≥14 inches DBH). In addition, and tough not directly measured, the age of these riparian zones is approximately 55 – 60 years old, with very low observed densities of conifer seed trees at the current year (2006) in most subwatersheds. Assuming the model captures the future profile of conifer and hardwood proportions, it can be concluded that the Wilson River watershed is hardwood dominated, and hardwoods (particularly red alder) will remain a significant proportion of the forested riparian landscape affecting vegetative shade, wood inputs, and nutrient inputs to the stream system for a long period of time (see subsequent analysis for overstory components).

6.2.1.2 Stand Structural Changes in Mid- and Over-story Canopy

Mid- and overstory canopy components were selected through the 100-year time series to illustrate the shifts in abundances for the dominant and co-dominant trees in the canopy strata. Tree sizes ≥14 inches DBH were considered to be "mid and overstory" components, as these size classes contain the majority of the basal area, or are most influential on basal area and stand-level structure within a given stand. Absolute abundances (trees per acre) for all tree species were considered, and stand-level averages were weighted on the basis of acre contribution to each subwatershed.

For the 100-year time series, the overall canopy tree abundances increase from a range of ~50 – 70 trees per acre in 2006 to a maximum range of ~75 – 95 in 2056. By the end of the time series (100 years), overall trees in the dominant and co-dominant canopy strata decrease to ~50 – 65 trees per acre, representing the approximate density under the current conditions (2006) (Figure 11).

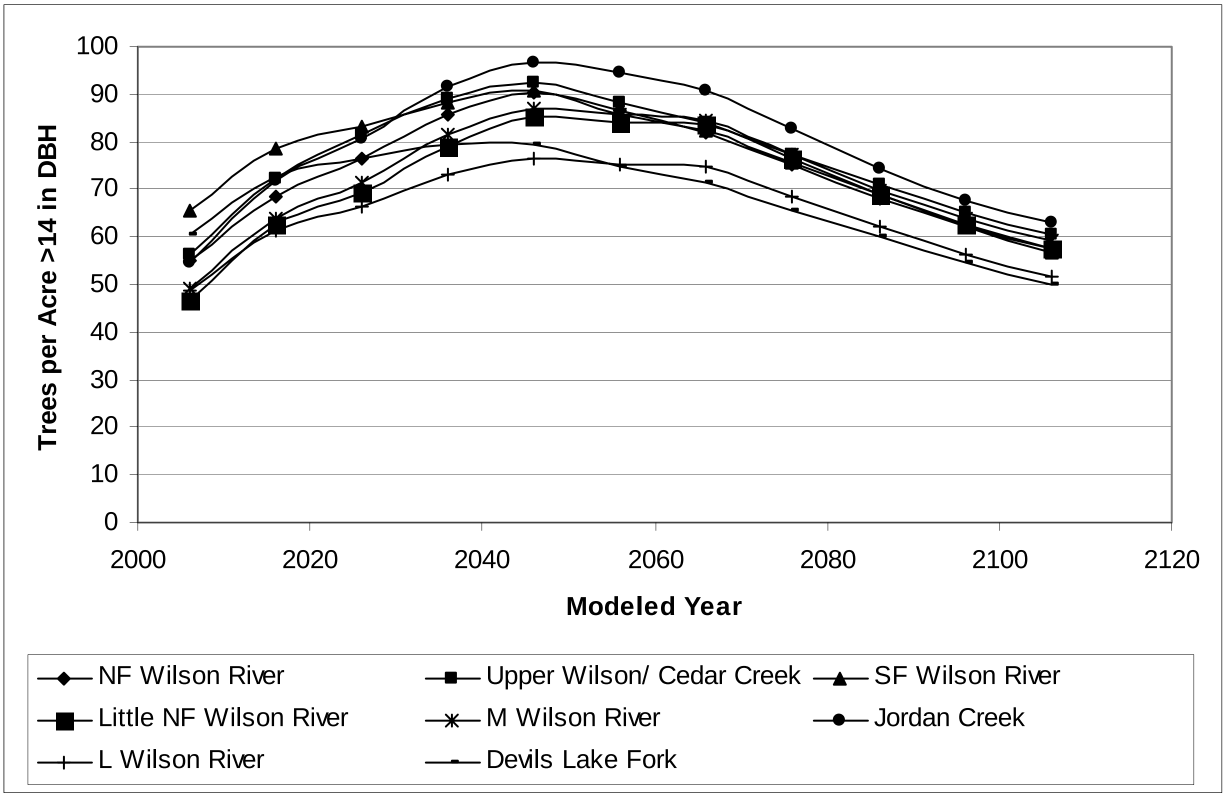

Figure 11. Projected Live Canopy Tree Densities. 100-year modeled weighted average standing trees per acre for conifers and hardwoods combined ≥14 inches DBH, reported by subwatershed.

Rates of "canopy recruitment", or the percentage increase (or loss) of trees entering the ≥14 inch DBH size class in a 10-year period, show increased rates of recruitment in the next ~30 years, followed by a gradual decline to the end of the first 50 year period. In the 50-100 year time steps, canopy tree recruitment rates decline steadily and level off at a steady decline of 10% loss in densities per model step for the final 30-50 years of the time series. This indicates the potential for growth stagnation and lack of recruitment of younger trees into the canopy size class.

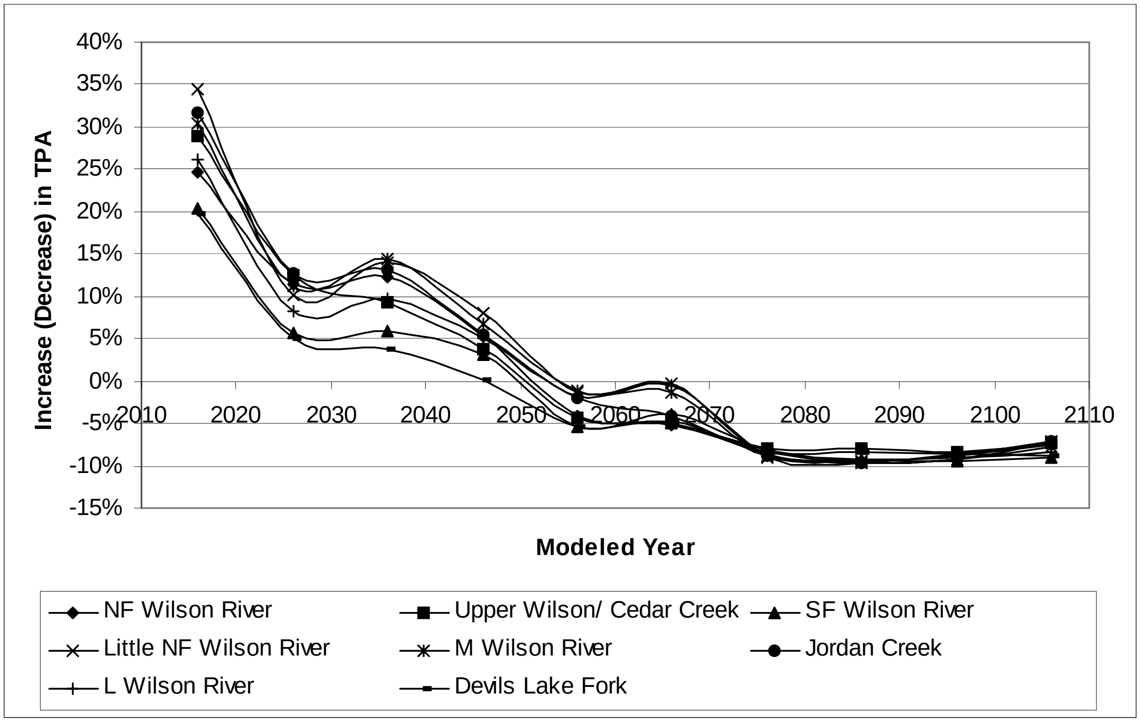

Figure 12. Projected Rates of Live Canopy Tree Recruitment. The percent increase or decrease in TPA for trees ≥14 inches DBH through time. Note negative values show declines in recruitment rates to this size class.

Modeled quadratic mean diameter (QMD) for canopy species increases steadily through the time series (Figure 13). Projected QMD increases steadily from the current ~22 inch diameter range to a range of 25 – 30 inches through time for the ≥14 inch size class. The smooth lines observed are probably legacies of the FVS model itself, though the combined increases in QMD with flux in the canopy-level TPA and rate of recruitment underscores evidence that there is a relative lag in mid-sized trees following the 50-year time period.

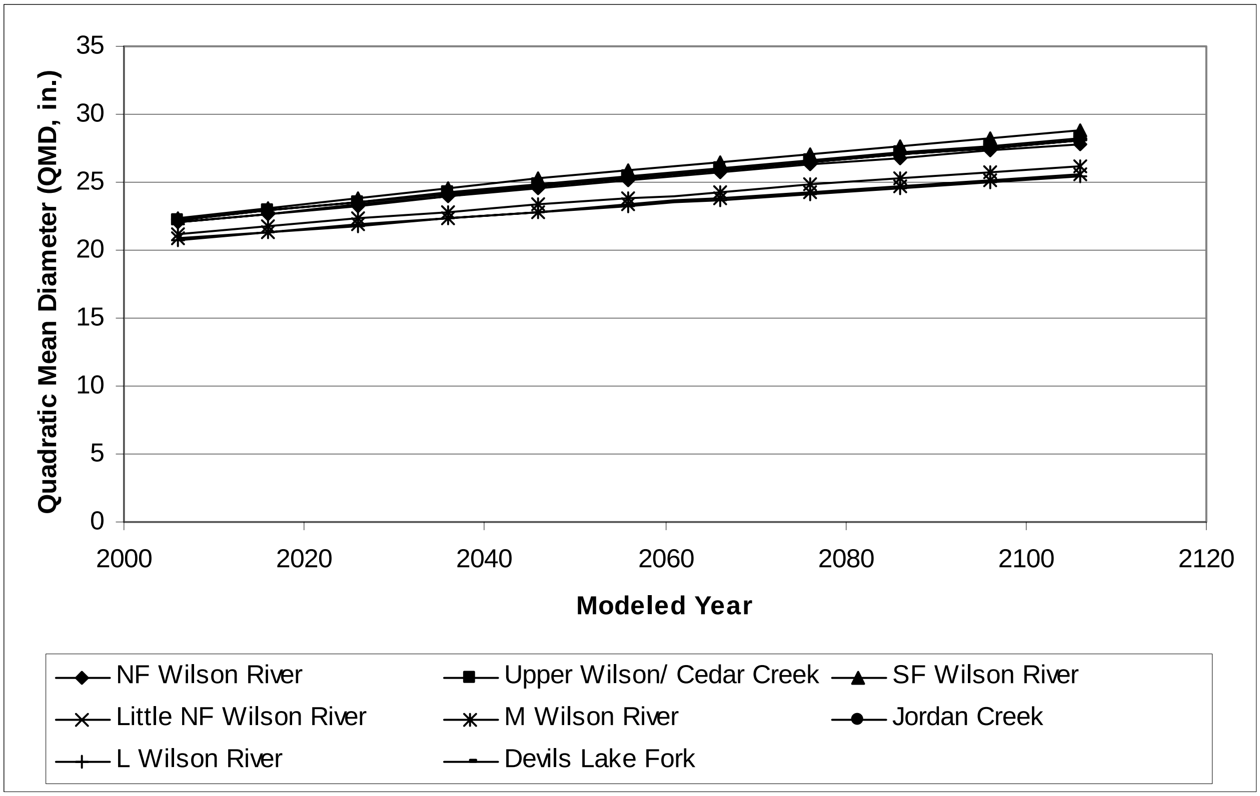

Figure 13. Projected Live Tree Quadratic Mean Diameter (Canopy strata). The 100-year projection of quadratic mean diameter for stand-level live trees ≥14 inches DBH, weighted for acre contribution by subwatershed.

The models and field observation suggest the canopy dynamics are currently entering in a 'stem exclusion' phase, where the overstory canopy is represented by smaller diameter trees that will experience a period of growth stagnation from competing canopy pressures. The long-term outlook suggests a decline in the number of trees entering the canopy strata through time, and more importantly, the *rate* by which trees will enter the canopy strata. The latter is of particular importance as it indicates a long-term trend of current trees getting larger in diameter (an ODF priority), but less replacement of those larger trees from the younger size classes of today. Hence, as the fewer, larger trees die, there does not appear to be a replacement cohort for those large-diameter trees in the future. These combined observations strongly suggest the trajectory of the riparian zones in all subwatersheds will not meet the definitions of "mature forest conditions" within the projected 100 year timeframe (refer to Appendix J – Desired Future Conditions).

6.2.1.3 Forest Structure and Compositional Dynamics

Following the similar methods presented in the previous section, canopy structure was evaluated on the basis of major species type (conifer and hardwood) to investigate the recruitment of these species types to the canopy.

The projected densities for live conifer (Figure 14) recruitment to the canopy (≥14 inches DBH) illustrates a slight increase in conifer recruitment within the next 10 years, followed by a steady decline over the remainder of the time period. Beginning approximately in 2040, the conifer density in the canopy declines to approximately that found in the current conditions for all subwatersheds, resulting in a net loss of canopy-sized conifers by the end of the time period. Both SF Wilson and Devils Lake Fork, the richest in conifer abundances, are projected to have the largest nominal decline, ending the model run at a density lower than the highs of the conifer poor areas. Stand-level mean diameters for conifers in this class are highly variable and range between 17-30 inches DBH and increase to 20 – 40 inches by the end of the model run, achieving a component of >35 inch conifers in most of the subwatersheds.

The majority of the recruitment to the canopy is in hardwoods (Figure 15), with a doubling of trees per acre in the upper strata of the forest structure by the 50 year time step. Following this time, the decline ends in a net gain by Year 100 of approximately 30% more hardwoods in the canopy strata as compared with the current conditions. The stand-level mean diameters of the canopy class, as with conifers, are highly variable, but do appear to increase in size from 15 – 22 inches DBH in the first 50 years, to ~18 – 25 inches DBH by year 100.

Similar to the canopy structural dynamics described above, understory structures and recruitment (defined as trees <14 inches DBH) were evaluated as subsets of conifers and hardwoods. Perhaps the clearest observation in this component is the effect of the modeled regeneration assumptions, evidenced by a “stair-step” increase and decline in abundances of persistent conifers (Figure 16) that corresponds to the forcing of regeneration feature of the model run. This pattern is attributed to the projection model reaching stand density thresholds to promote self-thinning. The magnitude of the conifer curve in combination with the canopy recruitment models presented above suggests that this size class distribution probably (a) contains sufficient stocking to not be limited for potential canopy recruitment but is (b) probably limited in stand density indices driving growth and mortality thresholds. This suggests the model will inherently favor the most shade-tolerant conifer species (e.g. hemlock).

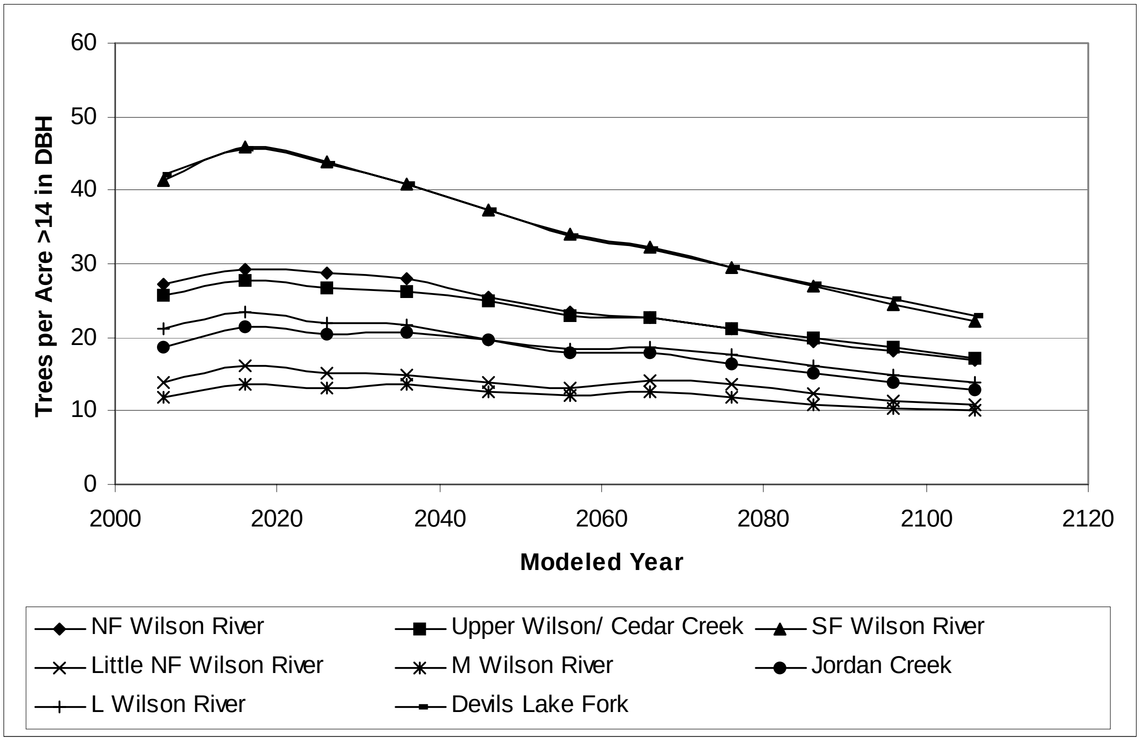

Figure 14. Projected Conifer Recruitment to the Canopy (>14 inches DBH). 100-year modeled weighted average live conifer trees per acre for riparian zones on ODF lands.

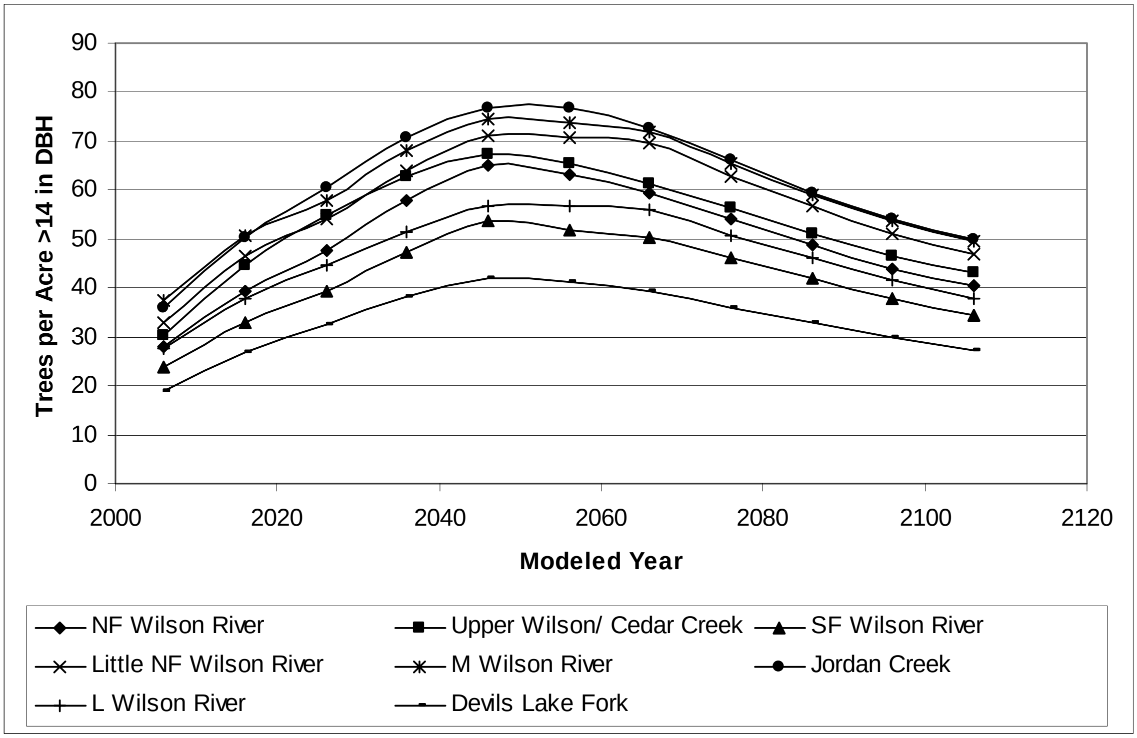

Figure 15. Projected Hardwood Recruitment to the Canopy (>14 inches DBH). 100-year modeled weighted average live hardwood trees per acre for riparian zones on ODF lands.

The hardwood understory component (Figure 17) follows a general decline for the duration of the model run, following model thresholds for stem density and shading affecting mortality triggers. Of important note, the current conditions show twice to three times the abundances of hardwoods to conifers; a trend that reverses by year 50. This is a legacy of the model run, where conifers are selected to persist on the basis of mortality thresholds. This also underscores how model assumptions affect projections during longer time periods. The question for monitoring purposes is to evaluate the true persistence of conifer species in the understory to ensure adequate "front end loading" of conifer species to ultimately recruit to the overstory canopy.

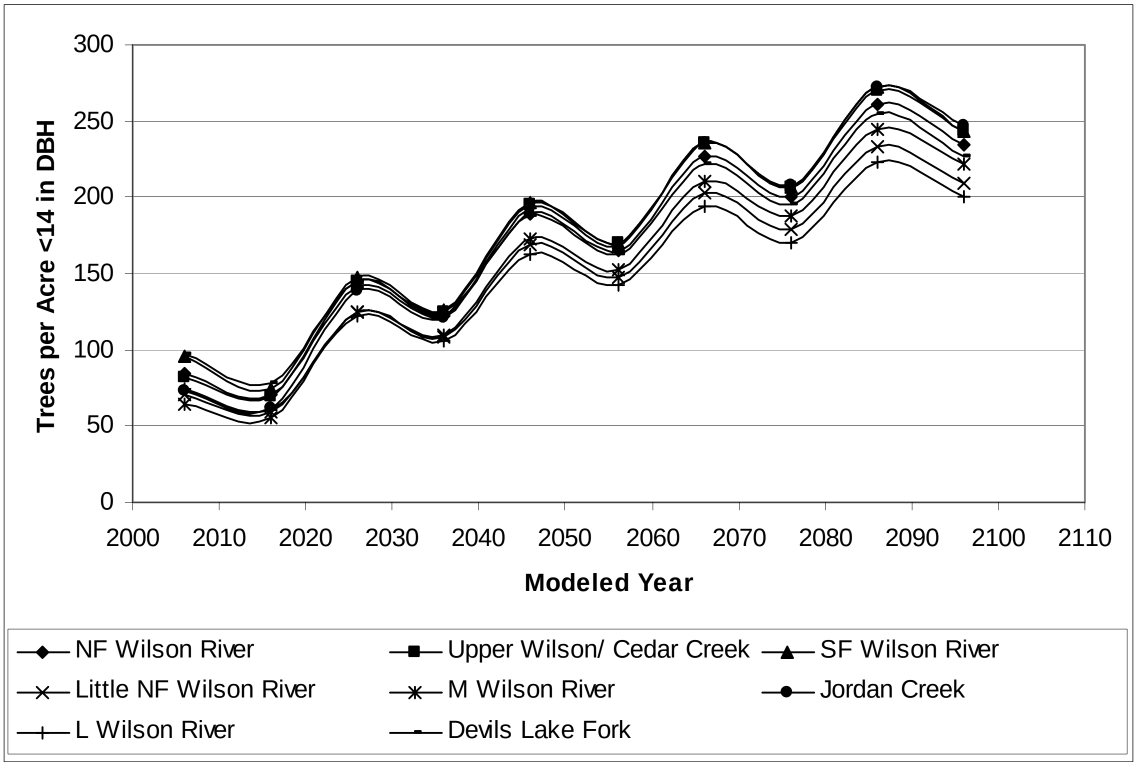

Figure 16. Projected Conifer Regeneration. The 100-year projected density of conifer trees per acre in size classes <14 inches DBH. Mean values are weighted for acreage contribution by subwatershed.

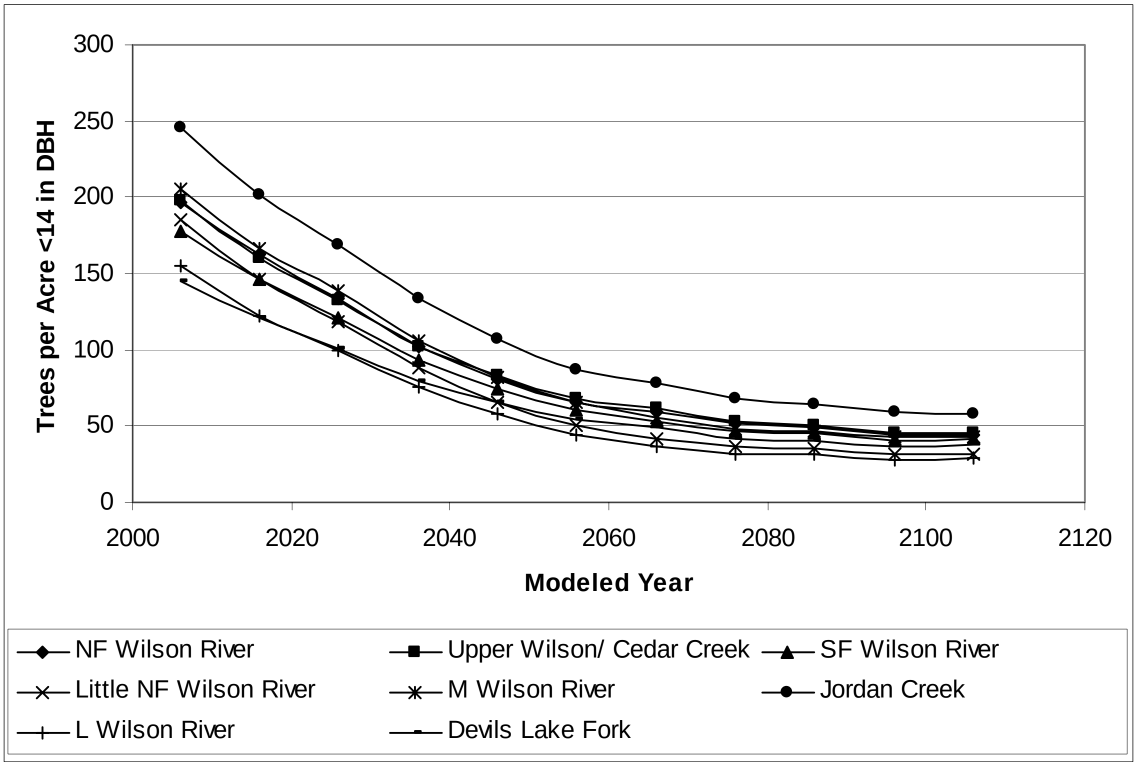

Figure 17. Projected Hardwood Regeneration. The 100-year projected density of hardwood trees per acre in size classes <14 inches DBH. Mean values are weighted for acreage contribution by subwatershed.

6.2.1.4 Stand Mortality and Creation of Downed Wood

Mortality rates, expressed as trees per acre, were calculated for the 100-year time period. The mortality rates expressed are through modeled mortality due to stem exclusion, competitive pressures, and other successional probabilities for mortality. As explained in earlier sections, these estimates do not include stochastic events such as landslides, debris torrents, flooding, insects or disease, animal pressures, or fire. In addition, human-caused damages are not a factor, including harvest, compaction, recreational impacts, road damage, etc.

The data presented in this section describes the potential mortality, of which a subset is potentially interactive with the stream channel. The data also provide important information for stand-level downed large wood, providing habitat components, large wood for nurse logs and overland sediment mediation, and for nutrient cycling. Further information about probabilities of stream channel interactivity are presented in a later section (refer to section 6.2.3 Stand Modeling of Large Wood Recruitment, below).

For the canopy strata (trees ≥14 inches DBH), there is an observed increase in the number of downed trees in the next ~40 years (Figure 18). Following this peak, there is a general decline in available downed trees ≥14 inches DBH for all areas, resulting in a net loss of available trees as compared with the current condition (approximately 30% fewer dead trees per 10 year period). Of particular note is the rate of change in downed wood creation, especially after ~2036 (Figure 19). Following two consecutive time periods with increases in medium-large downed wood, there is a marked decline in the mortality rates, with all subwatersheds continuing to have declining rates, excepting Jordan Creek, Little North Fork and Middle Fork Wilson River until 2056. Mortality rates continue in a steady decline at a rate of 10% to 20% per decade until the end of the period.

The "lag period" begins in approximately 2036 can be attributed to the beginning of the decline in conifer mortality (Figure 20) and the period of time before 2056, when hardwood mortality begins to reach its peak (Figure 21). This lag period has particular implications on available wood for riparian recruitment to the stream. Considering the relatively low *density* of conifers in the canopy on the landscape, the apparent slow *recruitment* of conifers to the canopy, coupled with the declines in *mortality* suggest this lag period may extend beyond 100 years for conifers, assuming the modeled scenario.

The influx of large wood in the next 30 years, followed by an extended lag period of tree mortality appears to follow a 'stem exclusion' pathway, where smaller-diameter trees in the canopy will compete and experience a minor "pulse" of mortality, allowing for the residual trees to compensate and grow to larger diameters and heights. However, there is concern for the available trees that will follow this pulse, with an apparent limited recruitment into the mid-story and upper stories throughout the time series – primarily found in slow-growing persistent conifers and declining hardwood abundances. In addition, the larger-diameter trees (especially conifers) do not appear to die during the latter portions of the time series – further underscoring the lack of instream large wood, especially durable conifer wood, during this time. While these patterns are not unusual for non-managed, ~60 year old mixed forests, and large trees appear to grow larger (but less plentiful), there is a limitation in the available large wood and stream shading (see sections below) in the mid- and later periods of the timescale.

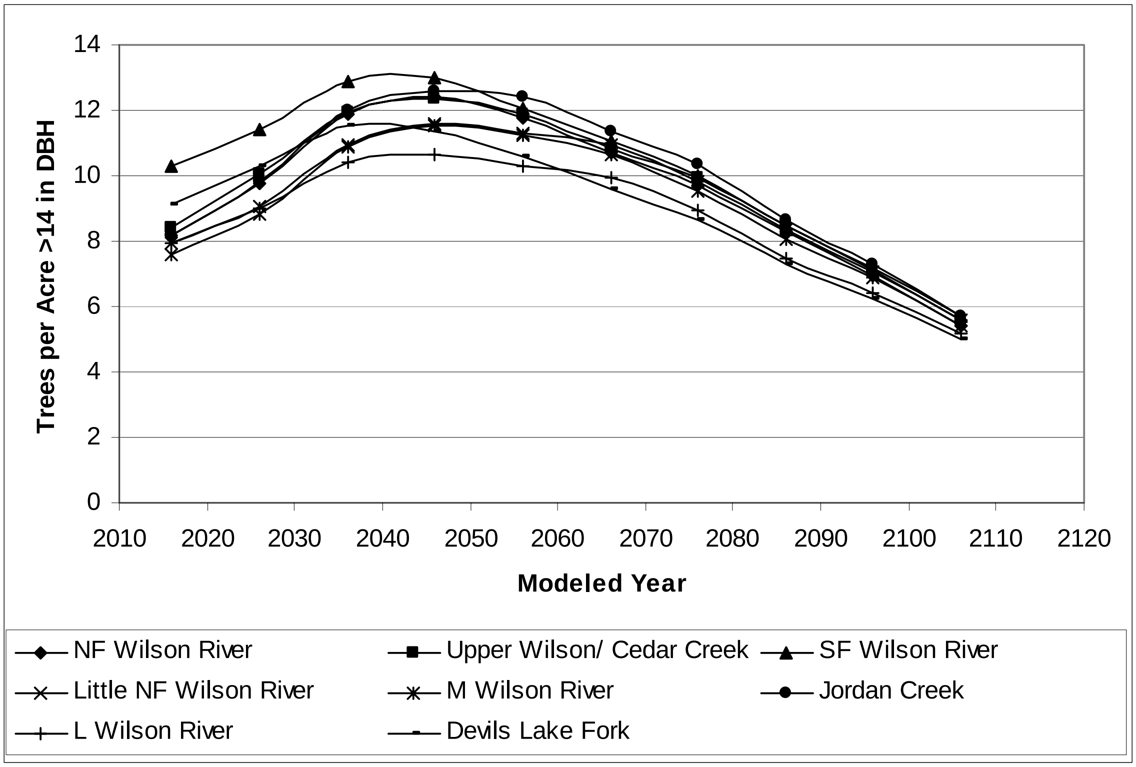

Figure 18. Projected Canopy Strata Mortality. 100-year modeled weighted average of dead trees ≥14 inches DBH per acre for conifers and hardwoods combined, presented by subwatershed.

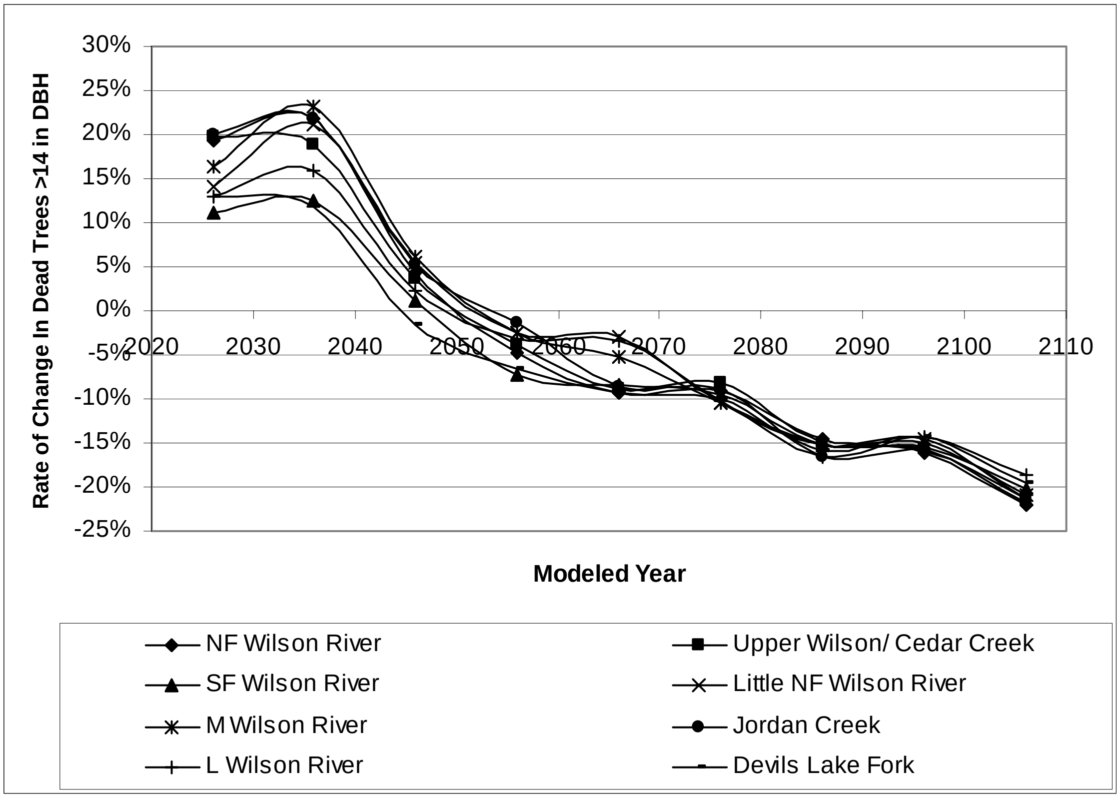

Figure 19. Rate of Change in Canopy Tree Mortality. Percent increase or decrease in tree mortality ≥14 inches DBH, presented as weighted averages by subwatershed.

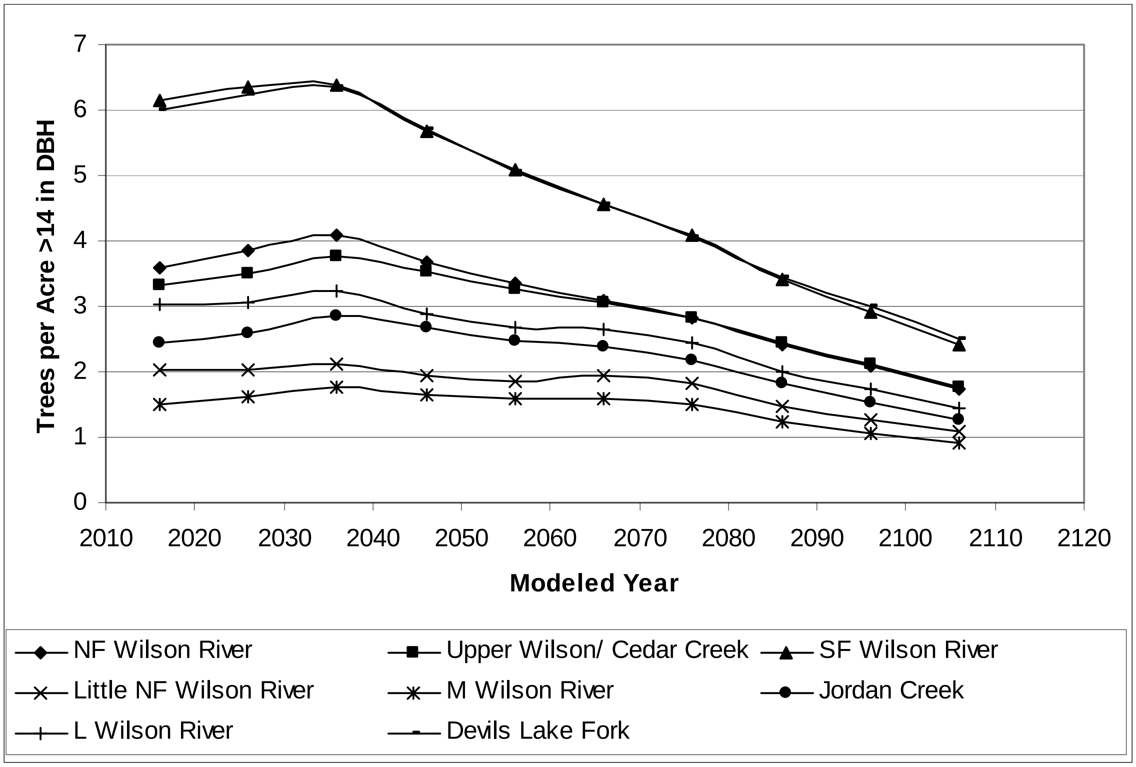

Figure 20. Projected Canopy Mortality of Conifers. 100-year modeled weighted average of dead trees ≥14 inches DBH per acre for conifers and hardwoods combined, by subwatershed.

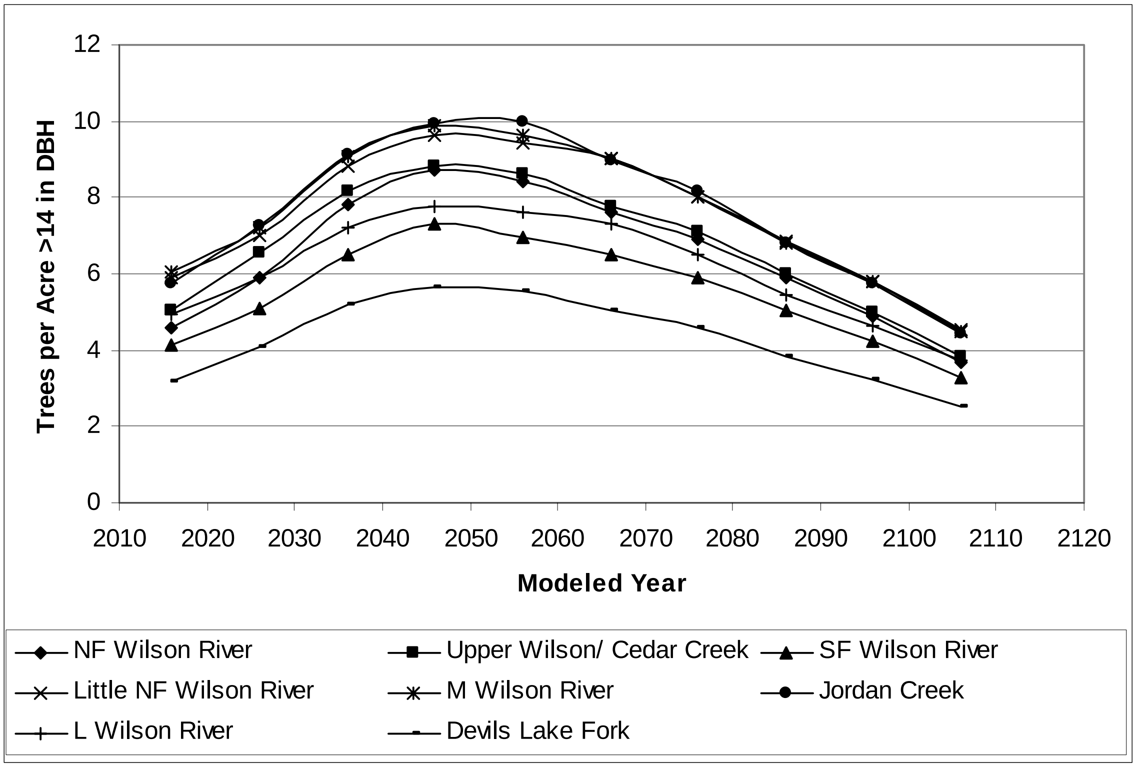

Figure 21. Projected Canopy Mortality of Hardwoods. 100-year modeled weighted average of dead trees ≥14 inches DBH per acre for conifers and hardwoods combined, presented by subwatershed.

6.2.1.5 Key Findings at the Subwatershed Scale

The following are key points regarding the riparian successional dynamics under the 100-year non-managed scenario:

- **Conifers Dominance is Dependant Upon Assumptions and Opportunity.** The model suggests the proportion (relative density) of conifers and hardwoods in the system begins to reverse by year 50, with hardwood abundances declining to below that of conifers in the second half of the model run. The primary assumption of this finding is that disturbances and management are not present to create gaps to allow for micro-site establishment opportunities by either species type. As such, trees most adapted to shade tolerance will persist (e.g. hemlock). Because these trees are a relatively small component of the seedling pool, their modeled dominance is primarily dependant upon modeled mortality of shade intolerant species.

- **Conifer recruitment to the canopy declines through time.** Rates of conifer tree recruitment to the ≥14 inch size class decline through time for the 100 year time period, especially following 2036. This trend appears to be attributed to few conifers available for recruitment, and mortality triggers that constrain the recruitment pool to slow growth, shade tolerant species. This trend is causing an apparent lag in conifer recruitment to the canopy, which is likely to extend beyond 100 years, until conversion to multi-structured forest types (e.g. shade tolerant hemlock dominant) becomes dominant. The projected time beyond 100 years for this conversion is unknown.

- **Trees are growing.** There is evidence that trees in the canopy strata are attaining larger mean diameters in both hardwoods and conifers. Stands are becoming multi-layered, though apparent recruitment to the canopy classes generally declines. This trend appears to peak at 50 years, where the completion of the stem-exclusion phase allows for additional cohort differentiation between hardwoods and conifers <14 inches DBH.
- **Lower mortality rates and fewer downed trees per acre.** Sharp declines in mortality of the ≥14 inch size class begin after 2036. These declines persist for the remainder of the model run, and the current rates suggest they will continue to decline for more than 100 years at a rate of ~20% fewer trees per 10 year period. In addition, fewer conifers are contributing to the mortality pool. This has direct implications for large wood recruitment to the stream channel.

The model results summarized above strongly indicate the current riparian stands in the Wilson River watershed are reaching the point of ‘stem exclusion’, where growth stagnation and competition for light will cause a pulse in mortality through self-thinning, followed by growth of a simplified, multi-layered (two or three layers) canopy, consisting of larger-diameter trees that increase in size over time. Though the Forest Management Plan (FMP; specifically, Appendix J of the FMP) recommends the growth of large-diameter conifer trees in the riparian zone as the ‘desired future condition’, the data suggest that this condition will likely not exist for 100 years and potentially longer, and there are limiting factors that will inhibit how the riparian zones function for streams within all subwatersheds during the modeled time period.

One limiting factor to the FMP strategies is the observation that conifer dominance and recruitment to the canopy is a very slow process, and does not appear to have an effect on canopy dynamics during the 100 year time frame (i.e. hardwood dominance persists)[47]. Understanding the model is limited in

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[47] For further growth model discussions, see Appendix Y – Potential Future Conditions: Riparian Modeling Scenarios and Comparisons.

quantifying these successional dynamics on the basis of the primary assumptions, the dominance of hardwoods observed through the models and in the field suggests there are limited opportunities for conifer establishment, recruitment to the canopy, and (ultimately) recruitment to the stream channel as instream large wood for at least 100 years assuming no management or disturbance. Hence, one management option would be to attempt to shift the species composition to favor conifer growth though time to enhance conifer establishment and increases in co-dominance percentages at earlier time periods, especially within the canopy strata.

The recruitment to the mid-story canopy by both hardwoods and conifers is also limiting. Following the stem exclusion mortality pulse, there does not appear to be good recruitment success to the lower and mid-canopy strata in the latter 50 years of the time series. This is especially true for conifer trees, though there are notable declines in canopy recruitment for hardwoods as well. Coupled with this shortfall in canopy establishment is the corresponding decline in tree mortality (for both hardwoods and conifers), which has direct implications on in-stream large wood recruitment to the stream channel in the last 50 years. Large trees, especially large conifers, are observed in the latter periods of the model runs, though the concern is a lag period in trees to ultimately replace the largest size classes (in 75 – 150 years), and to provide interim inputs of large wood. Management options to increase the diversity in size classes are recommended (see Pathways to Action Plan below), with the ultimate goal to sustain mid-term (~50 year) recruitment to the canopy and subsequent shade and large wood inputs during the 50-100 year period (and beyond).

It is not known if the canopy recruitment and species dynamics will change their current trajectories in time frames exceeding 100 years. Included with the inherent assumptions that form growth and yield models (such as FVS) are uncertainties associated with the disturbance patters on the landscape. Climate change, alterations in fire frequency and severity, stochastic factors, land uses, and shifts in the hydrologic regime are all factors that can (and do) change the species and structural dynamics of a given system. In fact, these factors ultimately stimulate structural and compositional diversity on the landscape, and promote conditions found in ‘first growth’ forests. Under this modeled scenario of no management in a managed system, and extrapolating the trends observed, the limitation and lag of young trees recruiting the canopy suggest a situation beyond 100 years that may provide less shade and wood inputs to the system than it will be projected to within the next 30-50 years.

Further discussion on management options that follow the FMP (specifically, Appendix J of the FMP) and recommended pathways for an action plan using current ODF resources are described in more detail below.

6.2.2 Large Wood Recruitment[48]

Estimates of large wood recruitment to the stream channel was evaluated in two different ways:

- Evaluation of standing wood through time, specifically targeting benchmark ranges for *conifer* trees in the riparian zone, based upon a range of reference stream reaches in the Coast Range (Kavanagh et al. 2005). This method provides "pass/no pass" criteria for *categorical* evaluation for the watershed as a whole.
- A time-series of tree growth and mortality, with modeled probabilities for large wood inputs (all species and sizes) to engage the stream channel. This method is specific to the Wilson watershed, and provides a range of expected conditions through time, expressed as nominal values. This method is *adaptive* for evaluating effects of potential treatments on large wood recruitment.

6.2.2.1 Methods: Categorical Evaluation of Standing Trees

Estimates of large wood recruitment to the stream zone was generated from the riparian dataset with expanded stand metrics (ODF lands only). Considerations of large wood inputs were made for conifer species at ≥20 and >35 inches DBH per 1,000 feet of stream length (by 100 ft buffer strip, ~30 m). Low and High values obtained from reference reaches in the Coast Range (ODFW unpublished) represent the 25th and 75th percentiles of the data:

Diameter Minimum	Stream Length (feet)	Low Range	High Range
>20 inches DBH	1,000 ft	<22 trees/ 1,000 ft	>153 trees/ 1,000 ft
>35 inches DBH	1,000 ft	0 trees/ 1,000 ft	>79 trees/ 1,000 ft

6.2.2.2 Results: Categorical Evaluation of Standing Trees

Figure 22 presents an overview of the potential future standing conifer stocks ≥20 inches DBH for each of the subwatersheds, assuming a no-management scenario (see Riparian Stand Dynamics section for further discussion). While Little North Fork and the Middle Fork Wilson River do achieve the minimum of the low range of conditions in the first time step, the overall modeled data

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[48] For a detailed wood recruitment *budget* for the Wilson River watershed, refer to Appendix L.

indicate most subwatersheds have standing stocks of conifers that are within the lowest quartile of the desired range between 2016 and the end of the model run. However, declines in conifer stocks and losses of conifer mortality and canopy recruitment are of concern in the later years of the model (see section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above).

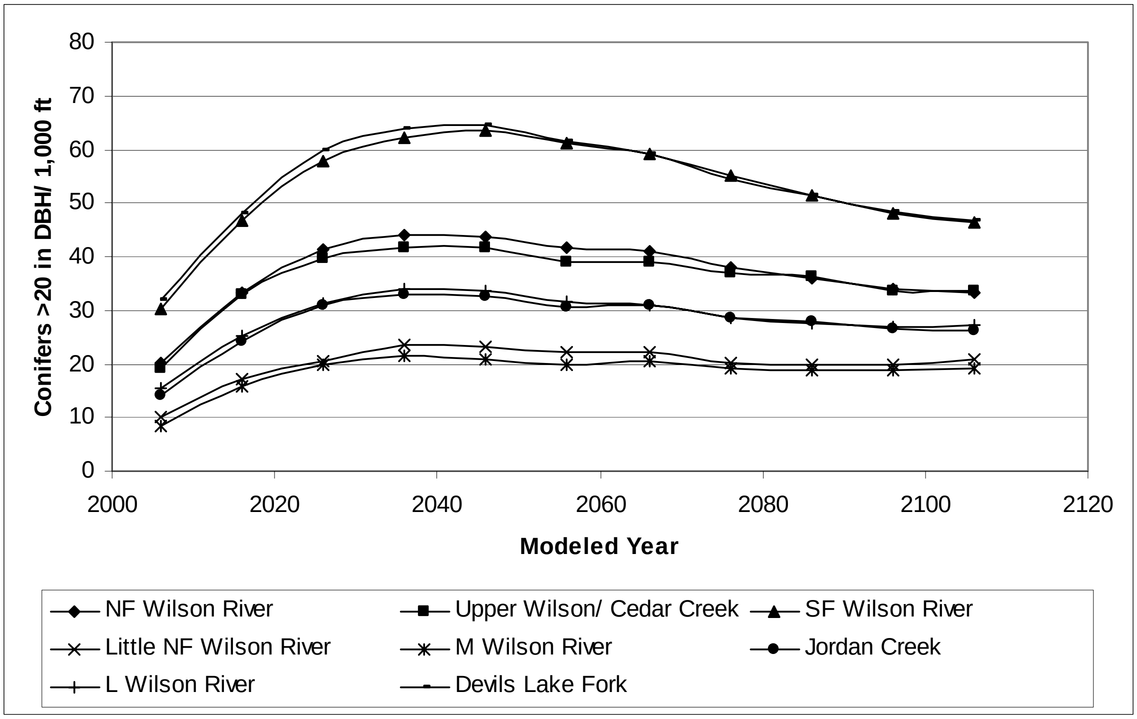

Figure 22. Standing Large Conifers (≥20 in DBH) per 1,000 ft of stream. The 100-year modeled scenarios of large conifers, presented as weighted averages for each subwatershed.

While recruitment of conifers to the canopy layer is slowed throughout the time series, conifer sizes do increase through time and provide a range of ~13 – 33 conifers >35 inches in DBH as standing trees in the riparian zones (Figure 23). These values are within the lower half of the desired range determined from reference reaches, though it is important note the recruitment of *new* conifers after the model period is likely very low. Without continued recruitment of large conifers to the upper canopy layers, the eventual mortality of these large trees will create a “lag point” where annualized standing conifer stocks will decline.

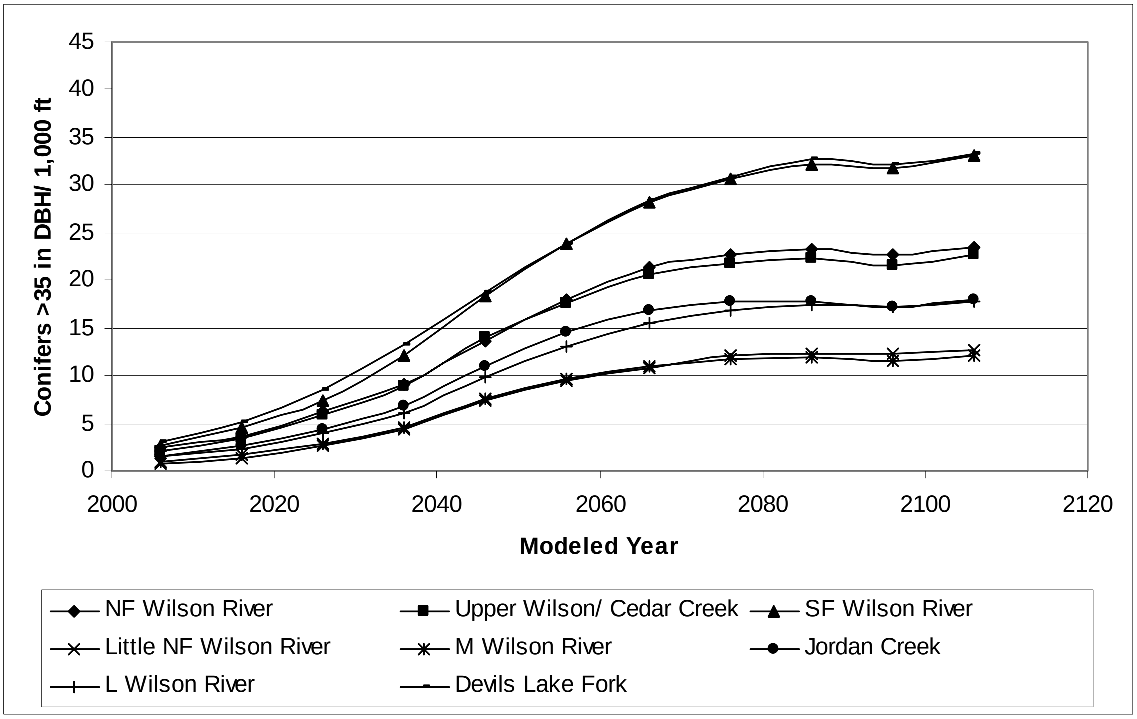

Figure 23. Standing Large Conifers (>35 in DBH) per 1,000 feet of stream. The 100-year modeled scenarios of large conifers, presented as weighted averages for each subwatershed.

Table 21. Standing stocks of conifers >35 and ≥20 inches DBH per 1,000 feet of stream channel. 100 year profile for conifers, in 10 year increments, averaged on a weighted acre basis and summarized by subwatershed.

Subwatershed	**2006**		**2016**		**2026**		**2036**		**2046**		**2056**		**2066**		**2076**		**2086**		**2096**		**2106**	
	>35”	**>20”**	**>35”**	**>20”**	**>35”**	**>20”**	**>35”**	**>20**	**>35**	**>20**	**>35**	**>20**	**>35**	**>20**	**>35**	**>20**	**>35**	**>20**	**>35**	**>20**	**>35**	**>20**
NF Wilson River	2	20	4	33	6	41	9	44	14	44	18	42	21	41	23	38	23	36	23	34	23	33
Upper Wilson/ Cedar Creek	2	19	3	33	6	40	9	42	14	42	18	39	21	39	22	37	22	36	22	34	23	34
SF Wilson River	3	30	4	47	7	58	12	62	18	63	24	61	28	59	31	55	32	52	32	48	33	46
Little NF Wilson River	1	10	1	17	3	21	4	23	7	23	9	22	11	22	12	20	12	20	12	20	13	21
Middle Wilson River	1	8	2	16	3	20	4	21	8	21	10	20	11	21	12	19	12	19	11	19	12	19
Jordan Creek	2	14	3	24	4	31	7	33	11	33	15	31	17	31	18	29	18	28	17	26	18	26
Lower Wilson River	1	15	2	25	4	31	6	34	10	33	13	32	15	31	17	29	17	28	17	27	18	27
Devils Lake Fork	3	32	5	48	9	60	13	64	19	65	24	61	28	59	31	55	33	51	32	49	33	47

6.2.2.3 Stand Modeling of Large Wood Recruitment

In-stream wood arrives via several potential routes: riparian trees die or are blown over and fall into streams, bank erosion undermines trees that topple into streams, overbank flooding carries wood to streams, and landslides and debris flows carry wood to streams. Of these processes, recruitment rates from the first three vary directly with the size, species, and age distribution of trees in the riparian zone; hence our focus on characterization of riparian stands and the use of reference size and species densities for evaluating the potential for wood recruitment from these stands.

However, the benefits for aquatic habitat provided by recruited wood vary both with wood-piece and channel size. To incorporate these factors into our evaluation of current and future wood recruitment from riparian stands, we use a spatially distributed wood recruitment model. The model estimates the number, diameter, and species type (conifer versus hardwood) of wood pieces entering each stream reach from modeled riparian tree mortality (see section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above). The recruitment model is spatially referenced to the 10-m DEMs. It uses preferential tree fall directions dependent on hillslope gradient and on tree location relative to all channel edges. Annual wood sources from every DEM cell and annual wood inputs to every channel reach are calculated for every year using tree mortality for riparian stands obtained from FVS (see section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above). Pieces are lost from the system by decay or fluvial transport. We assign a constant species-dependent depletion rate to approximate wood lost to these processes and then integrate recruitment and depletion rates over time to estimate future nominal in-stream wood abundance (pieces per unit length) from riparian tree fall by piece-size class for all delineated stream reaches in the fish-bearing channel network. The reported results are for an unmanaged scenario. To account for channel size, these results are compared to the minimum piece diameter required for pool formation to obtain the number of potential pool-forming (functional) pieces accumulated in each reach, calculated each year over a 100-year period. These values indicate the degree to which riparian stands can serve as functional wood sources, provide predictions that can be compared to field measurements, and help to identify reaches where riparian wood sources may be inadequate for production and maintenance of high-quality aquatic habitat.

Effects of debris flows on wood recruitment and consequences for aquatic habitat must also be considered. For type F channels, we view debris-flow effects both from the potential for debris flows to carry sediment and wood to these streams and from the potential for debris flows to trigger debris-laden floods that can remove accumulated wood from these streams. Both of these processes are addressed in Chapter 7 of this document. Channels subject to debris flow inputs are identified in Map 25; debris flow source areas to these channels can be identified from Maps 26 and 27; channels most susceptible to debris-laden floods are identified in Map 28. The debris-flow-prone Type F reaches shown in Map 25 identify areas where debris flow inputs of wood serve important ecological functions. At any time, some subset of these reaches may have high wood loading values, and other effects, due to inputs from recent debris flows. The abundance of reaches with high debris-flow-derived wood will vary over time, depending on the temporal sequence of large storms. The size of wood carried by a debris flow depends on the size of the trees present along the debris flow path and the size of buried wood scoured from steep Type N channels traversed by the debris flow. In general, upland stands in the Wilson basin do not currently provide opportunities for recruitment of key (>60cm) wood pieces (although such pieces may be present in steep type N channels that have not been traversed by a debris flow in the past century or so). However, potential for debris-flow recruitment of key pieces can increase over time as upland stands grow. Maps 26 and 35 identify source areas for these pieces.

6.2.2.1.1 Methods

Modeled tree mortality for un-managed riparian stands was calculated using FVS at 10-year increments (refer to section 6.2.1.4 Stand Mortality and Creation of Downed Wood, above). Dead trees were assumed to fall over a 10-year interval. Trees were divided into five size classes, with a mean stem density and height reported for each class, and divided between conifer and hardwood species. Every tree within a tree height of a channel edge can potentially fall into the channel; the probability that it does was calculated using an empirical distribution of fall angles for the Pacific Northwest reported by Sobota et al. (2006). The size of the piece entering the channel was calculated as a function of tree distance from the channel and tree height, using taper equations for conifer and hardwood. Wood inputs were tracked over 10 piece size classes. This provided an average annual input rate for each reach that varied over time in response to changing riparian stand conditions.

To estimate the number of pieces accumulating in each reach, the annual input rate was integrated over time. This gives the number of pieces likely to have fallen into each reach from the starting year (2006). To account for decay and fluvial export, pieces were removed using a constant depletion rate (Beechie, Pess et al. 2000). This assumes that fluvial inputs equal fluvial outputs. An annual depletion rate of 3% was used for conifers and 4% for hardwoods, based on values reported by Hyatt and Naiman (2001) and Bilby et al. (1999).

To estimate the minimum diameter of pieces large enough to persist in a reach (i.e., resist fluvial transport out of the reach) and likely to form pools, we used an equation reported by Beechie et al. (2000), based on data from Beechie and Sibley (1997):

$$D_{pf} = 0.025W \quad (1)$$

where D_{pf} is the pool-forming minimum piece diameter and W is channel width, both in meters. Channel widths were calculated for each reach from NetMap using equations reported in Clarke et al. (in press). Equation (1) provides a rough guide for the minimum diameter of wood to serve as a habitat-forming element. Not all pieces of this size (or greater) will be stable or form pools, these aspects of piece function depend on many site and event-specific factors, but we expect that pieces smaller than this will generally not serve as persistent habitat-forming elements.

6.2.2.1.2 Results

6.2.2.3.2.1 Wood Abundance

For any reach, the predicted wood abundance varies over time. Predicted values for all wood pieces > 15 cm (6 in) in channels between 2 and 20 m (6.6 – 65 ft) wide on ODF lands, using the unmanaged stand-growth scenario, are shown in Figure 24. This size range represents channels typically included in habitat surveys. Because we start with a wood loading of zero, piece numbers initially increase. The number lost each year increases as total wood load increases, until after about 25-30 years, around simulation year 2030 – 2040, the number depleted is of the same magnitude as the number recruited. Changes from this point on reflect changing riparian stand conditions. Simulated basin-wide wood abundance reaches a peak around 2050, corresponding to the peak in modeled mortality around 2036. Total wood abundance decreases over the remainder of the simulation. Throughout the simulation period, the proportion of accumulated pieces from hardwood species remains near 70%, decreasing very slightly over time. The median value obtained from channel surveys in the basin is 20 pieces per 100 m (Appendix P – Summary of Aquatic Habitat Conditions, Table 1). These surveys include wood from mass wasting, bank erosion, and legacy wood predating the current riparian stands, none of which were included in modeled wood abundances.

The predicted abundance of key wood pieces, those over 60cm (24 in) in diameter, follows a different pattern (Figure 25). Initially there are almost no riparian stands providing trees of this size, so modeled abundances are low and gradually increase over time as trees grow and larger trees become available for recruitment to the channel. A smaller proportion of these key pieces are derived from hardwood species, which don't grow as large as conifers, but this proportion increases over the course of the simulation as many of the now 30 to 40-year-old hardwoods in the riparian stands reach the end of their lifespan.

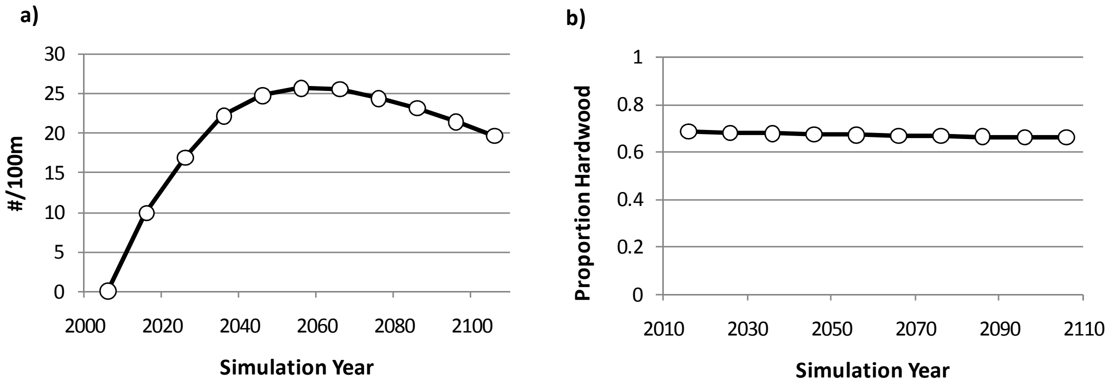

Figure 24. Temporal sequence of simulated wood abundance for all pieces >15 cm (6 in) in diameter by a) number per unit stream length and b) proportion of hardwood for all streams between 2m (6.6ft) and 20m (66ft) wide on state lands.

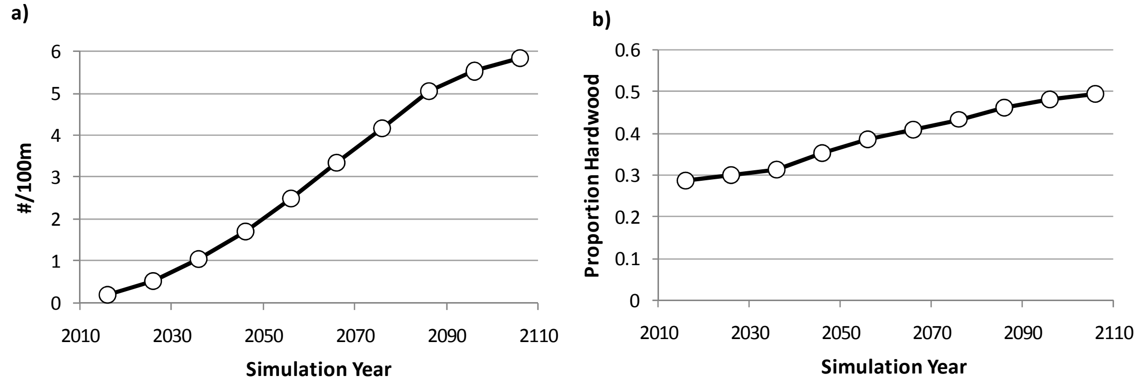

Figure 25. Temporal sequence of simulated wood abundance for key pieces, those > 60 cm (24 in) diameter by a) number per unit stream length and b) proportion of hardwood.

6.2.2.3.2.2 Functional wood

Map 30 shows how the minimum diameter for wood sufficiently large to resist fluvial transport and to significantly affect channel morphology (e.g., form pools), based on Equation 1 above, varies across the Wilson River channel network. Because larger channels require larger wood, the ability of riparian stands to provide functional wood varies in time and space across the channel network, as shown in Figure 26 and Maps 31-33. Because riparian stands in the Wilson River basin are of a relatively uniform age, with most post dating the large fires and extensive salvage logging of the mid century, the ability of riparian stands to provide functional wood is primarily a function of channel size. For small channels, less than about 10 meters (~33 ft) in width, there is abundant supply of functional wood,. Once past the 25-30 year lag time to account for the zero-wood starting condition (see above), modeled abundances exceed levels considered high – 20 pieces per 100 meters – with declining peak abundance after year 2050. For larger channels, the abundance of functional wood is persistently low, but increasing over time (Figure 26).

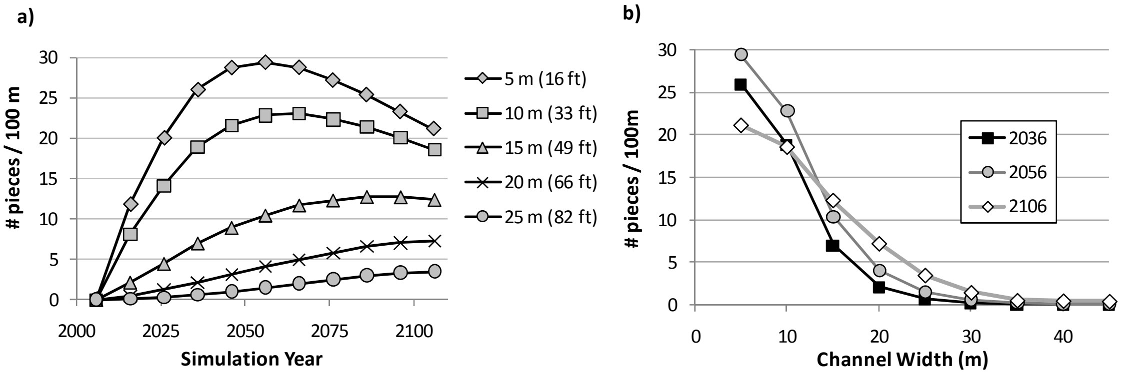

Figure 26. Simulated abundance of functional size (a) and dependence on channel size (b).

6.2.2.3.2.3 Debris Flows

Channel reaches susceptible to debris flow inputs of sediment and wood are identified in Map 34 (see also section 7.2 – Debris Flow-Prone Channels and section 7.3 – Deep-seated Landslides). Lack of riparian wood recruitment can increase the sensitivity of these reaches to debris-flow effects; reaches having both moderate to high debris-flow susceptibility and low anticipated riparian recruitment of functionally sized wood (<2 pieces /100m) are shown in Map 35. The fate of debris-flow deposited material and the consequences for in-channel habitat vary with the size of the debris-flow relative to the size and steepness of the receiving channel (Benda, Andras et al. 2004). Reaches most likely to be affected by debris-flow inputs include those classified in Chapter 7 (Sediment Sources) as morphologically significant and those having the potential of forming scouring debris-laden floods, shown here in Map 28. For both types, the negative impacts of debris flows are exacerbated by lack of large (i.e., functionally sized) wood. Reaches that are both particularly sensitive to debris flow inputs and that have low anticipated riparian recruitment of functionally sized wood are identified in Map 35. These are sites where upland sources of wood, identified with the landslide plus delivery susceptibility (refer to Maps 26 and 27 and

Chapter 7 – Sediment Sources), can have great influence on future channel conditions.

6.2.2.3.2.4 Upslope Wood Sources

Identification of upslope areas and headwater channels likely to provide the greatest benefit to fish involves overlay of results from three analyses: 1) identification and prioritization of reaches currently or potentially used by fish (section 9.14 Priority Streams), 2) evaluation of riparian wood sources (this section) for those reaches, and 3) identification of steep slopes and headwater channels that can provide wood and ranking of these source areas by the potential for delivery to those reaches (section 7.2.2 Results). Two factors aid in generalization of these results. First, the nearly uniform and relatively young age of riparian stands throughout the basin allows us to characterize riparian wood recruitment potential in terms of channel size; channels greater than 15m (~50 ft) in (estimated) width have widespread and persistent low abundances of functionally sized wood. Second, the widespread presence of fish, particularly steelhead, renders nearly all streams greater than 15m width of high importance for fish in this basin. Hence, delineation of slopes and headwater channels draining to these streams and overlay of estimated landslide and delivery potential within these areas serves to identify those upslope areas and headwater streams most likely to provide large wood that will benefit fish.

For example, Map 37 shows the fish-bearing portion of the channel network for channels less than and greater than 15m wide. (Note that these estimates of channel width are based on regional regressions to drainage area and mean annual precipitation. They serve as a reference of average stream size, verified by field visits within the basin (Appendix S – Field Validation of Some NetMap Parameters), but actual width varies dependent on reach-specific conditions. Our interest here is in average channel size). Overlain on these are reaches identified as high priority for fish because they have current high fish abundances or high habitat intrinsic potential (see section 9.14 Priority Streams). High-priority reaches falling within HU-code 6th-field basins designated as Salmon Anchor Habitat are also delineated. The potential for debris-flow delivery to all high-priority reaches was calculated using the methods described in Section 7 and Appendix T – Slope Stability Assessment. These were used with the calibrated landslide susceptibility model to determine the areas encompassing a given proportion of the expected landslide sites that might deliver sediment and wood to these high-priority reaches. The delineated areas are shown in Map 38. These results were also used to identify the headwater channels most likely to be traversed by debris flows that travel to the high-priority reaches. These headwater channels are shown in Map 39, in terms of the channels expected to contain specified proportions of debris flow events. The upslope areas that can potentially provide debris flows to these high-priority reaches are extensive, as indicated by the broad expanse of (low) hazard area in Map 38. This low-hazard zone primarily involves source areas for long-runout debris flows, which have a low (but greater than zero) probability of reaching a high-priority stream. The areas most susceptible to triggering landslides and debris flows that travel to a high-priority reach are concentrated on channel-adjacent slopes. Likewise, because debris flows from upslope are routed into headwater channels, the lower portions of these channels have the highest potential to be traversed by a debris flow from upslope source areas.

Nearly all debris flows that reach fish-bearing streams must traverse these headwater channels. Headwater channels form long-term storage sites for instream large wood, accumulating wood and sediment over decades to centuries, until the next debris flow scours the accumulated material and carries it downstream (May and Gresswell 2003). Riparian management zones along these headwater channels and extending into landslide source areas can help maintain sources of large wood, including trees that fall or are carried by small landslides into headwater channels, stored until scoured by a debris flow, and standing trees that get incorporated into landslide and debris-flow material.

Management goals for these source areas should include buffers to maintain live trees, and may include thinning to maximize the size of these trees. The fish-bearing streams that may someday receive these trees in debris-flow deposits are currently lacking key, jam-forming pieces (> 24 in diameter); the larger the trees available for debris-flow recruitment, the more likely it is that the recruited wood will provide stable channel structures.

6.2.3 Future Vegetative Conditions

Detailed discussions pertaining to future vegetation conditions, assuming a “no management (harvest)” scenario, can be found in section 5.4 – DHSVM Future Modeling.

6.3 Riparian Enhancement Opportunities

6.3.1 Potential Management Following Forest Management Plan Standards

Given that the majority of the riparian zones exhibit high proportions of hardwood species, and that the successional changes predicted in the 100-year time frame do not indicate any substantial shifts in species composition through time, the riparian zones are likely to remain predominantly hardwood dominated for the foreseeable future. At the subwatershed scale, the current trajectories indicate a period of a tree mortality pulse, followed by a lag period where mortality declines and mid-sized trees are not recruited to the canopy. This lag period trajectory appears to extend beyond the 100-year timeframe, assuming a no-management scenario. This has direct implications that limit the potential for large recruitment and stream shading.

As stated in previous sections, the structure and composition and apparent lag period in canopy recruitment is primarily due to the overall age of the stands. The stand-replacement fires, salvage logging, roads, and in-stream log drives have dramatically altered the riparian vegetation, and have effectively "reset" the successional age diversity of the system. Through a long timeframe (~250 – 300 years) with native disturbance patterns in place and limited land-use interaction, there may be a conversion to a multi-strata forest with old-growth conifer characteristics without considerations for active management. At present the area is within a potential ODF management zone, and priorities for active management can be shifted to evaluate whether active management can alter the composition and structure to favor multi-strata conifer co-dominance.

Though the current available data are not suitable for prescribing valid or practical site- and time-specific silvicultural treatments, it is possible to apply a qualitative approach to evaluate the Forest Management Plan (refer to Appendix J in the FMP) objectives to the riparian zones as a whole. The Forest Management Plan states for the Inner RMZ zone that the zone is to be managed for a "mature forest condition", following a range of other best management practices. This "mature forest condition" is further described as the following:

> "*Desired mature forest condition consists of a stand dominated by large conifer trees, or where hardwood-dominated conditions are expected the natural plant community, a mature hardwood/shrub community. For conifer stands, this equates to a basal area of 220 square feet or more per acre, inclusive of all conifers over 11 inches DBH. At a mature age (80-100 years or greater), this equals 40-45 conifer trees 32 inches in DBH per acre.*" (refer to Appendix J in the FMP).

Considering the prevalence of hardwoods, the apparent lack of conifer seed trees currently established in the riparian zones and neighboring uplands and the canopy dynamics favoring hardwoods through time (with slow-to-establish understory conifers), it is sensible to assume the foreseeable (100 year) projections will favor a hardwood-dominated system for the watershed as a whole. The Forest Management Plan describes specific management targets for conifer stands; these stand types represent the fewest acres (12%) of the riparian zones in the watershed. Although site-specific prescriptions based on the current data are not advised, it is possible to evaluate all stand types on the basis of their potential for obtaining a mature forest condition, on the basis of large conifer densities.

The Forest Management Plan describes the mature age at 80 – 100 years, which is equivalent to stand ages at ~2036 – 2056 model years. The 100 year Forest Vegetation Simulator model run was examined for conifer densities and basal area for the 10 representative *expansion stands*, or the weighted stand averages for the 10 major FPS codes sampled that represent the stand metrics for unsampled stands of like codes. The purpose of this analysis is to evaluate the Forest Management Plan standard for meeting mature age metrics for conifers. Acres were not considered, as the stand resolution (slope, patch size, etc) is not fine enough to follow other best management practices defined in the Forest Management Plan (SDI retention at the patch level, slope criteria, etc.). However, this analysis provides the "best case scenario" to evaluate if stand types will achieve the mature conditions (expressed as conifer density) through time. All stand types were considered in this analysis.

Figure 27 and Figure 28 below display scatterplots of the basal area and stem density of conifer trees >32 inches DBH for the 100 year timeframe. With the assumption that 'mature conditions' are reached at 80-100 years, data points after year ~2060 could be considered eligible for mature stand ages. Of particular note in the figures below is the divergence in both BA and TPA for these large conifers beginning in Year 2066, with a relatively flat level of growth for approximately one half of the stand types. These stand types are the mixed hardwood and pure hardwood stands that dominate the land area (1H and some HX types); other representative mixed types (DX and other HX) show moderate increases in large conifer basal area and density, ranging between 150 and 200 ft^2 per acre by the end of the model run. Lastly, the mostly pure conifer types (the least represented on the landscape) show increases in basal area between 158 and 230 ft^2 in 20-24 trees per acre in the second half of the model run.

Although there are observed increases in numbers and basal area of conifers for most vegetation types through time, the nominal values are far below the Forest Management Plan standard defining maturity (e.g.,40-45 trees per acre of conifers >32 inches DBH to meet the basal area targets), excepting near attainment in Jordan Creek. The fundamental limitations and retention numbers described for mature stages in the Forest Management Plan do not appear to be met for the major vegetation types, which indicates that management would likely not be allowable in the majority of the land area. Treatment options that promote even-aged patches of conifers (particularly on terraces and other near-stream environments) are potentials for increasing the density of large conifers, and meeting the Forest Management Plan objectives over time (see section 6.3.2 Pathways for Management Action, below).

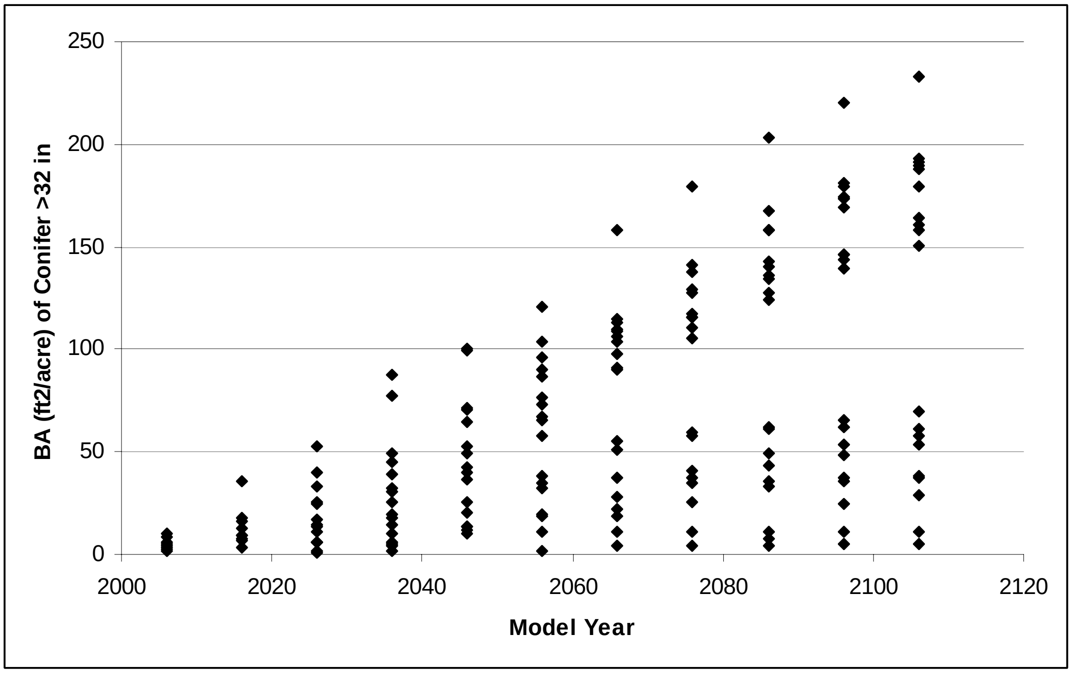

Figure 27. Basal Area of Conifers > 32 inches DBH -- All Measured Vegetation Types. The projected basal area (ft^2/ac) of available conifers for sampled stands within the 10 expanded vegetation types within the Wilson River watershed.

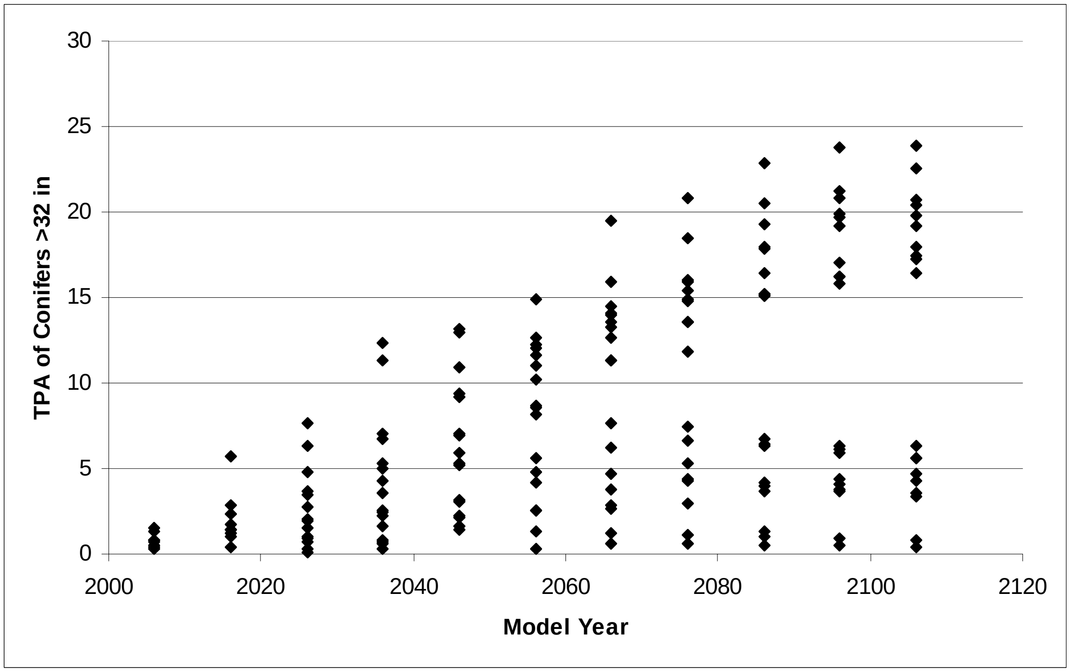

Figure 28. Trees Per Acre of Conifers > 32 inches DBH -- All Measured Vegetation Types. The projected TPA of available conifers for sampled stands within the 10 expanded vegetation types within the Wilson River watershed.

6.3.2 Pathways for Management Action

6.3.2.1 Current Data Sources and Limitations

This watershed analysis produced several key findings involving the riparian zone and the *ecosystem service* dynamics expected through time. The majority of these findings were based upon a map and subsequent ground-truth sampling based on aerial photography, coarse vegetation types, and relatively large stands. Stand sizes averaged 4.1 acres in size (range: ~1 – 93 acres) to a 100 foot buffer from the stream channel, and were designed to average ~1,500 feet in length (actual average: 1,786 feet). A total of 10 major vegetation types were sampled, and data were expanded to like FPS vegetation codes.

It is important to note that the current riparian vegetation map served as a very refined effort to ascertain the watershed and subwatershed level trends in species composition, structure, large wood recruitment, stream shading, and other intrinsic characteristics of the system. At the stage where Watershed Analysis enters the need for an Active Management Plan, however, the data do not provide enough resolution to assign site-specific silvicultural treatments, nor are they sufficient to evaluate the potential effects of those treatments on large wood, shade, and other ecosystem services to the stream system. That said, 1) the data were sufficient for developing "*general*" silvicultural prescriptions based upon the current and projected stand conditions (presented below) and 2) the acquisition and use of high resolution LiDAR data (Light Detection and Ranging; also called ALSM, Airborne Laser Swath Mapping) may help resource managers develop "site-specific" silvicultural treatments (and ODF is in process of obtaining LiDAR data for some districts).

LiDAR data have enormous utility in improving our understanding of elevation changes, including stream initiation, stream channel widths, site topography, landslides, etc. For riparian zones, LiDAR provides unique opportunities to characterize, type, and target specific locations for riparian enhancement.

The Forest Management Plan (Appendix J in the FMP) management standards, considerations for adverse effects on the stream system, and practical forestry all dictate that the potential management of riparian zones involves "patch management". Specifically, patch management is defined here as locating areas where specific silvicultural targets and operations can be applied on the ground, excluding areas that are outside of operational practicality, regulatory constraints, or may cause unnecessary damage to the stream system.

For purposes of illustration, a small portion of processed LiDAR data was obtained from the Nehalem River watershed (~1,000 acre segment), containing a reach of the mainstem Quartz Creek (~1.76 mi), a tributary to the Nehalem River (Hawksworth & Nile, pers. comm.). The data include a “bare earth” (BE) view and an “above ground” (AG) view, both at a 3-foot resolution (Watershed Sciences, 2007). Specific to the utility of mapping riparian zones, both of these sources in combination with the color aerial imagery (2006) are elegant tools to identify riparian features and highlight “manageable units” to evaluate potential management options.

6.3.2.2 Pathways for Riparian Management and Mapping

6.3.2.1.1 Recommended (General) Silvicultural Treatments

The inherent high variability of riparian stands hinders the collection of high quality stand inventory information from which silvicultural prescriptions are traditionally based. Remotely sensed information (e.g., aerial photograph interpretation) may provide coarse estimates of riparian stand conditions, but the inherent variability of riparian areas prevents fine-scaled interpretation of stand conditions. Despite this, the combined field-collected and photo-interpreted stand data provide a basis for identifying candidate stands for silvicultural treatments that produce large wood. The best resource for assessing any given stand for both large-wood potential and the best silvicultural approach is the field forester. We have identified areas that appear to have a high potential (at the coarse scale) for developing large wood (Maps 63-67; see below). These areas can be considered a “list” of potential sites that require evaluation by a professional forester.

We also assumed that the overall objective of treatments is the production of large-diameter trees (primarily conifers) that will eventually be recruited into streams as large wood. We considered a number of criteria (see below) that may make a given stand a good choice for silvicultural treatments that encourage in-stream large wood recruitment. Some of these criteria may appear at odds with each other, and again, the judgment of a field forester is necessary to determine if and how treatment should occur.

Table 22 shows the stand and geomorphic disturbance criteria used to arrive at 3 levels of candidacy for visitation and evaluation by a field forester for subsequent treatment. Maps were derived from overlay analyses using GIS layers representing relative landslide risk (Maps 25-29, 34-36, and 38-39; see Appendix T – Slope Stability Assessment), channel disturbance risk (Map 11 and section 3.4.4 – Simulation Models and NetMap Analyses), and classified riparian stands (Map 23-24 and sections 6.1 – Riparian Composition and Structure and 6.2 –

Potential Future Conditions). The resulting maps (63-67; see below) show the locations of stands identified by the criteria in Table 22.

Table 22. Matrix of treatment candidacy for various stand and disturbance conditions.

	Stand Conditions		
Disturbance Frequency	Conifer-dominated with no large diameter trees	Conifer-dominated with large diameter trees (>20 in DBH)	Mixed hardwood-conifer
Low landslide or flood disturbance frequency	High	Moderate	Low/Moderate
High landslide or flood disturbance frequency	Moderate	Low	None

6.3.2.2.1.1 Disturbance

Given our treatment objective, we focused our identification of candidate stands on those areas where short return-interval disturbance (e.g., landsliding and flooding[49]) is at a minimum and existing vegetation conditions are likely to respond. Treating stands in areas prone to frequent disturbance may not result in large diameter trees if a disturbance(s) returns before large tree growth is realized. This precluded many of the lower-elevation, wide stream channel areas with hardwood dominated, flood deposited terraces since most of these sites are intrinsically persistent hardwood-dominated stands and not suitable for encouraging large diameter conifers. Similarly, steep, higher-elevation sites that have high landsliding risks (refer to Chapter 7 – Sediment Sources, sections 7.1, 7.2, and 7.3) may also be poor candidates for treatment. It is worth noting, however, that landslides and debris flows are important processes for the movement of large wood into streams. Thus, some treatment in these stands may facilitate the recruitment of large wood into streams in an accelerated manner. Treating such stands, however, will require an evaluation of costs versus benefits of treatment given the possibility of a premature disturbance at the site. Treatment of such stands may also be opportunistic and incorporated while

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[49] Because the fire return interval in the Wilson (and surrounding areas) is relatively long (e.g., 300-700 years), we did not incorporate fire disturbance.

harvesting in adjacent areas. Nevertheless, we feel it reasonable to dedicate some portion of wood recruitment treatment efforts in these stands.

6.3.2.2.1.2 Stand Vegetation Conditions

Of the 2,364 identified riparian stands in the Wilson River watershed, 947 (40%) were identified as conifer dominated and densely stocked with smaller diameter trees. Release by thinning is a very effective treatment that may be applied in such stands to encourage rapid growth among the remaining trees. To maximize retention of large-diameter trees in these stands, we recommend thinning from below (e.g., thin the smallest diameter classes first). Specifically, we recommend that conifer-dominated stands containing large-diameter “legacy” trees occurring on high landslide-risk sites be passively managed since these large trees may already be of target size for in-stream large wood recruitment (Map 63). Likewise, conifer-dominated stands containing large-diameter trees occurring on low landslide-risk sites may be moderate candidates for active management because the densely-stocked younger cohort may respond to density control treatment (Map 63). Additionally, conifer-dominated stands *without* large-diameter trees on both high and low landslide-risk sites present good candidates for active treatment to encourage growth of large-diameter trees that will be delivered to streams via landslide-debris flows or direct treefall (Map 63).

6.3.2.2.1.3 Hardwood Conversion

It may be desirable to integrate hardwood conversion and large wood recruitment management objectives. Since riparian hardwood stands in the Coast Range are often perpetuated by relatively frequent disturbance (e.g., flooding), we considered hardwood stands identified in this assessment to be *intrinsically* hardwood stands that would not respond well to treatments designed to encourage conifer dominance. This does not mean that all pure hardwood stands are intrinsically hardwood but we have insufficient information to distinguish between stands with varying histories. Therefore, we identified mixed stands (e.g., hardwood and conifer) occurring on sites with low landslide/flood disturbance risk as potentially suitable sites for conifer-dominated stands. Map 63 shows stands that may be candidates for hardwood conversion treatments that also encourage large in-stream wood.

6.3.2.1.2 Riparian Mapping using LiDAR

Examples from Quartz Creek LiDAR were examined in the GIS to compare and contrast methodologies to improve a riparian base map and examine available data components to address potential management options. While this example is limited and does not provide specific examples for the Wilson River watershed, the available data components presented here will become available for many ODF lands in 2008.

The principle components to a riparian management map follow those presented that currently exist for the Wilson River. These components include the stream layer, riparian buffer widths, delineation criteria, and a ground-truth sampling plan. With the LiDAR data, there are several additional factors that can be considered that will influence the sensitivity and utility of the riparian vegetation map. These factors include topography, canopy characteristics, and other features that can be modeled and mapped in the GIS.

6.3.2.2.2.1 Stream Layer and Buffer Zone Comparisons

A quality stream coverage layer can be developed with added precision, using a combination of GIS tools and ground truth analysis to delineate and map current channels. In addition, it may be possible to identify points where streams initiate, or where a defined channel begins, to further understand the extent of the stream network. An accurate and comprehensive stream layer provides the foundation for a functional map for a variety of purposes, including riparian vegetation management.

Using the example from the Nehalem River watershed, a section of Quartz Creek, a low-gradient system with a wide floodplain, was examined with LiDAR. A simple stream line coverage was delineated following the LiDAR 3 foot DEM image. This example coverage was compared with the existing ODF stream coverage (sourced from 1:24,000 USGS quads from the State of Oregon Geospatial website).

A total of 1.74 mi of stream was captured from the ODF stream layer for the example area. The LiDAR stream coverage included three additional, unmapped streams for a total of 3.46 mi. Excluding the previously unmapped streams, the short section of the mainstem Quartz Creek showed 1.81 mi from LiDAR, contrasting with the 1.63 mi using the prior ODF coverage, demonstrating 11% more *sinuosity* that was captured by LiDAR over the existing stream coverage.

In addition to total stream length and sinuosity, the *accuracy* of the stream placement on the landscape has direct implications for riparian management (refer to Photographic Plate 25). Using the 100 foot buffer zone recommendations for both the stream bank and inner riparian zones, the stream segments of the mainstem Quartz Creek were compared in terms of riparian buffer areas. While both the buffer areas created from LiDAR and from the ODF coverage were similar in area (43.4 and 40.3 acres, respectively), the *placement* of the ODF riparian zone on the landscape had only 35.7 acres in common with that generated by the LiDAR, or ~82% spatial accuracy. For the Wilson River watershed, where 9,704 acres of riparian zones were identified on ODF lands using the ODF coverage, this could potentially result in an increase of ~2,100 acres of land area that could be considered under riparian management. In addition, it is possible to capture previously unmapped streams (and their associated riparian buffer zones), and/ or to invalidate current streams mapped on the ODF layer. Naturally, the simple increased detection of streams may not serve to better manage aquatic resources (i.e. streams are intermittent or simple gullies), but the detection limits of LiDAR provides managers with a decision to determine a new level of mapping standard.

6.3.2.2.2.2 Buffer Zone Utility and Modifications

The obvious implication with finer-scale mapping of stream areas is the increased areas in buffer zones, assuming a uniform buffer area (e.g. 100 feet). The Quartz Creek example found three additional tributaries to the mainstem, effectively doubling the stream area (and riparian buffer area) from the current ODF coverage. While this can be a potentially very significant change in management area and objectives, the important and underlying management question remains as to the *utility* of the buffer area for enhancing and promoting the *ecosystem services* to the stream system (large wood, shade, sediment buffering, etc.).

One pathway to refining the standardized buffer areas involves referencing the slope and elevation relative to the stream channel, and prioritizing these areas into different sub-management units. For example, in the mainstem Quartz Creek system, the riparian buffer area can be easily divided along terraces, steeper slopes, and floodplain. Each of these components provide different functions to the stream channel, and can have different management objectives, with possibilities for different treatment opportunities to enhance, restore, or otherwise utilize the available resources.

An unmapped tributary having a higher gradient and representative of the upper reaches of the Wilson watershed was identified using LiDAR, and its 100 foot buffer zone was examined. Polygons were delineated on the basis of slope only, capturing areas of homogenous slope, or delineating on abrupt changes in slope. For the small section of unnamed tributary (<0.5 mi), approximately 8.1 acres were within the 100 foot buffer zone of the stream channel. Of these acres, 2.6 acres (32%) were located in areas that would be considered to be outside of or have limited influence on the riparian shade and instream large wood inputs[50]. Hence, a management pathway to first identify and buffer, then later evaluate, or

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[50] Large wood inputs in this case does not refer to stochastic events (debris torrents, landslides, etc.), rather the simple project of an immediate interaction from falling trees into the stream channel through natural mortality processes.

prioritize the utility of those buffer areas to the desired *ecosystem services* is recommended.

Other environmental attributes can be considered in addition to slope (lateral gradient) for a buffer prioritization process, including channel width, perennial/ intermittent channels, longitudinal stream gradient, soils, etc. These, in addition to slope, are pathways by which a ‘first cut’ can be made at large scales (GIS and ground truth) to refine the buffer system for a given watershed and set of watershed priorities (refer to Photographic Plate 26 and Photographic Plate 27).

6.3.2.2.2.3 Vegetation Typing

Following the development of an accurate stream map and utility prioritizations within buffer zones, the vegetation component can be classified on the landscape. The primary objective to vegetation typing is to develop a standardized, simplified, and representative system that serves an ultimate goal to minimize field sampling efforts for expansion. To be effective, this system should be adaptable for changing management needs and should be relatively inexpensive to modify and improve through time.

The current system (Wilson River) has used FPS codes, which are 4-digit classifications to designate forest type (conifer, mixed, hardwood), size class, and density values. A system such as this serves well, if (1) there are enough categories to describe subtle, but significant difference, and (2) the polygons are delineated to a scale that fits the classification well. In the case of the Wilson River, the system of FPS codes did not provide the resolution necessary for vegetation types, nor did the polygon delineation requirements provide enough resolution to sample and manage with high confidence at the stand-level. The classification served well at larger scales (subwatershed) and identified key needs, patterns and trends on the landscape.

In addition to the bare earth view of the LiDAR, there is a coverage that includes the ‘above ground’ elevation value, or the highest value at the 3 foot scale of resolution. This above ground coverage can be compared with the bare earth coverage to obtain canopy height and a classification for a categorical stand structure designation. To illustrate this coverage as a potential pathway for riparian mapping and management, canopy height was calculated for the Quartz Creek example. The level of resolution, in this case, can present its own problems, as the “characteristically patchy” nature of riparian zones is evidenced by the wide array of tree heights. However, simplifying the output to highlight different heights of the overstory strata (e.g., 50 foot increments) provides refinement in describing the stand structure.

For purposes of illustration, the Quartz Creek and tributary example area were delineated on the basis of canopy output only, based upon maximum size classes and like differences in patch size. Patches were identified as having tree heights of 0-25 feet (gap), 25 – 50 feet, and at 50 foot increments to the maximum observed height (<250 feet). Polygons were delineated on the homogeneity of size class and the evenness of spread of different size classes (i.e. gaps interspersed with larger trees, etc.).

Following this illustrative method, delineations occurred at a very fine scale, averaging 0.7 acres for the 26 polygons (average 0.7 acres, range 0.25 – 1.6 acres) in the 17.4 acre riparian buffer area. While this is clearly delineated at a scale far below common upland forest practices, these stands resemble and appear (with the use of aerial imagery) to represent the patch mosaic of the riparian zones, and may be of the appropriate size to attempt management activities to promote conifer growth for the long term (refer to Photographic Plate 28). Considerations for minimum size, stratification of size classes, and incorporating elements of automation in the GIS process may provide a cost-effective pathway for achieving a ‘first cut’ of stand structure at landscape scales using available LiDAR tools.

Stand composition can likewise be reviewed at large scales. The availability of Infrared imagery is a useful tool in determining differences between conifer and hardwood canopies; these, in combination with use of crown modeling from the above ground LiDAR (Nile, pers. comm.) can provide algorithms to estimate basic stand compositional differences between hardwoods and conifers. Specifically, crown areas can be modeled to predict mean diameter ranges of the canopy, thus giving a range of density classes expressed as trees per acre.

Ultimately, the delineation criteria for vegetation typing should include elements of stand structure, composition, and stand density. Combinations of canopy height patch analysis (structure), assessing species using infra-red (IR) or photo interpretation (composition), and crown characteristics (density) are useful elements of an accurate and fine-scale vegetation typing design that can be attributed at the landscape scale for use at local scales.

6.3.2.2.2.4 Uses in Management

The use of fine-scale mapping is an important and necessary component to developing site-level or “type-level” prescriptions in meeting management objectives. The current vegetation types for the Wilson River watershed are at a scale that contain a range of physical and compositional conditions (slope, aspect, stream type, species composition, etc.), and their size and delineations are at a scale that contain many “manageable units” as well as “non-manageable units.” Hence, within each different type – especially the mixed types HX and

DX – a range of treatments can be considered for riparian enhancement (see section 6.3.2.1.1 – Recommended (General) Silvicultural Treatments, above). Generally speaking, however, these treatment ranges are discussed below, and (at the scale of the current vegetation typing), treatment objectives can be applied according to on-the-ground professional judgment. Additionally, another approach would be to use a LiDAR classification scheme (as described above) to better target the range of manageable units within the larger vegetation types.

Following a classification scheme that incorporates buffer utility and vegetation components, it is possible to gear ground-truth sampling toward the major types that would be considered "manageable units" within the buffer zone. This is of critical importance, as sampling will focus on the major vegetation types in areas where management will be possible, and prescriptions can be evaluated at the same time to meet management objectives. Management objectives specific to the Wilson River involve:

1. **Promote conifer recruitment to overstory, ≥14 inches DBH (40-80 years).** Using small, manageable patches, treatments can be applied to promote even-aged mosaics of conifers in areas that have high potentials for interaction with the stream channel, and where operations will have the lowest impact to stream function. Depending on the topography and methods used, the 25 foot designation for "no harvest" within the streambank zone may or may not be appropriate. Serious evaluation of the prescribed buffer zones (refer to Appendix J in the FMP) is recommended following the implementation and use of LiDAR mapping.

2. **Limit "lag period" in large wood recruitment (30-50 years).** The competition pressures associated with the apparently ubiquitous stem exclusion phase will create a short-term pulse in large wood (particularly hardwoods), but a lag in mortality is projected in conifers (30 years) and hardwoods (~50 years). This lag is expected to last beyond the 100 year time series. Management priorities include promoting a conifer overstory *and* time treatments to add wood through selective thinning during lag periods.

3. **Monitor reach-level responses to instream large wood and stream shading (5-10 year increments).** Treated areas will likely be smaller in size (~0.7 acres), and treatments should be applied at reach-level scales. Effectiveness monitoring (and validation of modeling) should be conducted to evaluate treatment effects at scales large enough to measure signals (reach-level or larger).

4. **Refine the desired future condition in the Forest Management Plan.** A review of the Forest Management Plan (refer to Appendix J in the

FMP) is strongly recommended to define goals that are more specific to the ecosystem services of the riparian zone (instream large wood, shade targets, sediment buffers, etc.). The current plan provides retention targets for conifer trees—these do not directly address large wood recruitment or stream shade.

6.4 Wetlands, Ponds and Lakes – Condition and Location

This section is intended to update the original 2001 assessment of the Wilson River watershed (E&S Environmental Chemistry), with emphasis on ODF lands.

Wetland, pond, and lake locations were gathered from the SLI upland vegetation layer (ODF), the National Wetland Inventory (NWI)[51] and a survey of the aerial photographs and USGS quads (this study). All wetland or potential wetland types were assigned a wetland classification type (Cowardin et al. 1979) and assigned a calculated acreage value from a GIS (Map 40).

Digital NWI data locations were available for the lower reaches of the Wilson River watershed only (Lower Wilson River subwatershed); the majority of this coverage was located on non-ODF lands (~564 acres, Table 23). A summary review of the ODF SLI vegetation mapping dataset[52] coupled with aerial photo review using USGS maps and ground truth analysis yielded few acres but several potential wetland sites.

The major wetland types on ODF lands included freshwater forested and emergent wetland types. These were primarily seeps or draws, and areas influenced by beaver activity (Photographic Plate 8). Wetland areas created by beaver are especially important for enhancing fisheries habitats, as they are connected with the stream system, slow water flow, create highly interactive areas with the floodplain, and provide visual isolation for fish species (to provide more habitat per length of stream).

The overall condition of the wetlands and ponds within ODF lands is generally good; road influence may cause increased siltation in some areas, though there appears to be relatively intact riparian buffers available to slow sediment delivery. In areas where management has occurred near wetland areas, standing tree buffer areas appear to be present on ODF lands.

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[51] http://wetlandsfws.er.usgs.gov/NWI/download.html

[52] Upland FPS code classifications, “Vegpoly.shp”. Duck Creek Associates, 2006.

Table 23. Wetlands, Lakes and Ponds. Wetland composite from National Wetland Inventory (NWI), vegetation mapping (ODF), aerial interpretation/ review and ground-truth analysis (this study).

Subwatershed	Wetland Type (NWI Code)	ODF Acres	Non-ODF Acres
NF Wilson River	Freshwater Emergent Wetland	0.6	
NF Wilson River	Freshwater Forested/Shrub Wetland	0.3	
NF Wilson River	Freshwater Pond	1.2	3.2
SF Wilson River	Freshwater Forested/Shrub Wetland	3.4	
SF Wilson River	Freshwater Pond	1.9	
Little NF Wilson River	Riverine		4.2
Jordan Creek	Freshwater Emergent Wetland		0.6
Jordan Creek	Freshwater Forested/Shrub Wetland	1.5	
Lower Wilson River	Freshwater Emergent Wetland		185.2
Lower Wilson River	Freshwater Forested/Shrub Wetland	0.9	192.5
Lower Wilson River	Freshwater Pond		2.2
Lower Wilson River	Lake		<1.0
Lower Wilson River	Riverine	1.2	183.8
Devils Lake Fork	Freshwater Emergent Wetland	20.4	3.0
Devils Lake Fork	Freshwater Forested/Shrub Wetland	56.6	
Devils Lake Fork	Freshwater Pond	0.8	
	Totals	**88.8**	**574.8**

Data describing the recreational impacts of OHV use to wetlands have not been directly quantified, though it represents an important consideration with the development of Best Management Practices (BMPs) for recreational uses on the forest. Examples of buffer area enhancement could be the placement of large logs or other obstructions in the near-wetland zone, and relocation of campsites within 100 feet of a wetland area. This would serve to minimize impacts associated OHV use in the near-wetland and riparian environment, and would decrease sedimentation from up-gradient sources near existing trails or roads.

In addition, as part of the BMPs, it is important to evaluate areas of potential emergent wetland environments and provide mechanisms of buffer enhancement to increase the success of wetland establishment. This is especially true for lower gradient systems where beaver activity is observed. Accommodation of natural disturbance processes, such as beaver activity, provides the mechanisms necessary to create patch diversity of wetland communities. Minimizing recreational and other land-use impacts in these areas would increase the potential for wetland diversity in the watershed.

6.5 Noxious and Non-native Weed Species

The Wilson River, because of its proximity to other areas of known infestations, is a prime location for establishment of noxious weeds. Though the Wilson

River watershed may have been slow to establish weed species compared with nearby drainages, the presence of Scotch broom (*Cytisus scoparius*), garlic mustard (*Alliaria petiolata*) and Japanese knotweed (*Polygonium cuspidatum*), are of growing concern to the watershed. Invasion vectors for these species include recreation, equipment use, roads, and imported material from infested areas (e.g., road fill). Flood events, and post-flood restoration efforts provide particular vectors for disbursement and establishment.

The 2005 and 2006 Tillamook Rapid Biological Assessments[53] (Bio-Surveys, LLC) indicated the presence of knotweed in 30 locations in the Wilson River, 8 locations in the Little North Fork Wilson and its tributaries and 5 locations in Devils Lake Fork (Map 41). Knotweed infestations in the Wilson River were in small, scattered and isolated patches (i.e., new establishments), with several large and continuous (600 x 40 ft) patches throughout. The majority of these populations were encountered at the mouth to the confluence of the Little North Fork, outside of the majority portions of ODF land. Other populations are somewhat smaller and extend up the Wilson River to the Jones Creek Bridge. In the Little North Fork Wilson, a continuous patch begins at the confluence with the Wilson River and extends ~8,800 feet to an unnamed tributary stream that is mostly on private lands, though has some overlap with a strip under ODF management. The proximity of these patches to ODF lands suggests that collaborative restoration efforts between ODF and private landowners would help to minimize potential risk to ODF lands.

Devils Lake Fork had 5 encounters (all on ODF lands) of knotweed that were all relatively small in size, but are high-risk colonies because of the mid-channel position and the up-gradient location in the watershed (potential source for downstream spread). The knotweed distribution effectively stops at the Idiot Creek Bridge (RM ~2.5 of Devils Lake Fork), suggesting the road fill for the bridge may be the likely source. These sightings were new sightings in 2006; the 2005 survey did not detect these colonies. A *high priority* for enhancement in this area is to curtail the knotweed spread to minimize spread downstream. Surveys and evaluations of potential source quarries or materials outlets for knotweed prior to organizing restoration work (e.g. road fills) would help to minimize importation into the watershed. Other invasive species observed were Himalayan blackberry (*Rubus armeniacus*)[54] throughout ODF riparian zones. Garlic mustard is a relatively new invasive weed concern in the watershed and has been found in the Gales Creek sub-basin on public and private land. Known

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[53] GIS data available for the 2005 assessment only.

[54] Originally from Armenia, *Rubus armeniacus* has long been incorrectly described as *R. procerus* or *R. discolor* in North America.

vectors include OHVs, pets, livestock, wildlife and humans (foot traffic) as well as floods.

6.6 Key Findings and Recommendations

- Develop a riparian management action plan focuses on 1) improved canopy recruitment, 2) areas that have high potentials for interaction with the stream channel, 3) selecting variable-sized treatment patches to better typify natural variability, 4) pairing treatments with similarly functioning reference reaches, and 5) monitoring and evaluation of treatment trajectories with reference trajectories.

- Given the variability in the stand-level vegetation data and the predicted large wood (LW) recruitment, shade, and other ecosystem trends, developing additional focused field and mapping efforts should help to refine subwatershed-scale estimates to the stand-level.

- Riparian areas that could be considered likely candidates for treatment (harvest) occur throughout the Wilson River watershed. The highest candidacy stands for treatment (e.g., mixed species stands and densely stocked conifer stands without large legacy trees and occurring on low-moderate landslide risk sites) are concentrated in the Devils Lake Fork and South Fork Wilson River subwatersheds.

- Refinement of the riparian base map, using LiDAR tools, will identify “management patches” on terrain that is the most interactive with the stream channel (shade and LW recruitment), while minimizing the effects of potential harvest management. One example includes terraces and areas of appropriate size (~0.7 acres) to allow for patch harvests and replanting of conifer species. Using this fine scale map, the patch dynamics and successional trends at the reach- and subwatershed scales can be evaluated to allow managers means to better predict how stand treatments could enhance or detract from LW recruitment, shade, peak flows, weeds, etc.

- Include current road issues when selecting potential riparian management sites.

- In areas where the road infrastructure permits, allow beaver to persist as their activities will likely result in increased wetland areas, improved water storage capacity and improved fisheries habitats.

- Restrict recreational uses (primarily OHV use) in the near-wetland environment (within ~100 feet) to limit potential negative effect on wetlands.
- Several invasive noxious weed locations were identified in the Wilson River watershed. ODF should, when developing future Best Management Practices (BMPs), probably include management of OHV use in riparian zones and the incorporation of wash stations at trailheads.
- Careful consideration should be given to the type of seeds utilized for bank stability control reseeding projects.
- Collaborate with other agencies and landowners for weed eradication.
- Initiate noxious weed outreach programs targeting recreation groups.

6.7 Recreational Impacts on Riparian Vegetation – Direct and Indirect Effects

Recreation trends, activity use levels and intensities in Tillamook State Forest indicate a greater risk to watershed health from recreation than would normally be expected. Contributing environmental factors are climate, topography, soil type and vegetation sensitivity. Contributing human factors are use intensity, lack of defined site boundaries, lack of regulation and maintenance.

OHV management takes up a considerable amount of recreation and other staff time in dealing with permitting, supervising and post event restoration. In the last five years 102 OHV events were held (133 event days, with 7,128 participants). That is an event average of 20 per year.

Forest wide issues related to the site conditions, staff capacities and recreation demand have been documented in a recent report by David Reed and Associates and provide staff with a comprehensive status report and set of recommendations.[55] This assessment and analysis focused solely on the Wilson River watershed primarily utilizing results from field data.

Recreational activities that disturb, destroy or remove vegetation are a concern to watershed health. To determine the extent and intensity of impacts requires a framework of standards and thresholds by which impacts can be monitored. These do not yet exist for the Wilson River watershed but recommendations have

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[55] Reed, David. 2007. David Reed & Associates. Recreation management Assessment for the Oregon Department of Forestry NW Oregon State Forests. Draft Final Report. April 16.

been included below. Current recreational impacts to riparian vegetation can be characterized by the following descriptions:

Camping: Both designated and dispersed camping activity is widespread across the watershed but impacts are more acute along streams and river edges because that is where people prefer to camp and where facilities have been developed or allowed to continue. Designated campgrounds attract users that prefer the convenience of defined parking, toilets, trash collection, firewood supplies and a management presence. There is still considerable riparian vegetation impact through vandalism, firewood cutting, trampling, trash dumping (fire pit waste) and human waste.

Use levels at the established campgrounds continue to climb. According to ODF staff, campgrounds are at or over capacity during most weekends of the event season. Warm weather and holidays exacerbate the pressures sending overflow campers into the forest to find alternate sites. In addition, overflow comes from other parts of the region due to the high cost of alternatives along the coast and the scarcity of campgrounds on other public land.

Dispersed campsites absorb overflow and attract those seeking more rustic, secluded camping sites that have no fees. However, such sites exhibit the most impacts because use is unrestrained and unregulated. Spot checking of dispersed campsites in the watershed during the 2007 Memorial Day weekend provided evidence that people were camped or occupying most of the sites along the main stem of the Wilson and tributaries. A significant number of people were well established and stated intentions to camp for 4-10 days. Severe impacts are common where OHV use is focused on social trails in and around campsite areas, especially those in riparian zones, and several photographic examples have been provided in Photographic Plate 9.

The challenge for this assessment is to put these impacts into a framework that is used to measure impact and human disturbance. In the case of campsite-related impacts, the literature offers methodology developed for wilderness settings that typically exhibit much smaller scale environmental damage (Cole, 1989).[56] The type of use that is most prevalent in the Wilson River watershed is car camping, OHV use or a combination of the two. While this is not a wilderness setting, the methodologies are sufficient to determine the intensity and extent of campsite impacts in the watershed.

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[56] Wilderness Campsite Monitoring Methods: A Sourcebook, Cole, David N., GTR-INT-259, April 1989.

6.7.1 Methods

Recreational impacts on riparian vegetation were assessed using two different methods, the first based on ODF's dispersed campsite inventory data (existing); the second based on a field sample of ODF dispersed campsites from the existing inventory data (new). To evaluate the direct and indirect effects to the riparian vegetation, the first method utilized data from ODF's dispersed camping inventory database. The second assessment required field-measurement of vegetation loss, tree damage and soil exposure in a sub sample of 10% of the ODF dispersed camping site inventory (shown on Map 31) Both assessments are presented below.

Small disturbances associated with near-stream campsites create disruptions in the continuity of stream shade, increased mortality to the overstory, and inhibition of vegetation regeneration and recruitment. At larger scales and at increasing sizes of campsites and camp use, the patch-level disturbances increase sediment flow to the stream channel, offer increasing potentials for firewood cutting, and minimize the potentials for other *ecosystem services*, including LW recruitment, stream shading and sediment retention. At small scales with managed uses (i.e., minimize OHV use in the riparian zone), dispersed campsites offer a balance of human appreciation and use while retaining quality riparian functions.

6.7.1.1 Dispersed Campsite Inventory Data

For the dispersed campsite impacts, ODF provided a database of site survey records and hardcopies of inventory datasheets (FG District, only). The ODF inventory datasheet included a list of parameters related to site location, use type, impacts, size and site characteristics. These data provided important baseline data against which future monitoring efforts could be compared but offered few metrics beyond presence/absence of indicators.

6.7.1.2 Field Sample of Dispersed Campsites

To better quantitatively assess dispersed camp impacts, a sample was drawn from ODF's dispersed campsite inventory to represent hydrologically connected sites within the upper tributaries, the mainstem Wilson River, and the lower tributaries. A total of 18 sites (~10%) were assessed using the Minimum Recreation Site Monitoring Protocol[57]. The condition class ratings are applied to ground cover, tree damage and soil disturbance area on a numerical scale (Table 24) of 1-10. We recommend that a tree density metric be added to future

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[57] Recreation Site Monitoring Procedures and Protocols: David Cole, Aldo Leopold Wilderness Research Institute

monitoring protocols to indicate a percentage degree of damage. A count would have to be made of *all trees/severely damaged trees* within the disturbed area assessed for condition class. To ensure consistency and accuracy, boundary trees may need to be marked for future re-measurement. This is addressed in greater detail in sections 7.5.11 (Future Inventory and Monitoring) and 7.5.12 (Effectiveness of Recent (post-1994) Recreation Site Upgrades).

Table 24. Recreation Site Monitoring and Frissell Condition Classes. The monitoring criteria and condition classes associated with dispersed campsite evaluations. Scores for FGI, TD and DA are summed and presented as a scale of 1-10.

Criteria	Condition Class				
Frissell Groundcover Impact **(FGI)**	1 – Ground vegetation flattened but not permanently injured	2 - Ground vegetation worn away in activity center	3 – Ground vegetation lost on most of the site	4 – Bare mineral soil widespread, exposed roots	5 – Soil erosion obvious, trees reduced in vigor or dead
Tree Damage **(TD)**	0 – No more than 3 severely damaged trees.	1 – 4 to 10 severely damaged trees.		2 – More than 10 severely damaged trees.	
Disturbed Area **(DA)**	0 – No more than 25 m^2 (0-250 ft^2).	1 – 26 to 100 m^2 (251 – 1,000 ft^2).	2 – 100 m^2 to 1,000 m^2 (1,000 to 10,000 ft^2).	3 – More than 1,000 m^2 (more than 10,000 ft^2).	

6.7.2 Results

6.7.2.1 Dispersed Campsite Inventory Data

Results based on ODF's dispersed campsite database indicate that OHV impacts and unrestricted use of riparian have significant impacts on riparian vegetation. Table 25 summarizes the data collected by ODF. The two most frequently reported impacts were tree damage and soil compaction – both of which have direct and indirect impacts on riparian vegetation health. Several photographic examples of impacts typical of those found next to Wilson River streams can be found in Appendix B – Photographic Plates 9-13.

Table 25. ODF Dispersed campsite inventory provides a baseline record of conditions found during the field survey of 2006.

ODF Dispersed Campsite Inventory Observation (n=184)	Number of Sites	Percentage of Sites
Road Damage	34	18.5
Tree Damage	93	50.5

ODF Dispersed Campsite Inventory Observation (n=184)	**Number of Sites**	**Percentage of Sites**
Vehicle Damage	41	22.3
Streamside Damage	19	10.3
Soil Compaction	121	65.8
Erosion*	NA	-
Water Quality*	NA	-
Distance from water <25 feet**	33	17.8
Overall Impact Rating		
Very High	28	15.1
High	34	18.4
Moderate	52	28.1
Low	70	37.8
Disturbance Area (sq ft)		
<250	128	69.6
250-1000	48	26.1
Larger than 1000	8	4.3
Number with Site Improvements	***43***	***23.4***
Rated effective	19	44.0
Rated partially effective	16	37.0
Rated ineffective	8	18.0

** Field data missing from the database.*
*** Simplified by ODF to +/- 25 feet during data entry; from field record of actual distance (in feet) from camp edge to water.*

Of the 184 dispersed campsites inventoried by ODF, those sites within the Stream Bank Zone and the Inner Riparian Zone were most relevant to this study. Unfortunately, the ODF data entry protocol for "water access distance" only called for an entry distance of +/- 25 feet from water. Therefore, we can only say that 33 sites (or 17.8%) are in the Stream Bank Zone but are not able to say how many sites are in the Inner Riparian Zone[58]. The data entry process also excluded the number of sites exhibiting erosion, although the Forest Grove District hard copies show 50% of site forms were marked as having visible erosion and 64% were within 100 feet of water. As most of the observed high impacts conditions were within the Inner Riparian Zone, the loss of this data is unfortunate.

Overall impact ratings were applied by ODF recreation staff as a subjective judgment of observed impacts to the sites and results show over 62% of the sites were found to have moderate, high or very high impacts (See Map 31). Site

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[58] This could, however, be extracted from the original field forms.

dimension was used as an indicator of erosion severity and of the 184 sites, three-quarters of them were less than 250 sq ft, a quarter were 250-1,000 sq ft of bare ground, and 8 sites were larger than 1,000 sq ft. However, two of these were 15,000 and 22,000 sq ft respectively. Total area of all site dimensions combined was 82,760 sq feet.

Combined recreation impacts (soil exposure, tree damage) can inhibit reproduction of tree species (Bratton et al. 1982) much more than any one impact type. Wilson River dispersed campsites exhibit very heavy combined impacts, particularly OHV damage, indicating that buffering the Inner Riparian Zone from dispersed campsite use would be more effective than specific regulations targeting one or two impact types (Reid and Marion, 2005).

Data gaps: There appears to be some important information lost in the data entry phase which limits an assessment of the severity of erosion from ODF data. Field forms had human impact categories that were inconsistently entered, including the “Erosion” category mentioned above.

6.7.2.2 Field Sample of Dispersed Campsites

Field assessment work of the dispersed campsites is summarized in Table 26 below. Of the 18 sites visited, 13 were within 10 feet of the high water mark of a stream, 3 were within 20-50 feet, and 2 sites were within 100 feet (i.e., 100% were within the Inner and Stream Bank riparian zones; Map 31). Overall, the majority of the sites had bare soils with widespread and exposed root systems, or with trees showing visible signs of reduced vigor or mortality (average FGI = 4.25, average tree damage = 1.3). Several photographic examples of impacts typical of those found next to Wilson River streams can be found in Appendix B – Photographic Plates 9-13.

Disturbance areas were generally ~1,000 ft^2 in size, though 4 sites with extensive OHV use had disturbance areas of more than 0.25 acres. The total condition class (i.e., all factors considered) ranged between 2 and 10 (low impact to severe impacts), and averaged 7.4. OHV damage was prevalent on 72% of the sites. Human impact observations included direct erosion to the stream channel or wetlands, site-level tree mortality, severe compaction, and multiple user-defined trails to the stream channel. Several photographic examples of impacts typical of those found next to Wilson River streams can be found in Appendix B – Photographic Plates, numbers 9-13.

Table 26. Dispersed Campsite Condition Classes. Groundcover impacts, tree damage, disturbed areas, and total condition class score for the 18 campsites reviewed. See Table 24 for score definitions and classification scheme.

Site I.D.	ODF Sitecode[1]	FGI class	TD class	DA class	Total Score	Distance to drainage (ft) [59]	Notes
1	FG053	5	1	2	9	<100	extensive OHV damage
2	TL012	2	1	1	4	<50	low OHV damage, erosion direct to creek
3	TL016	5	2	2	9	<10	high OHV in streams and road drainage
4	TL017	4	2	3	9	<10	high OHV use in streams
5	TL077	5	2	2	9	<10	Mod OHV use in stream
6	TL019	5	1	1	7	<10	Mod OHV use
7	FG059	4	1	1	6	<10	Mod OHV use
8	FG091	2	0	0	2	<100	Mod OHV use
9	FG094	4	1	1	6	<10	Erosion over cliff direct into Wilson River
10	FG103	4	1	1	6	<10	Large pool overflows towards river
11	FG076	5	1	2	8	<10	Direct mud flow to drainage and creek
12	FG066	4	1	2	7	<10	Edge of wetland
13	FG067	5	1	1	7	<20	Edge of wetland, OHV use, blocked culvert
14	FG029b	5	2	2	9	<10	Erosion to stream and culvert
15	FG029d	5	1	3	9	<10	OHV use extensive
16	FG029a	5	2	3	10	<50	OHV use extensive
17	TL129	5	2	3	10	<10	OHV use
18	FG104	4	1	2	7	<10	OHV use

[1] As identified in ODF's dispersed campsite inventory database.

6.7.3 Recommendations

In general, recreation impacts can be addressed by specific management actions on-site, but targeting the disturbing agent is likely to be most effective in minimizing impact levels (Marion and Cole, 1996). Marion (2003) describes management responses to three distinct types of recreation impacts:

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[59] Edge of main activity area to high water mark.

- impacts from visitors knowingly engaging in illegal actions require a law enforcement response.
- Careless, unskilled or uninformed actions are often most appropriately addressed through visitor contacts and educational responses.
- Unavoidable impacts are commonly reduced by relocating visitation to resistant surfaces or by limiting use.

One critical factor in campsite impact management is location, and in this case, proximity to water is the key variable. The ODF has a recreation management guideline that requires campsites be kept at least 25 feet from high water. Backcountry camping research gives the most common distance as 100 feet (Cole, Petersen, and Lucas; 1987). Practical concerns about tree damage, soil erosion and human waste indicate the latter be a better minimum distance. Long term implications for protecting future LW recruitment into the streams would also dictate at least one tree length be a prudent minimum distance to apply.

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7 Sediment Sources

Previous work in the Wilson River Basin has identified slope instability, road instability, and runoff from rural roads as the primary sediment sources (E & S Environmental Chemistry, Inc, 2001). For this assessment, slope instability was assessed using topographically based models for landslide susceptibility and runout (Miller and Burnett, 2007a&b; Burnett and Miller, 2007; Benda et al., 2007), calibrated to landslide inventories collected by ODF after the 1996 storms (Robison et al., 1999), results of which are reported below (see Appendix T – Slope Stability Assessment for a detailed analysis). Road instability and runoff were assessed based on detailed road surveys following the "Rapid Watershed Risk and Current Conditions Survey" protocol (Mills et al., 2007), reported below (for a detailed analysis, see Appendix M – ODF Roads Protocol).

7.1 Slope Instability

All analyses in this section are based on overlay of mapped landslide initiation points and runout tracks on 10-m digital elevation models (DEMs). Hence, references to topographic attributes, such as slope gradient, refer to quantities calculated from DEM elevations. DEM-based measures of topography will not generally match field-based measures; they are based on different length scales and involve different resolution of topographic details. The models we use are based on empirical relationships between observed (mapped) landslide and debris flow locations and DEM-derived topographic attributes. This allows us to use a GIS to extrapolate results to areas without mapped landslides and debris flows, but also constrains our resolution of potential landslide and debris flow sites to those that can be identified with the digital data. These results identify potential hazard zones that can be verified through field observations.

7.1.1 Shallow Landslide Susceptibility

7.1.1.1 Methods

All steep slopes within the watershed can potentially generate shallow, rapidly moving landslides. For this assessment, potential landslide-source areas are characterized in terms of susceptibility to landslide initiation. All potential sites are ranked in terms of landslide susceptibility, starting with the least-stable sites and progressing to the most stable, and hazard zones are then defined to encompass a specified proportion of the expected landslide initiation sites (refer to Appendix T – Slope Stability Assessment), starting with the least-stable sites.

Landslide susceptibility is characterized in terms of an empirically calibrated dependence on slope gradient, based on the density (number per unit area) of landslide initiation sites in different slope classes (e.g., 70 – 80% gradient). As described in Appendix T, other topographic attributes can also be used to define susceptibility, with slope gradient potentially working better for identifying potential landslide sites during high-intensity rainstorms, and a combination of slope and drainage area working better for landslides triggered by long-duration rainstorms. GIS layers provided with this assessment report results based on empirical calibration to both sets of topographic attributes.

Landslide susceptibility can also be defined to include the potential for a landslide, or subsequent debris flow triggered by a landslide, to travel to a Type F (fish-bearing) stream (Appendix T – Slope Stability Assessment). For this case, hazard levels are defined to encompass a specified proportion of the initiation sites for landslides that deliver to Type F streams, and thereby highlight the most likely upslope source areas for debris-flow-delivered sediment and woody debris to fish-bearing streams.

Landslide source areas defined solely on the potential for initiation and delivery do not include, however, any assessment of the potential magnitude of the event. A low-probability, long-runout debris flow may pose a similar hazard as many higher-probability, short-runout debris flows in terms of the cumulative length of channels affected and the volume of sediment and wood incorporated into the deposit. A third GIS coverage was created (refer to Appendix T – Slope Stability Assessment) that used a combination of susceptibility to landslide initiation, probability for debris-flow delivery (to a fish-bearing stream), and runout length to a fish-bearing stream to define hazard levels.

This set of map coverages (based on landslide susceptibility; susceptibility + probability of delivery; and susceptibility + delivery + runout length) provide three slightly different contexts for identifying potential landslide-hazard zones. The appropriate map depends on the intended use. Susceptibility alone identifies landslide-prone areas without reference to channel effects; susceptibility + delivery identifies areas most likely to generate landslides that travel to fish-bearing streams, and susceptibility + delivery + runout highlight source areas in terms of the quantity of wood and sediment (based on relative runout length) they might carry to fish-bearing streams.

7.1.1.2 Results

Map 44 shows three hazard levels based on slope gradient. High hazard zones cover the least stable sites and are set to encompass 50% of the expected landslide occurrences. Moderate hazard zones include progressively more stable sites and are set to include an additional 40% of the expected landslides. Low-hazard zones include the most stable (but still landslide-prone) sites and are set to encompass the remaining 10% of potential landslide sites. All DEM-inferred slopes less than ~30% have zero hazard. These levels are illustrative; hazard zones based on different proportions of the expected landslide occurrences can be generated using the prop_slope GIS raster coverage (Appendix T – Slope Stability Assessment).

Map 26 shows hazard zones defined using both landslide susceptibility and probability for delivery to a fish-bearing stream. A high hazard is set to encompass 50% of the expected initiation sites for landslides that can trigger debris flows that travel to fish-bearing streams; the moderate hazard zone encompasses an additional 40% of the initiation sites for landslides that deliver, and the low hazard zone encompasses the remaining 10% of these sites. Incorporating the probability for delivery reduces the size of each of these hazard zones, because many landslide-susceptible sites have a low (or zero) estimated probability for delivery.

To incorporate an estimate of debris-flow magnitude, Map 27 shows hazard zones based on landslide susceptibility, probability of delivery, and runout length to a fish-bearing channel. Here, the runout length is used as a measure of the potential magnitude of debris-flow effects. This definition tends to highlight longer-runout debris flows and incorporates many upper headwall areas into a high-hazard zone that fell into moderate or low hazard zones when runout length was not considered. This is the best definition of hazard within the context of potential for debris-flow delivery of sediment and wood to fish-bearing streams.

7.2 Debris Flow-Prone Channels

7.2.1 Methods

The potential for debris-flow runout is based on a cumulative assessment of slope gradient, degree of topographic confinement, and channel-junction angles encountered along any potential debris-flow track. Details of model design, calibration, and validation are given in Appendix T – Slope Stability Assessment.

Susceptibility to debris flows is defined separately for Type N (non-fish-bearing) and type F (fish-bearing) channels. For each case, debris-flow susceptibility is defined in terms of the proportion of debris flow travel length (Type N) or depositional sites (Type F) expected over the entire watershed.

7.2.1.1 Type N Channels

We characterize Type N channels in terms of the relative potential for traversal by a debris flow from upslope that continues to a Type F stream. Susceptibility to debris-flow traversal and delivery to a fish-bearing stream is gauged in terms of the proportion of expected debris-flow track length. Each of four hazard levels are defined to encompass 25% of the expected debris-flow travel length through

Type N channels, starting with the most debris-flow-prone channels in the High category and progressing to the least debris-flow-prone channels in the Low category. Thus, high hazard zones encompass the Type N streams expected to include, on average, 25% of the debris-flow-track length; the high hazard zone plus the next zone encompass the Type N streams expected to include, on average, 50% of the debris-flow-track length, etc.

7.2.1.2 Type F Channels

To assess the potential for debris-flow deposition in these Type F streams, all Type F channels were divided into reaches with relatively uniform gradient and confinement averaging about 100 meters in length (using methods described in Clarke et al. in press). All potential landslide sources for each reach were identified and the probability for landslide initiation and delivery calculated for each source. The product of the probabilities for landslide initiation and delivery defines the probability that each potential source initiated a debris flow that traveled to the reach. Each reach was then assigned the maximum of these debris flow probabilities. Four hazard rankings for Type F streams were then defined to each include 25% of the expected Type F reach length affected by debris flows, starting with the most susceptible sites. Thus, high-hazard zones encompass the Type F channels expected to include, on average, 25% of the debris-flow-depositional sites; the sum of the high and the next hazard zone encompass the Type F channels expected to include, on average, 50% of the debris-flow-depositional sites, and so on.

7.2.1.3 Effects of Debris-Flow Deposits on Type F Channels

When evaluating the role of debris flows on fish-bearing streams, it is important to consider how debris-flow deposits affect channel and habitat morphology. In depositional areas, debris flows can construct levees; build fans at tributary junctions (Dietrich and Dunne 1978); create boulder deposits along fan margins (Benda 1990, Wohl and Pearthree 1991); form ponds at fan constrictions (Everest and Meehan 1981); create wide valley floors (Grant and Swanson 1995); force channel meanders (Benda 1990); and spates of debris flows can lead to widespread channel aggradation and formation of terraces (Roberts and Church 1986, Miller and Benda 2000). In addition, debris flows can incorporate logs and whole trees that have accumulated in small (Type N) channels over decades to centuries and deposit them on fans, valley floors, and at low-order confluences (Hogan Bird et al. 1998, May and Gresswell 2003). Debris flows entering larger rivers with greater transport capacity can be rapidly eroded, potentially forming destructive debris torrents and debris-laden floods (Benda Veldhuisen et al. 2003).

The nature of these effects varies from site to site depending on debris-flow size and composition (e.g., amount of wood and boulders), valley geometry, and the sediment transport capacity of the channel where the debris flow deposits. Regional data on the rate of erosion of debris-flow deposits provides an indication of debris-flow effects on channels as a function of channel size and gradient (Benda 1990, Benda et al. 2003). Using these data and field observations of deposit types (Benda 1990, Grant and Swanson 1995, Hogan Bird et al. 1998, May and Gresswell 2004, Lancaster and Grant 2006, Bigelow Benda et al. 2007), we define four classifications:

Deposit type	Criterion (slope*drainage-area threshold)	Channel effects	Habitat effects
Colluvial (transported soil and debris) deposits, with little to no subsequent fluvial erosion	< 0.13 km^2 (32 acres) and-or drainage area < 3 km^2 (741 ac)	Channel and valley burial; potential sediment and wood source for subsequent long-runout debris flows.	Deposits of sediment and wood modulate runoff through headwater channels, provide habitat for amphibians and invertebrates.
Morphological Significant Deposits	< 0.40 km^2 (99 ac)	Create fans and terraces, log jams, boulder deposits.	Short-term destructive effects: burial of channel habitat, increased fine sediment load, increased bedload with associated loss of pools and increased channel instability. Long-term constructive effects: boulder and wood deposits contribute to channel complexity and formation of pools.
Dilution and rapid erosion of deposit	< 1.0 km^2 (247 ac)	Formation of scouring debris-laden floods	Damage to downstream channel and riparian areas.
Hyper Dilution	> 1.0 km^2. (247 ac)	No major in-stream deposits, minor effects on channel morphology	

7.2.2 Results

7.2.2.1 Type N Channels

All Type N channels with upslope debris-flow sources are potentially debris-flow prone. Map 29 (and discussed in greater detail in Appendix T – Slope Stability Assessment) identifies the Type N channels susceptible to debris flows that continue on to fish-bearing (Type F) streams, using the hazard definitions described in the methods section above. The greatest concentration of high-hazard zones is coincident with areas having a high probability for landslide initiation and delivery (Map 26), particularly in the North Fork Wilson sub-basin. Along any debris-flow-prone Type N stream, the hazard rating tends to increase downstream, reflecting the increasing number of potential debris-flow source areas encompassed in the drainage area to the channel. These hazard ratings rank Type N channels in terms of potential for delivery of any available woody debris to fish-bearing streams.

7.2.2.2 Type F Channels

Debris flows enter fish-bearing streams primarily at confluences with debris-flow-prone Type N channels. These locations are identified in Map 25. Potential debris-flow depositional reaches are scattered discontinuously throughout the channel network, with a spacing between sites that tends to increase with increasing channel size. Channels near the headwaters in debris-flow-prone areas (e.g., North Fork and Jordan Creek subwatersheds) have numerous, closely spaced debris-flow input points with potentially overlapping effects; downstream and in less-debris-flow-prone areas, debris-flow sites are more widely spaced.

7.2.2.3 Debris-Flow Deposit Effects

Colluvial deposits are primarily confined to headwater (Type N) channels (Map 28; note that these deposits may be subject to subsequent erosion by long-runout debris flows). Morphologically significant depositional sites occur through many of the smaller fish-bearing (Type F) streams. Debris flows depositing in these channels can be important sources of large wood, suggesting that protection of upslope sources of wood is particularly important for these channels. Of note in the Wilson River watershed are the extensive reaches with sufficient stream power to generate debris-laden floods. Overlap of debris-flow sources with these reaches, as found along the North Fork Wilson and Jordan Creek, identify channels subject to these destructive flood events.

7.3 Deep-seated Landslides

No active, large deep-seated landslides and earthflows were detected in the Wilson River basin using aerial photography or during the field surveys.

However, an ODF aerial survey in March 2007 revealed numerous incidences of small, deep-seated failures. On March 28, 2007, ODF staff flew a plane (Partenavia) to conduct a coarse scale aerial survey to assess effects of the November 2006 storms within the Wilson watershed. The survey was qualitative in nature, but provided an excellent overview of channel conditions in the Wilson River watershed at the subwatershed scale. Storm effects were concentrated in the Jordan Creek and South Fork subwatersheds, with locally heavy effects elsewhere. This applied to both landslide locations and stream channel effects. Interestingly, a greater number of small deep-seated landslides were noted than were shallow-rapid landslides.

Another type of deep-seated failure common to certain areas in the Wilson River watershed is episodic deep failures that occur on relatively steep, planar slopes during very intense rains. A good example of this type of landsliding occurred in the West Fork of the North Fork Wilson River in early December 2007 following a major rainstorm. The deep-seated slides were 10 meters or more deep and thus they were unlikely affected by historical timber harvest. The volume of sediment released was estimated to range from tens to hundreds of thousands of cubic meters and was sufficient to inundate the channel and valley floor for kilometers below the landslide.

Unfortunately it is difficult to accurately predict where landslides of this type will occur in the future. The ground surface characteristics of these areas prior to failure are not well understood and the most reliable indicators may be below ground and thus not detectable by geoscientists. Thus these types of failures are not covered in this analysis. They should be considered as part of the natural (background) disturbance regime. However, when building new roads or refurbishing old roads in basins known to have had historical deep-seated slides it is recommended that the character of both the subsurface rock (weathered, highly fractured or competent) and surface topography be carefully examined. In geomechanical suspect terrain, road construction that involves significant excavation of hillslope material should be carefully considered. LIDAR may be useful for detecting the hillslope areas with a long history of this type of failure.

The analysis here is limited to larger features since there is no reliable method to detect existing small features or to predict future occurrences of small, deep-seated landslides.

7.3.1 Methods/Background

Two methods are used to predict the likely locations of large deep-seated landslides and earthflows in the Wilson River basin. One uses the Roering and others (2005) model that is based on detecting specific combinations of hillslope gradient and curvature, empirically calibrated to the central Oregon Coast Range.

The other method relies on perturbations in the longitudinal profiles of river valleys. Neither approach indicates the activity level of deep-seated landslides (e.g., active versus dormant). Because large landslides occur relatively infrequently, the majority of such features in a watershed should be old and hence could be viewed as sources of physical heterogeneity in rivers by creating knick points that reduce valley gradient upstream and increase gradients downstream (Grant and Swanson 1995, Cruden and Thomson 1997). Lower-gradient valley segments upstream of large slides can create wide valleys containing more floodplains, side channels, and more sediment and woody debris (Figure 29); the large slide in the Devil's Lake Fork subwatershed is a good example of this. For a more detailed discussion of the methodologies used in this section, refer to Appendix E – Detailed Methodologies.

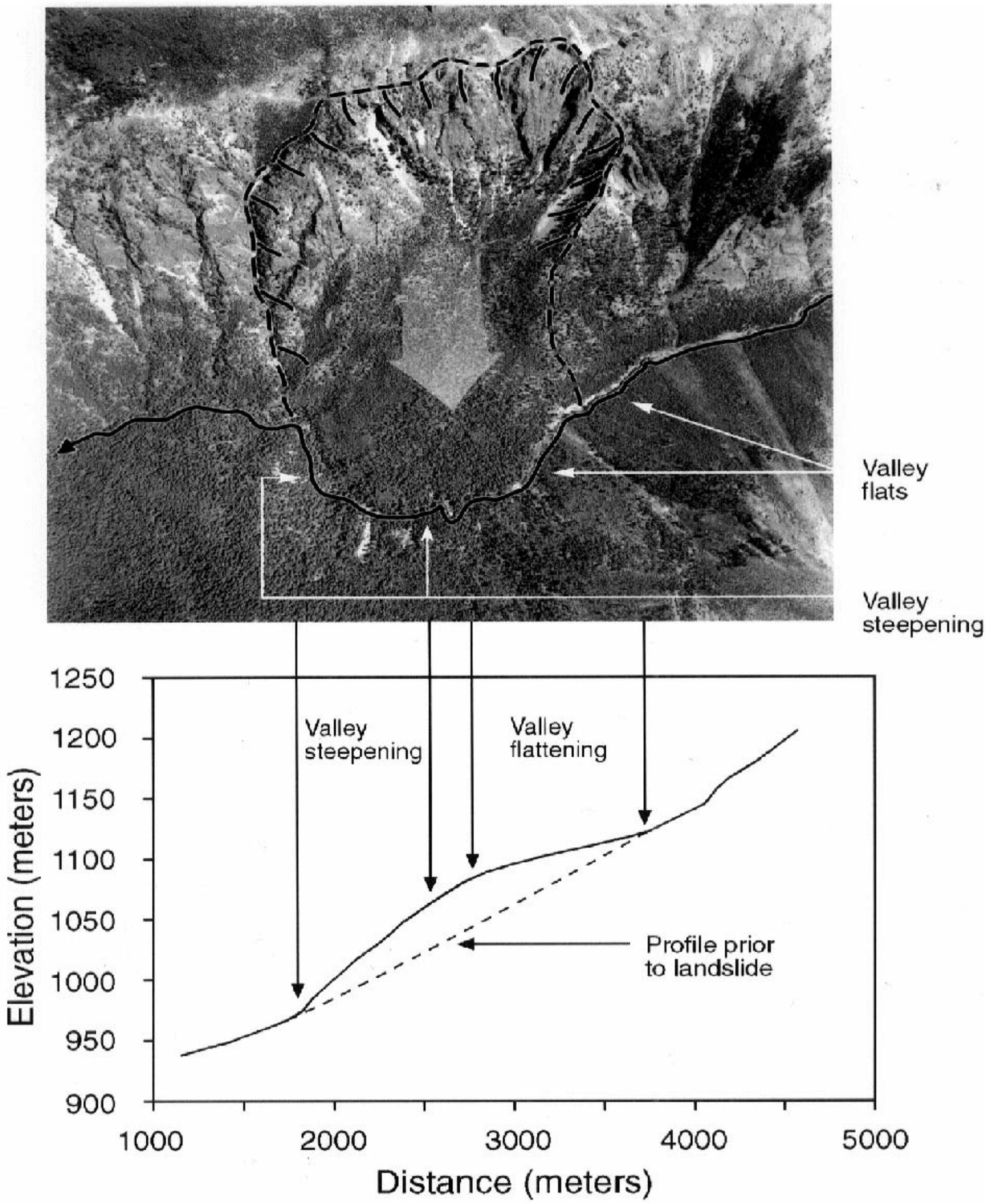

Figure 29. Large, ancient deep-seated landslides can be a source of habitat development and heterogeneity. The landslide depicted here, located in eastern Washington, has resulted in a large bulge in the longitudinal profile of the river. Upstream of the landslide low gradient valleys and channels have created floodplains and lower gradient, meandering channels. Younger deep-seated landslides can pose a threat to aquatic resources through increased erosion and turbidity. Because of the rarity of large landslide events, the majority of such features in a watershed should be old.

7.3.2 Results

Predicted deep-seated terrain using the Roering and others (2005) model is shown in Map 45. Much of the Wilson River watershed is classified as having topography indicative of deep-seated landslides. In particular, a high concentration of such terrain is located in the far eastern portion of the basin. The deep-seated algorithm likely over-predicts the occurrence of deep-seated landslides and earthflows since it does not evaluate the level of activity (i.e., ancient and non active terrain is not differentiated from more recent or active landslides). Additionally, other types of low gradient topography could get included in the deep-seated designation. Finally, due to the algorithm used, this method does not intrinsically demarcate fine scale boundaries of deep-seated landsliding.

The second method produced twelve individual longitudinal profiles of the major channels in the Wilson River watershed (Figure 30). The longitudinal plots that correspond to the locations in Figure 30 are shown in Figure 31 through Figure 34. All but three of the profiles (9) show some type(s) of perturbations in the elevational profiles suggesting that large deep seated failures exist in the watershed and are affecting valley profiles. The highest concentration of elevational perturbations occurs in the eastern portion of the Wilson River watershed (profiles #1 and 2) and they occur in an area predicted by the Roering and others (2005) model to have a high density of terrain indicative of large landslides and earthflows (e.g., Map 45). For example, the upper most perturbation in the profile in #1 (LLID 4540661238739; Lower Wilson River subwatershed) (Figure 31) identifies what appears to be a large ancient failure at that location (Figure 35). Although the large landslide analyses can be used to help screen for occurrences of large failures in the Wilson River watershed, field reconnaissance and detailed field surveys will be required to verify predicted patterns as well as level of activity (e.g., active versus dormant).

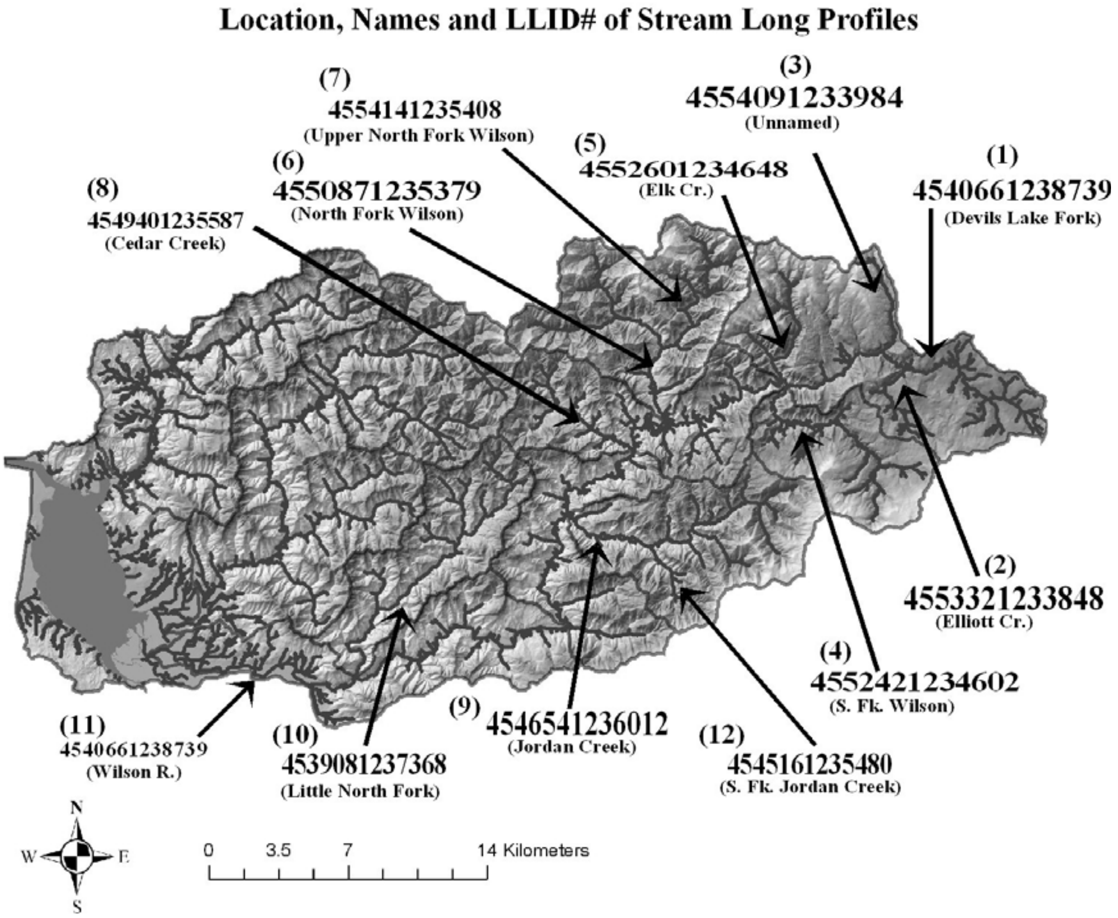

Figure 30. Locations of three principal Tillamook Bay basins (Miami, Kilchis, Wilson) with locations of principal tributaries in the Wilson River watershed where longitudinal profiles were used to search for potential deep-seated landslides.

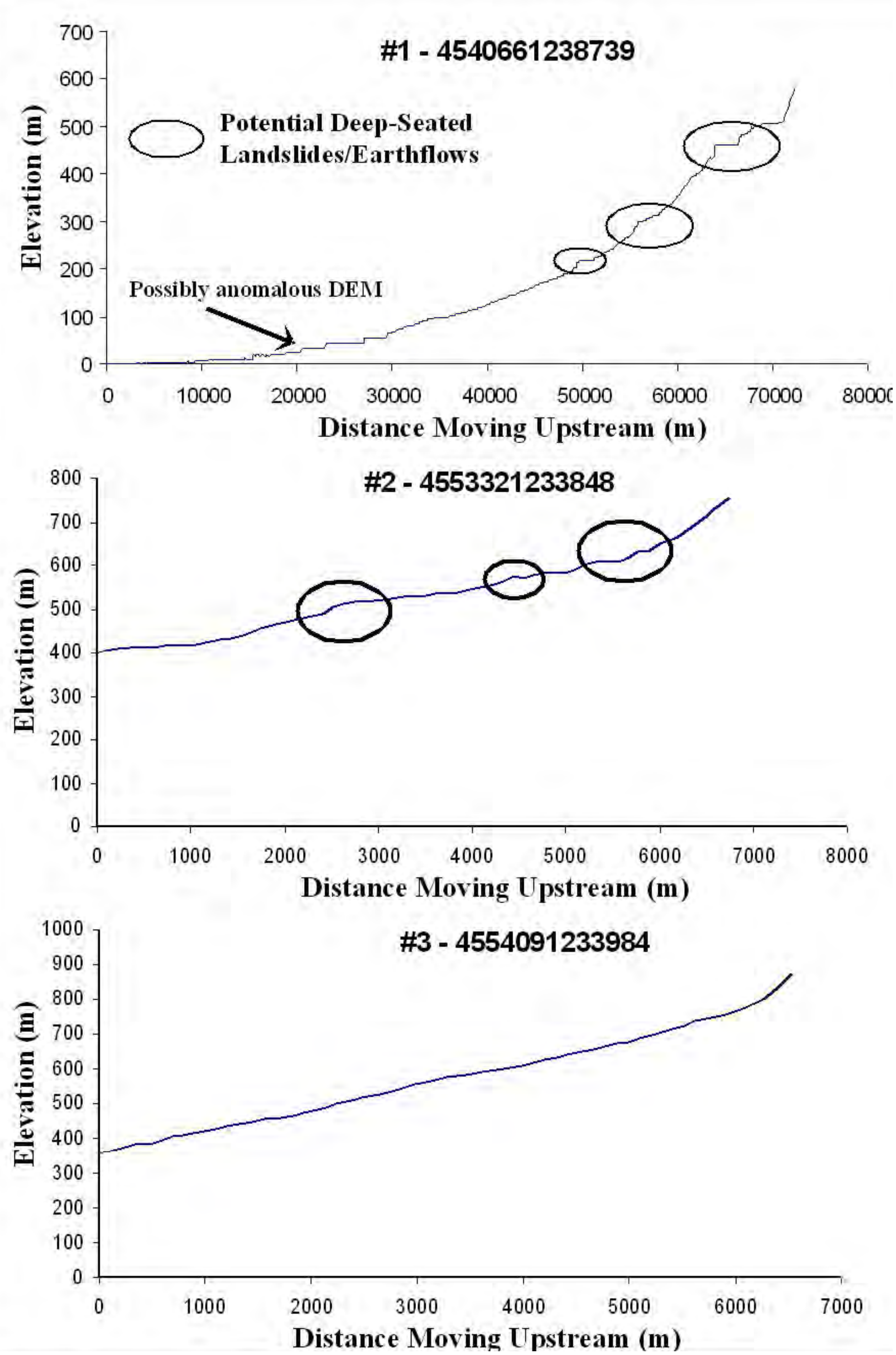

Figure 31. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

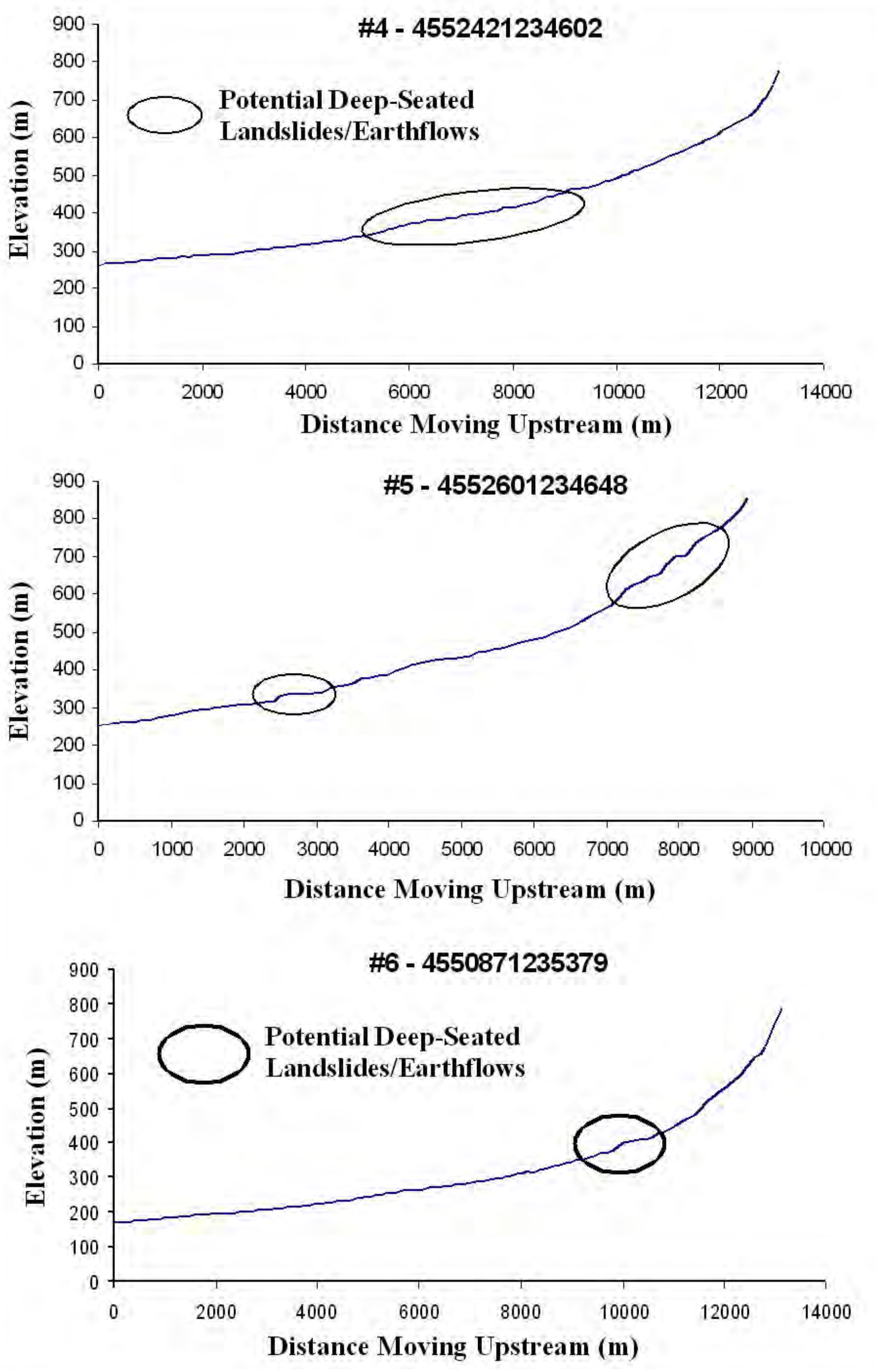

Figure 32. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

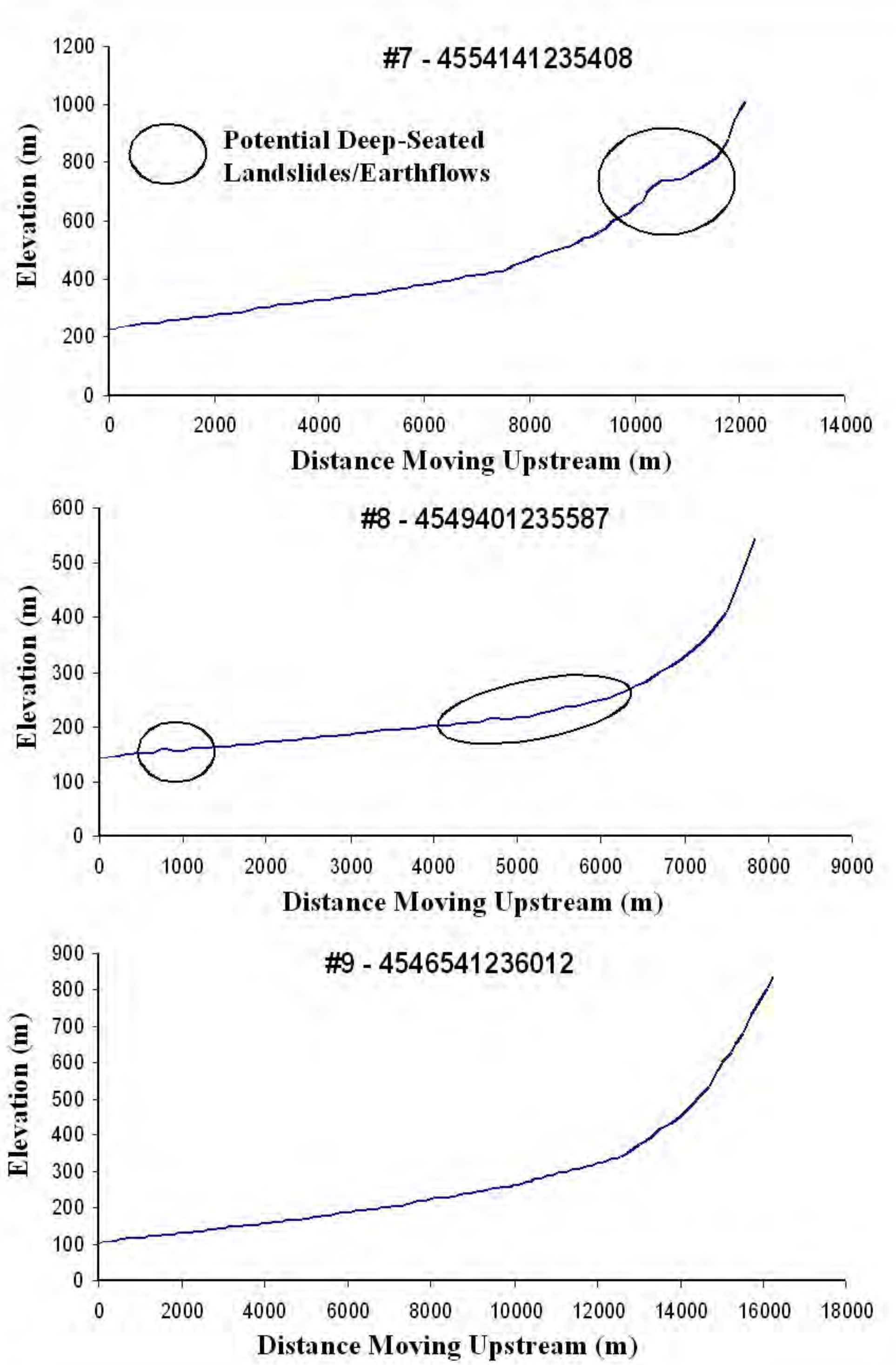

Figure 33. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

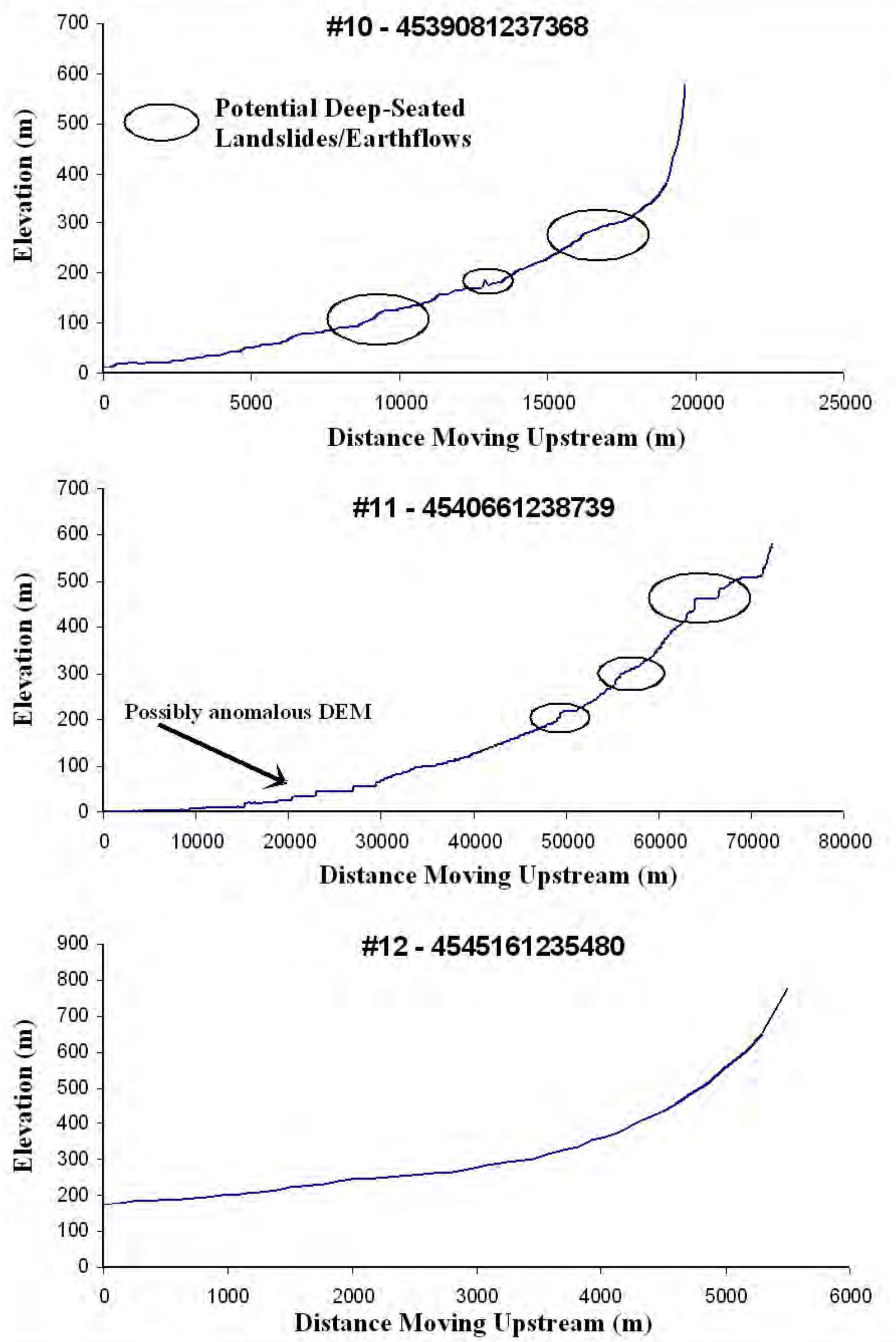

Figure 34. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

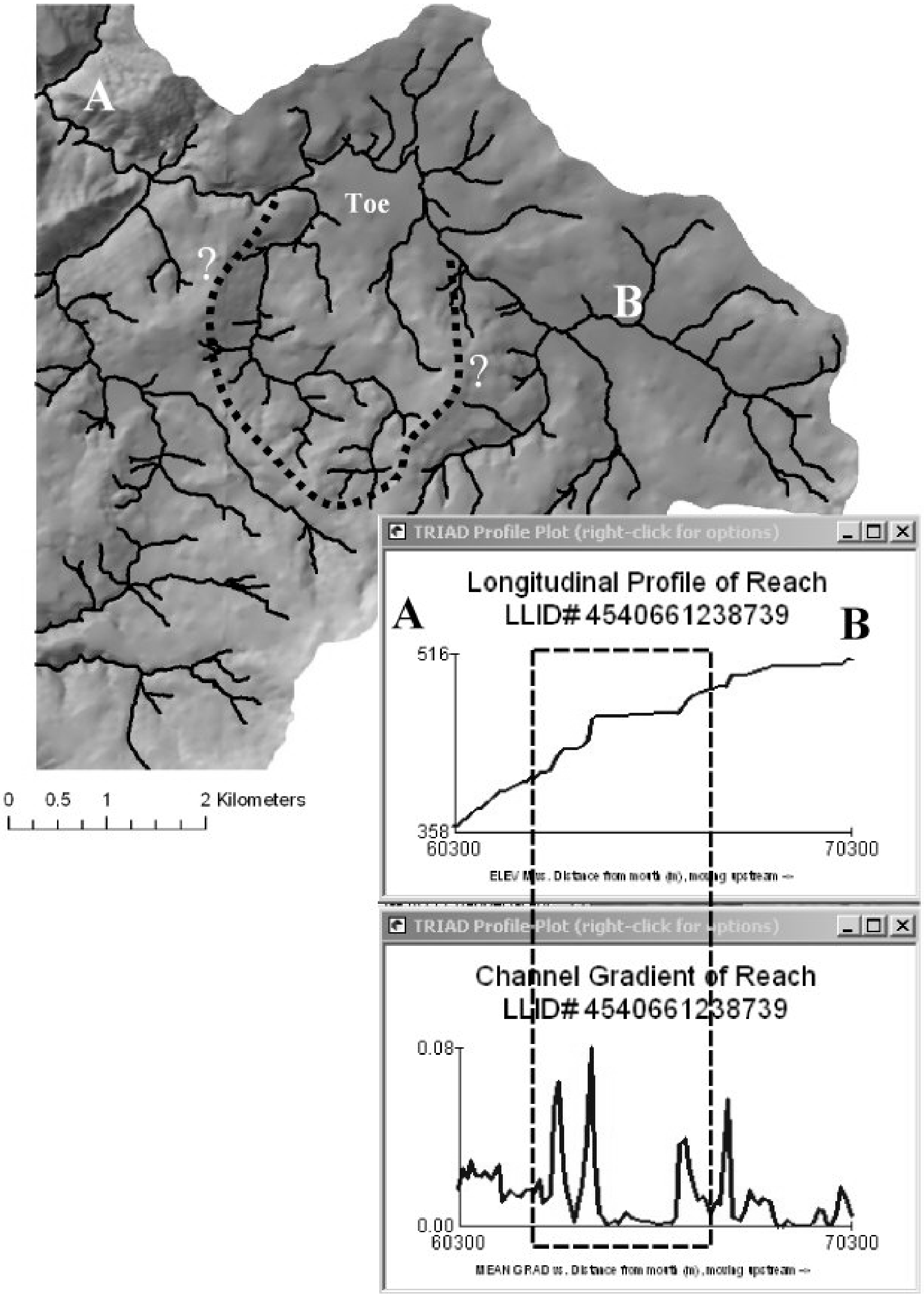

Figure 35. An example from the far eastern corner of the Wilson River basin where an apparent large deep-seated landslide is altering the longitudinal profiles of channel gradients, elevation, and valley widths (refer to Figure 30 for LLID/stream names).

7.4 Road-Related Issues

Roads provide access to a wide variety of activities within the Wilson River watershed. From timber harvesting and log hauling to recreating with Off Highway Vehicles (OHV) and motorcycles, the roads within the watershed are well used and often a busy place.

The Oregon Forest Practices Act of 1971 and the rules governing forest roads that were adopted in 1972 considered the impact of roads on aquatic resources in terms of road location, construction and maintenance (Mills et al. 2007). Since 1972, the body of knowledge regarding the interaction between roads and aquatic resources has grown. Similarly, ODF has continued to research, monitor, and develop Best Management Practices (BMP) for forest roads.

The environmental impact of forest roads are well known and widely documented. Mills and others (2006) and others summarized the environmental effects of forest roads on aquatic resources as:

- Restriction of fish, flow, sediment and debris passage at stream crossing structures;
- Input of sediment in amounts over background;
- Alteration of aquatic habitat from sediment, increased fines in stream sediment, and, for roads adjacent to streams, directly filling and eliminating habitat;
- Change in hydrology and stream flow when roads intercept rainfall and groundwater and alter rate of water delivery to streams.

Even though the effects of roads have been understood by researchers for some time, land managers have generally focused on road density, proximity to streams, and surface material in their assessment of forest road condition. The need to better characterize the current condition of State forest roads led to the development of a road assessment protocol that went beyond calculating road density, proximity to streams, and surface material. The State developed the "Rapid Watershed Risk and Current Condition Survey" (Appendix I) to evaluate the current effect forest roads have on aquatic resources within a particular watershed. The survey categorizes and rates linear features such as drainage system, critical location, prism stability, surface condition, and vegetation along the roadway. At specific point locations the survey categorizes and rates stream crossings, cross drains, and other features as they affect streams and the watershed. The survey allows managers to evaluate current and near-term road conditions as they are likely affected by flood producing storms. Generally, the survey captures attributes associated with roads and their potential environmental risk. Mills and others (2007) identified the environmental risk factors associated with roads in forested mountainous terrain as:

- Road location in relation to streams or landslide/other serious erosion prone slopes;
- Stream crossing effects on fish passage;
- Washout and diversion risk at stream crossings;
- Percent of road system with hydrologic connection to streams;
- Land area dedicated to roads and not growing forests; and
- General condition rating of the prism, surface, drainage system, and brush/weeds.

Road segment features are rated and attributed with Attention Priority Codes (AP). There are 5 AP codes and are described by Mills and others (2007) as:

- **AP Code 1**: blocks road, prevents drainage, makes the road unsafe to use, or otherwise is causing damage and/or serious erosion that affects water quality. Road-work is required immediately if the issue affects water quality or the road is not intentionally closed.
- **AP Code 2**: significantly restricts road use, or the ability of water to drain across the road, and if left alone will likely get worse over time.
- **AP Code 3**: has a moderate effect on road use, speed, or water flow across the road, but is not an imminent forest practices problem and though it may reduce driving speed, is not a serious safety hazard. Code 3 conditions need maintenance or repair in the future (next few years for inactive roads, sooner for active logging roads).
- **AP Code 4:** is a minor impairment in the function that does not require immediate maintenance or repair.
- **AP Code 5**: indicates perfect working order and there is no effect on the road function as designed nor is there increased erosion.

7.4.1 Survey utility

The survey data are readily available for use by ODF District managers and engineers in terms of identifying specific road segments in need of immediate repair. The survey data may also be used to help prioritize maintenance efforts by focusing on road segments that are in the most need of maintenance. The data are also useful for longer-term strategies such as prioritizing road hazard reduction activities. A principal use of the survey is to assess overall road conditions and risks when the survey was conducted, for comparison with other road systems or with benchmarks and performance measures.

Maintenance needs are best determined using an Attention Priority Code (especially codes 1 and 2). Stream crossing structure replacement should be based on washout risk, fish passage restriction, and also on attention priority code. Sidecast pullback is evaluated by prism stability and critical location risk level. Road vacating should be based on a combination of factors, especially a large percentage of the road in the more critical locations. Limits on winter road use can be determined by road surfacing and the percent of road hydrologically connected to streams.

In 2006, workers from Duck Creek Associates, Inc. surveyed the Wilson River watershed road and trail system using the Rapid Watershed Risk and Current Condition Survey. The results of that survey are the basis for this assessment.

7.4.2 Roads in the watershed

It is important to understand while reviewing this section of the document that the rapid road risk assessment is a snapshot of current conditions at the time of the survey. Although the survey was completed in 2006 and provides a comprehensive dataset from which to characterize the road system, the survey occurred prior to November 2006 when records indicate that the Wilson River flooded to its greatest extent since recorded history. The storm changed conditions on the ground and ODF managers and engineers are well aware of many of the changes that have occurred. District engineers have documented many washouts caused by the November 2006 storm (refer to Map 54, addressed later in this section), resource specialists have conducted aerial surveys and qualitatively assessed channel and road conditions, and the authors of this document have been on the ground since the storm observing many of the changes the storm produced. The results of those post-storm investigations are qualitative in nature and discussed throughout this document. Nevertheless, the road survey data still represent the best available quantitative assessment of the current road conditions.

7.4.2.1 Methods

All open and blocked roads were surveyed by traveling the road either by vehicle or by foot. An open road is defined as “a road that can now be used safely by trucks and maintenance equipment”. ODF defines a road with a “blocked” status as being “a closed road that cannot be driven by a pick-up because of a tank trap, boulders or debris on the road, or by vegetation growing on the road. These roads should be routinely inspected if they include any stream crossings or steep fills/sidecast. Construction equipment is required to remove the blockage." They may also be used as trails.

There are many older and difficult to find road prisms in the Wilson River watershed. Most of these older "grown over" roads are covered by 10- 20 inch diameter alders and in some cases conifers. These old road prisms were typically not on the ODF road map layer that was used to locate roads during the survey. Most of these very old (>30 years) blocked roads are difficult to find while surveying and were not included in this survey. The majority of blocked roads included in this survey were easy to locate and find. The distinction is important because the blocked roads included in this survey should not be considered road abandoned prior to the Forest Practices Act of 1971.

7.4.2.2 Road area in the watershed

The 2006 survey found that there were approximately 3 times more open roads than blocked roads in terms of both overall length and area. Total road area was calculated for the entire Wilson River watershed. Road area equals the sum of the prism width, (cut-slope width plus sub-grade width) multiplied by the overall segment length. Less than 2% of the land mass owned by ODF in the Wilson River watershed is covered by roads and unavailable for timber production (Table 27, Map 46).

Table 27. Summary of road data collected in 2006 for ODF lands within the Wilson River watershed.

Road Status	Road Length (in miles)	Area (in acres)	Road Density (miles/sq mile)	Percent of ODF Land Ownership Covered by Roads (area)
Open	432.0	1,053.0	2.8	1.1
Blocked	197.0	406.0	0.9	0.4
Total	**629.0**	**1,459.0**	**3.8**	**1.5**

7.4.3 Hydrologic Connectivity

Hydrologic connectivity occurs when water intercepted by the road prism flows from a road directly to a stream or waterway (Mills et al. 2007). A hydrologically connected road segment may be a source of fine sediment loading to streams if the connected segment is actively eroding. Depending on the location of cross-drains, ditches and culverts, the water flowing over a road can either end up in a stream or waterway (hydrologic connection) or it can be directed to porous forest soils (not hydrologically connected). Reducing the hydrologic connectivity of forest roads on State lands has been adopted as a State Forest performance measure. Reducing the area of road that is hydrologically connected is critical in terms of protecting the streams and waterways from sediment loading. Forest roads have illustrated hydrologic connectivity percentages as high as 50-75 (Reid and Dunne 1984). Properly designed roads direct sediment to the forest floor rather than allowing sediment loading to streams. Improved design has reduced the percentage of hydrologically connected roads in watersheds from greater than 50% to as low as 15% (Dent et al. 2003 and Bilby et al. 1989).

Table 28. Miles of forest roads that were hydrologically connected in the Wilson River watershed during the 2006 survey. Open and Blocked roads were surveyed within the Wilson; open roads for the Upper Nehalem and Miami River watersheds are reported for comparison purposes.

		Percent of the total number of miles of open road by watershed (length)		
Road Status	**Miles of hydrologically connected road**	**Wilson River**	**Upper Nehalem**	**Miami River**
Open	68.5	16.0	16.0	20.0
Blocked	20.7	10.0	NA	NA

Table 28 lists the length, area, and relative percentages of open and blocked roads that were hydrologically connected during the 2006 field assessment on the Wilson River watershed. For a regional comparison, the percent of hydrologic connected road segments in two neighboring watersheds are shown. Of the three watersheds, the Wilson River watershed had the lowest percentage of open roads (length) that were connected to the respective stream networks. Approximately 15% of open road length was classified as hydrologically connected. The 15% value is at the lower end of the 15% - 20% connectivity predicted for improved roads (Mills et al. 2007). We also calculated hydrologic connectivity for the Wilson River watershed in terms of road area. Hydrologically connected open roads covered 0.2% (162.5 acres) of ODF lands within the Wilson River watershed, while blocked hydrologically connected roads covered an area of only 0.03% (29.7 acres) (Table 28). Hydrologic connection was spatially distributed throughout the watershed somewhat equally (Maps 47 and 48). The data and subsequent analysis from the 2006 survey strongly suggest that roads in the Wilson River watershed have been improved to limit direct runoff of water from roads to streams.

7.4.4 Critical Locations

Road location remains one of the most important design criteria in terms of affecting aquatic resources. Critical Locations were defined by the Oregon Board of Forestry as locations with inherent risk to resources regardless of construction technique, although construction technique can reduce risk (ODF Forest Practices Technical Note # 7, 2003) Roads that are in critical locations tend to be risk prone for the life of the road. The 2006 field assessment surveyed and categorized road location as stream-associated, slope-associated, or non-critical. A risk factor of highest to negligible is assigned to each risk category. Stream-associated risk factors include (listed according to their relative risk from high to low):

- Canyon Fill - roads located in a steep, narrow, canyons with high cuts and fills that encroach on the stream (highest risk);
- Channel Fill - roads located next to and sometimes encroaching on a stream, yet these roads may be stable (highest risk);
- Stream in Ditch – streams that are routed down a roadside ditch (moderate risk);
- Stream Parallel - roads located within 100 feet of a stream (elevated risk);
- Wetland – roads that intersect or are adjacent to a wetland (elevated risk).

Slope-associated risk factors include (listed according to their relative risk from high to low):

- Cut and Fill Slides – roads with failures of both cut and steep side-cast slopes that are difficult to stabilize (highest risk);
- Fill Slides – roads with side-cast slope failures along segment and illustrate cut-slope failure (highest risk);
- Deep Active Slides – roads located on a deep active slide where the slide is moving the prism (moderate risk);
- Steep Fill – road comprised of side-cast fill placed on natural slopes that are over 65 percent, with a resulting slope of over 75 percent (moderate risk);

- Deep Inactive Slides – roads located through the toe of an old slide (elevated risk);
- Steep Full-bench – road constructed with an effective end haul, or repaired with effective pullback (elevated risk).

Roads that do not receive a critical location designation are considered non-critical, and if well maintained pose negligible risk to aquatic resources

Table 29 lists the critical condition and location of open roads located in the Wilson River watershed. Roads considered non-critical located make up over 80% of the open roads in the Wilson River watershed (Maps 49 and 50). In terms of a comparative percentage, non-critical open roads in the Wilson River watershed are just about mid-way between the percentage of non-critical segments in the Upper Nehalem River (94.4%) and the Miami River watersheds (63%). One trend visible in the data presented in Table 29 is that less than 2% of the open roads within the Wilson River watershed are in the most critical locations. Roads in the Wilson watershed have a higher percentage of high-risk critical locations than the Upper Nehalem watershed but a considerably lower percentage than the Miami watershed. Within the stream associated severity category, roads parallel to the stream made up 7.0% of the overall roads in the Wilson River watershed. The highest risk factor roads related to streams are canyon and channel filled segments. These two categories combined accounted for 0.3% of the open road system length. In the slope-associated severity category, steep fill roads dominated all other types (11.2%). The highest slope-related risk factor on open roads were roads affected by cut and fill slides (0.3%).

Table 29. Critical location of open roads in the Wilson River Watershed. Critical location is expressed as the percent of the total length of open road system; the Nehalem and Miami watershed percentages for critical location are shown as a reference of nearby road conditions.

		Percent of the open road system (length)		
Critical Location Risk	**Risk**	**Wilson**	**Upper Nehalem**	**Miami**
Stream-related				
Canyon fill	Highest	0.1	0.0	4.7
Channel fill	Highest	0.2	0.0	6.1
Stream in ditch	Moderate	0.1	0.0	0.1
Wetland	Elevated	0.0	0.0	0.0
Stream parallel	Elevated	7.0	4.1	4.0
Slope-related				
Cut and fill slides	Highest	0.3	0.0	0.6
Fill slides	Highest	0.8	0.0	4.1
Deep active slides	Moderate	0.1	0.0	0.0
Steep fill	Elevated	11.2	1.2	15.0

Critical Location Risk	**Risk**	**Percent of the open road system (length)** **Wilson**	**Upper Nehalem**	**Miami**
Full bench	Elevated	0.0	0.2	2.4
Non critical	Negligible	80.1	94.4	63.0

Surveyors also assessed the critical location for blocked roads. These are roads that tend to go unnoticed by managers because of their relative isolation. The percentage of roads in critical locations is essentially the same for both open and blocked roads (Table 30) and 3.1% of blocked roads were located on cut and fill slides. While roads located parallel to streams were essentially the same for blocked and open roads, we identified nearly 5% less blocked roads located on steep fill than on open roads. In spite of these minor differences, blocked roads generally follow the same pattern in terms of critical condition and location as open roads in the Wilson River watershed.

Table 30. Critical condition and location for blocked roads in the Wilson River watershed.

Critical Location Risk	**Risk**	**Percent of the blocked road system (length)**
Stream-Related		
Canyon fill	Highest	0.2
Channel fill	Highest	0.1
Stream in ditch	Highest	0.3
Wetland	Highest	0.1
Stream parallel	Elevated	6.9
Slope-Related		
Cut and fill slides	Highest	3.1
Deep active slides	Highest	0.1
Fill slides	Highest	2.1
Steep fill	Elevated	6.3
Full bench	Elevated	0.0
Non critical	Negligible	80.8

Critical location can be considered alone or in conjunction with hydrologic connectivity. For example, roads classified as stream parallel when considered alone may not pose an immediate risk to the aquatic resource. We considered the spatial distribution of hydrologically connected roads that coincide with critically located roads. A series of spatial queries were run that included intersecting hydrologically connected roads with an AP of 1, 2, and 3 with critically located roads. A total of 8.6 acres of blocked and critically located roads were hydrologically connected and eroding to streams, whereas, critically located open segments totaled 6.4 acres. Open road area considered under this scenario covered 0.6% of the total open road area, while blocked roads under this scenario covered 2.1% of the total blocked road area. The higher percentage of critically located and connected roads potentially delivering sediment from blocked roads could be a function of maintenance as blocked roads receive less attention and maintenance than open roads.

Table 31. The length and area of sediment loading segments (hydrologically connected and a surface drainage AP of 1, 2, and 3) coincidental to critically located road segments.

Relation	Critical Condition	Road Status	Segment Length (ft.)
Stream-related	Canyon Fill	Blocked	1,434.3
	Channel Fill	Blocked	130.0
	Stream in Ditch	Blocked	1,897.9
	Wetland	Blocked	475.5
	Stream Parallel	Blocked	6,790.0
Slope-related	Cut/fill Slides	Blocked	3,026.0
	Deep Active	Blocked	510.0
	Fill Slides	Blocked	4,589.8
	Steep Fill	Blocked	3,112.0
	Blocked Sub Total		21,965.5
Stream-related	Channel Fill	Open	165.2
	Stream in Ditch	Open	152.5
	Stream Parallel	Open	7,570.0
Slope Related	Fill Slides	Open	49.3
	Steep Fill	Open	5,983.8
	Open Sub Total		**13,920.8**

The survey data collected and presented in this assessment provide a unique characterization of the current conditions in the watershed. However, the key word is “current”. Photographic Plate 18 illustrates how conditions changed in less than one year in the watershed and adds legitimacy to the idea that critically located roads remain risk prone for the life of the road. The photograph was taken approximately 3 months after the record setting November 2006 storm. The green highlighted segment was characterized as being stream parallel, hydrologically connected and not delivering sediment to the stream. After the storm, the road classification changed to a stream parallel “fill slide”, hydrologically connected and delivering sediment directly to the stream.

Therefore, ODF should consider resurveying the roads after a significant storm event (see recommendations).

7.4.5 Prism Stability

Surveyors measured prism stability along all open and blocked road segments in the watershed. The prism was ranked according to Prism Stability Codes (Table 32). Prism ratings categorize the extent to which a landslide or erosion is affecting a road prism. Approximately 10.5% of the open roads have significant blocking by landslides or erosion (Prism Stability Codes 1-3). Blocked roads have nearly 23% in the same categories. Maps 51 and 52 illustrate the spatial distribution of prism stability in the watershed.

Table 32. Prism stability as a percentage of the total open and closed roads by Prism Stability Code. Prism Stability Codes are defined as 1= Landslide Blocking, 2=Landslide Partially Blocking, 3=Severely Eroding, 4=Minor Erosion, 5= No Erosion

Prism Stability Code	Percent of total open road	Prism Stability Code	Percent of total blocked road
1	0.0	1	5.7
2	0.7	2	5.5
3	9.6	3	12.3
4	60.8	4	53.1
5	29.0	5	23.0

7.4.6 Stream Crossings

Road stream crossings present the greatest challenge to road engineers in terms of limiting negative impacts to aquatic resources. Stream crossing structures generally include culverts, fords, and bridges. The greatest challenge at a stream crossing is providing adequate fish passage for both adult and juvenile fish. For a discussion of fish passage see both the fish passage discussion in this chapter (below) and Chapter 9, Fish and Fish Habitat.

7.4.6.1 Condition of stream crossings

Stream crossings were evaluated in terms of the need for maintenance (Table 33). On open roads, stream crossings with AP Codes 1 and 2 (the most seriously degraded crossings) made up just 2.7% of the overall percentage of stream crossings; whereas, 29.4% of the stream crossings on blocked roads are considered in need of attention. Again, the data indicate that the blocked roads that are out of sight of managers may be in greater need of attention than the easily accessed open roads, for culverts still in place need another inspection and may need scheduled repair or removal.

Table 33. The number of stream crossings and the respective Attention Priority (AP) Codes identified and ranked during the pre November 2006 storm field assessment. The percentage of the total for each ranking is also shown.

Stream Crossing AP Codes (Open)										
# AP 1	% of total	# AP 2	% of total	#AP 3	% of total	# AP 4	% of total	# AP 5	% of total	Total # Surveyed
3	0.4	18	2.7	72	10.8	391	58.5	184	27.5	668
Stream Crossing AP Codes (Blocked)										
# AP 1	% of total	# AP 2	% of total	#AP 3	% of total	# AP 4	% of total	# AP 5	% of total	Total # Surveyed
44	17.0	32	12.4	44	17.0	102	39.4	37	14.3	259

At each stream crossing, surveyors examined the opportunity to install a cross drain that would filter most of the drainage currently destined for the stream crossing (Table 34). Approximately 30% of the current stream crossings along open roads could benefit from the installation of additional cross drains. Similar percentages exist for blocked roads; although, 44% of the stream crossings on blocked roads do not need additional filters. On both blocked and open roads, at least 30% of stream crossings have no option for increased filtering.

Table 34. Stream crossing filter opportunities are shown by the relative availability and need.

Filter Opportunities	Number	% of Total	Road Status
Available	206	30.8	Open
Unavailable	252	37.7	Open
Not Needed	210	31.4	Open
Filter Opportunities	**Number**	**% of Total**	**Road Status**
Available	68	26.3	Closed
Unavailable	77	29.7	Closed
Not Needed	114	44.0	Closed

7.4.6.2 Washout Risks

This section discusses stream crossings and sedimentation in terms of washout potential and stream crossing condition. Floods in 2006 and 2007 have shown that washout risk at stream crossings may be the most important road issue facing managers. Mills (2006) describes washout potential occurring when fill material, acting as a dam at a stream crossing, is overtopped causing a dam break flood to occur. Much like a debris flow, the ensuing flood washes out the structural crossing material and scours out the channel downstream of the road carrying and scattering debris. Diversion occurs when water overtops the fill and diverts down along the road creating deep rills and gullies resulting in significant damage to the road and excess loading of debris to streams and creeks downslope of the diversion.

Surveyors rated every stream crossing in the Wilson River watershed for washout potential and diversion. Crossings were rated as being high, moderate, or low (Table 35, Map 53). Most stream crossings exhibited low washout potential. However, the increase in high potential from 9 to 15.4% on open to blocked roads respectively may be explained by the lack of maintenance on blocked roads. Washed-out roads only occurred along blocked roads; this is because once a washout occurs, the road is considered blocked.

Table 35. Stream crossing washout potential survey data for open and blocked roads.

Open Roads Washout Risk	Number	% of total
Low	313	46.9
Medium	295	44.2
High	60	9.0
Total	**668**	**100**

Blocked Roads Washout Risk	Number	% of total
Low	109	42.1
Medium	41	15.8
High	40	15.4
Washouts	69	26.6
Total	**259**	**100**

7.4.6.3 Inspecting and Servicing Stream Crossings

As discussed previously, stream crossings were rated for washout potential in terms of being Low, Moderate, or High. For the purposes of this analysis, we looked at stream washout potential where crossings were rated as High or Moderate and also had an Attention Priority Code of 1-3. The results for stream crossings that fit these criteria on blocked roads are found in Table 36. These crossings have the ***highest priority for inspection and repair***; these crossings have been out of sight for some time and rarely, if ever, get inspected. Road name and the distance from the start of the road are given. Note: some of these crossings may have had been inspected and repaired after the November 2006 storm.

Table 36. Stream crossings on blocked roads prioritized for inspection and maintenance. These crossings have a High or Moderate washout potential and an Attention Priority Code of 1-3. These crossings are considered a high priority for inspection because these crossing are not routinely visible to managers and may pose significant risks to the Wilson watershed aquatic resources.

RTID	Distance from road start	Road Status	Washout Potential	AP Code
1-7-11.13	1965	Blocked	H	3
1-7-33.3	2720	Blocked	H	3
1-7-7.4	125	Blocked	M	2
1-8-1.2	6690	Blocked	M	3
1-8-10.5	545	Blocked	H	2
1-8-22.4	6770	Blocked	M	3
1-8-25.2	8600	Blocked	H	3
1-8-25.2	9805	Blocked	M	3
1-8-25.2	10780	Blocked	H	3
1-8-25.2	11160	Blocked	M	3
1S-8-1.0	3145	Blocked	H	3
1S-8-1.1	6895	Blocked	H	2
1S-8-11.411	3155	Blocked	H	2
1S-9-18.2	650	Blocked	M	2
1S-9-18.2	1165	Blocked	M	3
1S-9-18.4	572	Blocked	H	1
2-7-15.3	145	Blocked	H	1
2-7-15.3	240	Blocked	H	2
2-7-15.31	870	Blocked	H	3
2-7-15.31	1035	Blocked	H	3
2-7-15.31	1500	Blocked	H	3
2-7-22.3	625	Blocked	H	3
2-7-22.3	930	Blocked	H	3
2-7-22.3	6435	Blocked	H	3
2-7-33.1	2400	Blocked	M	3
2-7-33.1	2480	Blocked	M	2
2-7-33.1	2555	Blocked	M	2
2-7-33.1	4280	Blocked	M	2
2-8-25.2	2705	Blocked	H	1
2-8-25.2	3390	Blocked	H	1
2-8-25.2	1965	Blocked	H	3
2-8-25.2	4600	Blocked	H	1
Arch Cape MI	4970	Blocked	M	1
Arch Cape MI	5300	Blocked	H	1
Arch Cape MI	6500	Blocked	H	1
BLU CK	3715	Blocked	H	2
BLU CK	11855	Blocked	H	3
CLIN4.50	2865	Blocked	H	2
CLIN5.51	1610	Blocked	M	3
CLIN5.51	2740	Blocked	H	2
CLIN5.51	3420	Blocked	M	3
CLIN5.51	4700	Blocked	H	3
CLIN5.85A	1655	Blocked	M	2
D FNCE	13245	Blocked	M	1
D FNCE	13615	Blocked	H	3
D FNCE	13735	Blocked	M	3
D FNCE	14380	Blocked	H	1
D FNCE	14540	Blocked	M	2
HOSKINS	1165	Blocked	H	3
HOSKINS	1665	Blocked	H	2
JONES	13880	Blocked	M	2
N FK WIL	26820	Blocked	M	3
OLD CDR	6855	Blocked	H	1
POLLO	620	Blocked	M	2
POLLO	725	Blocked	M	1
Powerline1	1890	Blocked	H	3
Powerline10	1810	Blocked	H	2
Powerline11	960	Blocked	M	3
Powerline11	3165	Blocked	M	2
ROGERS RD	16480	Blocked	H	3
RUSH RD	695	Blocked	H	2

Stream crossings on open roads were also rated using a slightly different criteria than those on blocked roads. Open road stream crossings are considered a high priority for inspection if they had a High washout potential and an Attention Priority Code of 1 or 2 (Table 37).

Table 37. Stream crossings on open roads prioritized for inspection and maintenance. These crossings have a High washout potential and an Attention Priority Code of 1 and 2. These crossings are considered a high priority for inspection.

RTID	Distance from road start	Road status	Washout Potential	AP
2-8-25.1	2,915	OPEN	H	2
7CED2.25	1,240	OPEN	H	2
7CED2.25	2,760	OPEN	H	2
BEN SMITH	9,285	OPEN	H	2
CDR CK	4,750	OPEN	H	2
CDR CK	10,585	OPEN	H	2
CDR CK	12,930	OPEN	H	2
D FNCE	7,615	OPNE	H	1
E ACCESS	3,090	OPEN	H	2
FALL CK	1,275	OPEN	H	2
FALL CK	2,225	OPEN	H	1
KANSAS CK LP	2,830	OPEN	H	2
MILLS_BRDG	5,508	OPEN	H	2
N FK WIL	1,910	OPEN	H	2
N FK WIL	20,270	OPEN	H	1
NF WF	16,300	OPEN	H	2
SFWI	23,215	OPEN	H	2
SFWI1.42	7,455	OPEN	H	2

7.4.6.4 Fish Passage

Fish passage was evaluated at all stream crossings during the winter of 2006. Each crossing was rated in terms of its ability to allow fish to pass. Specifically, we evaluated if stream crossings that crossed fish-bearing streams were a barrier to adult and juvenile fishes, only juveniles, or not a barrier to fish passage. A stream was considered a fish-bearing stream if it had a Type F designation, or if fish were observed. A stream was considered likely to support fish if it did not have a Type F designation, but the stream was less than 10% gradient and had an active channel width of more than 3 feet. Table 38 contains a list of stream crossings determined to be likely or known barriers to fish passage. These stream crossings should be inspected and repaired to allow for full fish passage.

Table 38. Prioritized stream crossings on both open and blocked roads identified as being barriers to fish passage. Shown is the road name, distance from the beginning of the road, the barrier type, and the field determination of whether the stream is known or likely to support fish. **NOTE:** some crossings may have already been inspected and repaired since the November 2006 storm.

Route ID[1]	Road Status	Distance from start of road (in feet)	Barrier Type[2]	Is the Stream Fish Bearing?
JUNO	Open	14,760	AB	Known
BDAM6.45	Open	1,535	FB	Known
BDAM	Open	35,555	FB	Known
SCCK	Open	8,335	FB	Likely
SAD2	Open	3,950	AB	Likely
CLIN	Open	3,225	AB	Likely
SCCK0.53	Blocked	790	AB	Likely
SFWI	Open	24,335	AB	Likely
BDAM	Open	24,400	FB	Likely
BDAM	Open	30,625	AB	Likely
DRCK	Open	24,345	FB	Likely
BDAM	Open	28,550	AB	Likely
LAMT1.37	Open	695	AB	Likely
BDAM	Open	26,270	FB	Likely
IDCK1.56A	Open	2,425	FB	Likely
KILCH LO	Open	7,675	FB	Likely
BDAM	Open	21,025	FB	Likely
POLLO	Blocked	2,950	AB	Likely
1-7-11	Open	4,350	FB	Likely
1S-9-18.2	Blocked	2,600	AB	Likely
N FK WIL	Open	10,415	AB	Likely
SMITH	Open	2,960	FB	Likely
KNS CK	Open	3,860	AB	Likely
BVR	Open	2,580	AB	Likely
MUESL	Open	5,665	AB	Likely
KNS CK	Open	3,165	AB	Likely
1-7-9.2	Open	125	FB	Likely
BDAM	Open	9,715	AB	Likely

[1] Route ID as identified in the ODF roads database.

[2] AB = adult and juvenile barrier; FB = juvenile barrier.

7.4.7 Reducing Hydrologic Connectivity at Stream Crossings

Reducing hydrologic connectivity of roads to streams depends on engineering strategies that effectively divert road surface runoff to the forest floor where it is effectively filtered. Strategically placed cross drains perform this function. Cross drains are most often culverts 18 – 24 inches in size. Surveyors inspected each cross drain along open and blocked roads and assigned an AP Code to each drain

(Table 39). Open roads had a total of 2,491 cross drains of which 3.8% are in need of servicing. Of the 241 blocked road cross drain total, 18% require attention. Cross drains were also surveyed and rated for additional filtering opportunities (Table 39). As with stream crossings, increased filtering can divert runoff to the forest floor thereby limiting sediment loading to streams and creeks. In all, 89% of open road cross drains need no additional filters while 88% of blocked road stream crossings were determined to not need filters, indicating that ODF road planners and engineers have done an excellent job limiting sediment loading from the watershed's roadways.

Table 39. AP Codes for cross drains on open and closed roads.

Cross drains AP Codes (open)										
AP 1	**% of Total**	**AP 2**	**% of Total**	**AP 3**	**% of Total**	**AP 4**	**% of Total**	**AP 5**	**% 0f Total**	**Total**
11	0.4	83	3.4	411	16.5	1,460	58.6	526	21.1	2,491
Cross drains AP Codes (blocked)										
AP 1	**% of Total**	**AP 2**	**% of Total**	**AP 3**	**% of Total**	**AP 4**	**% of Total**	**AP 5**	**% 0f Total**	
18	7.5	25	10.4	43	17.8	128	53.1	27	11.2	243

Table 40. Filter opportunities for cross drains on open and blocked roads.

Cross drains (*open*)	**Number**	**Percent of total**
Available	114	4.6
Unavailable	148	5.9
Not Needed	2,224	89.3
(*blocked*)	**Number**	**Percent of total**
Available	28	11.6
Unavailable	56	23.2
Not Needed	159	66.0

7.4.8 Short-term Risk Analysis

7.4.8.1 Field-verified Sediment Delivery to Streams

The 2006 road assessment data may be queried in various ways to detect where road features interact. For example, in order to determine the spatial distribution and quantity of roads actively delivering sediment to streams we combined four features and queried them based on a specific attribute; hydrologic connectivity, drainage codes 1, 2, and 3, surface condition 1 and 2, and prism stability code 3. The codes are defined below to illustrate why they were queried for interaction and used additively to determine the extent of roads actively delivering sediment to streams.

Drainage AP 1: surface drainage not controlled; surface water is causing severe erosion of road prism and needs immediate attention; unsafe to drive

Drainage AP 2: surface drainage not controlled; surface water is causing moderate erosion of road or onto steep fill; needs attention in next dry period

Drainage AP 3: surface drainage poorly controlled, potential to cause erosion of road prism or weakness in road surface; needs attention within a year

Surface Condition 1: road surface very deeply rutted or ponded, difficult or impossible driving conditions

Surface Condition 2: road surface rough or rutted (over 6 inches, or with many deep potholes or severe washboards)

Prism Stability 3: serious surface erosion or minor cutbank slump

When these feature attributes were combined and intersected with hydrologic connectivity, we found that 30 miles, or ~5% of the total roads in the Wilson River watershed, are actively delivering sediment to streams. Of those 30 miles, 16 miles, or 53% of the delivering total originates from blocked roads, while 14 miles, or 47% originates from open roads. Recall that 16% of all open and 10% of all blocked roads were hydrologically connected (Table 28). Of note is that approximately 76% of the hydrologically connected blocked roads are actively eroding into streams. In contrast, approximately 3% of the hydrologically connected open roads are actively contributing sediments to streams. Although overall hydrologic connectivity was found to be low on blocked roads, these results indicate that blocked roads are a persistent source of sediment loading in the Wilson River watershed. Hydrologically connected blocked roads need monitoring to reduce their impact on aquatic resources. A list of specific roads and the length of road potentially delivery sediment are listed in Appendix X – List of Priority Inspection Roads.

7.4.8.2 Prism Stability and Delivery of Sediment to Fish-bearing Streams

Prism stability has been rated for all road segments and discussed previously in this analysis. To better understand how prism stability may interact with the probability of landslide delivery to fish-bearing streams, road segments with a Prism Stability Code of 2 (Landslide Partially Blocking) were intersected with the results from the landslide delivery model where landslide delivery potential was considered “High”. The modeled data characterized the probability that a particular 10 meter cell on the landscape would deliver to a fish-bearing stream during a landslide (Miller and Burnett 2007). The modeled values range from 0-1 where a value of 1 indicates that any debris flow initiated from that 10 meter pixel will reach a fish-bearing stream, and a value of 0.5 indicates that about half the debris flows from that pixel would reach a fish-bearing stream. The following categories were used for the modeled probabilities:

0.0 - .09 = "Low", 0.1 - .49 = "Moderate", and 0.5 – 1.0 = "High".

Logically, if a landslide is partially blocking a road it is probably is actively eroding. If we consider this source of sediment along with a high potential for delivery to a fish-bearing stream, we can pinpoint short term risk to aquatic resource. Thirteen individual segments on eleven individual roads were identified as meeting posing a short term risk. The road segments listed in (Appendix X – List of Priority Inspection Roads) should be monitored to determine if maintenance is required to limit the sediment delivery to fish-bearing streams.

Table 41. Road segments rated with a Prism Stability Code of 2 (landslide partially blocking road) and the modeled high potential delivery to a fish-bearing stream. Segment distances are given in feet from the start (MP 0.0) of the road.

RTID	Segment Starting Distance (feet)	Segment End Distance (feet)
1-8-1.2	4,500	4,700
1-8-22.3	850	1,200
1-8-22.3	4,525	4,725
1-8-22.4	7,265	7,465
1-8-33	2,520	2,800
ARCH CAPE MI	7,600	7,800
ARCH CAPE MI	8,000	8,200
CLIN5.85A	4,435	4,730
DRCK	24,725	25,085
FALL CK	2,125	2,325
N FK WIL	29,220	29,720
RUSH RD	950	1,150
SFWI	25,500	25,700

7.4.9 Long-term Risk Analysis

7.4.9.1 Critical Location and Debris Flow Risk to Fish-bearing Streams

Data were compared from two independent sources; one source was modeled and one source was field derived, to investigate the interaction between road critical location and the landslide delivery potential to a fish-bearing stream. The modeled data characterized the probability that a particular 10 meter cell on the landscape would deliver to a fish-bearing stream during a landslide (Miller and Burnett 2007). The modeled values range from 0-1 where a value of 1 indicates that any debris flow initiated from that 10 meter pixel will reach a fish-bearing stream, and a value of 0.5 indicates that about half the debris flows from that pixel would reach a fish-bearing stream. Field derived data were collected to describe the extent of critically located roads and have been discussed in detail in earlier sections.

The following categories were used for the modeled probabilities:

0.0 - .09 = "Low", 0.1 - .49 = "Moderate", and 0.5 – 1.0 = "High".

We looked at road segments where the highest slope severity categories (in this case it was limited to Fill Slides) intersected a high potential of landslide delivery to a fish bearing stream. The results are shown in Table 42. These road segments should be field inspected to determine if the fill slides identified in the road survey pose a long-term risk to the aquatic resource.

Table 42. Road segments where field derived high slope severity critical locations were intersected with high modeled landslide delivering potential to a fish bearing stream. Segment distances are given in feet from the start (MP 0.0) of the road. These roads potentially pose a long-term risk to the aquatic resources of the Wilson and should be inspected.

RTID	Segment Starting Distance	Segment End Distance	RTID	Segment Starting Distance	Segment End Distance
1-8-1.2	4,500	4,700	1-8-25.2	16,000	16,400
1-8-1.2	5,650	5,800	1-8-33	2,520	3,890
1-8-1.2	6,250	6,400	ARCH CAPE MI	7,600	7,800
1-8-1.2	7,050	7,500	ARCH CAPE MI	8,000	8,200
1-8-1.2	8,300	8,600	ARCH CAPE MI	8,400	8,600
1-8-1.2	9,000	9,450	KANSAS CK LP	1,900	2,400
1-8-1.21	600	1,180	N FK WIL	29,210	29,720
1-8-1.24	130	300	SFWI	27,030	27,600
1-8-22.4	2,250	2,700	UFAL	25,550	26,780
1-8-22.4	3,665	3,925			

7.4.10 Roads with Higher Long-term Risk

The 2006 field assessment of stream crossings in the Wilson River watershed rated each stream crossing and cross drain for various attributes including but not limited to; washout potential, diversion, and structural integrity. Afterward, the November 2006 flood occurred that significantly altered many stream crossings throughout the watershed. The Tillamook District road engineers' surveyed the storm-affected roads and crossings and produced a "coarse scale" map of impacted areas that was later head-up digitized into GIS (Map 54). ODF engineers tallied 53 sites impacted by the November 2006 storm and rated the impacts as either High or Low.

An analysis was conducted using a combination of critically located road segments that also had at least one stream crossing with a high wash out potential (Table 43). These roads need to be inspected and possibly vacated to limit negative impacts to aquatic resources. We determined that if a road has a Risk Index of 0.50, it would require pulling back steep fill and stream crossings where accessible by equipment. When it is not feasible to get equipment to a particular site, crews could hand construct overflows at high washout risk culverts.

Table 43. Roads rated by a "Risk Index". The index was calculated by finding the product of critically located road segment length and a critical severity category. Critical Severity categories include Highest = 5, High = 3, Moderate = 1, and Elevated = 0.5. The product was then added to a high washout potential rating of 20 for every high washout potential occurrence along a critically located segment. Then for each complete road length the individual segment values were summed and then divided by the total road length to determine the overall Risk Index. The high Risk Indices may indicate the need to vacate a road. **Road segments with a risk index of >0.50 are shown in bold and are the highest priority for inspection.**

RTID	STATUS	(Segment Lengths * Critical Risk Factor + High Washout Potential) (SUMMED)	Total Road Length	Risk Index
2-7-15.31	**BLOCKED**	**6,385**	**1,630**	**3.92**
2-7-22.3	**BLOCKED**	**6,270**	**7,400**	**0.85**
BLU CK	**BLOCKED**	**11,140**	**13,520**	**0.82**
OLD CDR	**BLOCKED**	**8,820**	**14,725**	**0.60**
SFWI2.65	OPEN	2,337.5	7,135	0.33
1S-8-11.4	OPEN	1,135	3,625	0.31
E ACCESS	OPEN	1,857.5	6,140	0.30
2-8-25.1	OPEN	980	4,075	0.24
TILLISON CK	OPEN	2,025	8,595	0.24
NF WF	OPEN	5,647.5	29,235	0.19
KANSAS CK LP	OPEN	1,260	7,310	0.17
SFWI	OPEN	6,425	39,785	0.16

RTID	STATUS	(Segment Lengths * Critical Risk Factor + High Washout Potential) (SUMMED)	Total Road Length	Risk Index
MUESL	OPEN	3,080	19,145	0.16
N FK WIL	OPEN	2,432.5	23,120	0.11

Further analysis was conducted on critically located roads that did not have stream crossings with a High washout potential (Table 44). Interpreting the indices requires professional judgment. As mentioned before Blocked roads with an Index of over 0.5 should be pulled back where feasible. Open roads with an Index between 0.25 and 0.5 should be improved or relocated and those over 0.5 should be vacated.

Table 44. Critically located roads rated by a "Risk Index". The index was calculated by finding the product of critically located road segment length and a critical severity category. Critical Severity categories include Highest = 5, High = 3, Moderate = 1, and Elevated = 0.5. Then for each complete road length the individual segment values were summed and then divided by the total road length to determine the overall Risk Index. The high Risk Indices may indicate the need to vacate a road.

RTID	STATUS	Segment Lengths * Critical Risk Factor (SUMMED)	Total Segment Length	Risk Index
2-7-22.7	BLOCKED	4,625	925	5.00
2-7-15.31	BLOCKED	6,325	1,630	3.88
2-8-24	BLOCKED	5,050	1,310	3.85
1-7-36.31	BLOCKED	12,160	2,335	2.60
1-8-10.5	BLOCKED	5,225	2,375	2.20
1-8-1.21	BLOCKED	7,605	1,180	2.15
1-8-1.24	BLOCKED	1,125	750	1.50
1-8-33	BLOCKED	5,192.5	4,190	1.24
1S-8-1.0	BLOCKED	15,987.5	14,795	1.08
LIL NF	BLOCKED	8,005	7,410	1.08
BLU CK	BLOCKED	26,320	13,520	0.97
2-7-16.2	BLOCKED	1,950	2,280	0.86
2-7-18.2	OPEN	4,987.5	6,040	0.83
1-8-23.2	BLOCKED	1,335	1,655	0.81
2-7-22.3	BLOCKED	23,325	29,600	0.79
1-7-12.1	OPEN	2,512.5	3,200	0.79
1-8-1.24	BLOCKED	1,125	1,500	0.75
1S-8-6.3	BLOCKED	2,550	3,530	0.72
CLIN5.85A	BLOCKED	18,975	26,720	0.71

RTID	STATUS	Segment Lengths * Critical Risk Factor (SUMMED)	Total Segment Length	Risk Index
2-7-15.3	BLOCKED	2,960	4,240	0.70
2-8-25.4	BLOCKED	1,000	1,455	0.69
1-7-36.2	BLOCKED	2,770	4,190	0.66
1S-8-8.7	BLOCKED	1,200	1,910	0.63
1-8-33	BLOCKED	5,192.5	8,380	0.62
2-7-32.4	BLOCKED	2,150	1,760	0.61
1-7-36.3	BLOCKED	4,220	7,315	0.58
N FK WIL	BLOCKED	5,480	9,985	0.55
1-8-1.2	BLOCKED	8,037.5	14,725	0.55
HOSKINS	BLOCKED	2,500	4,605	0.54
1-7-31.11	BLOCKED	1,350	2,500	0.54
2-8-25.1	OPEN	2,200	4,075	0.54
CST RNG LP	OPEN	2,782.5	5,225	0.53
1S-7-10.55	BLOCKED	4,175	4,070	0.51
1-8-36.2	BLOCKED	47.5	95	0.50
N FK WIL SP2	OPEN	255	510	0.50
1S-8-1.2	OPEN	270	540	0.50
W FK WIL SP1	OPEN	185	370	0.50
N FK WIL SP3	OPEN	135	270	0.50
CST RNG LP	BLOCKED	757.5	1,515	0.50
SFWI0.29	OPEN	285	570	0.50

Table 45. Roads identified as having the stream running in the ditch. These roads should be inspected and repaired. Roads determined to have the stream running in the ditch were distributed evenly among open and blocked roads.

Route ID	Segment Distance (in feet) from Road Beginning	Segment Length (feet) in Ditch
1-7-11.13	2,120	895
1-8-21.5	3,545	130
1-8-21.5	2,800	375
2-7-15.3	930	1,040
2-8-26.2	245	140
CDR CK	12,930	470
CLIN	7,600	200
CLIN4.50	2,410	455
GILMR	2,000	315
SFWI	10,595	240
SFWI	29,025	200
Total		**4,460**

7.4.11 Road Findings and Recommendations

This analysis evaluated forest roads in the Wilson River watershed using a survey protocol developed by ODF to rapidly assess the risk roads pose to aquatic resources. The survey, conducted in 2006, found that culverts at stream crossings are one of the most important road features in terms of the need for ongoing inspection and repair. Severe storms in the winter of 2006 and 2007 caused failure at many crossings and illustrated the vulnerable nature of stream crossings. Based on survey data, we found many stream crossings with a high wash-out potential including many on blocked roads that are not routinely inspected. We have identified stream crossings with high washout potential and in need of servicing. These crossings are listed in Tables 36 (on blocked roads) and 37 (on open roads). Managers need to inspect these crossings to determine if the current structure needs to be removed and replaced. Inspection of critical stream crossings should occur during high flow events. Repairs should include removing debris, constructing dips, and constructing berms in the ditch at the lower spot on the stream crossing fill.

Surveyors also rated fish passage at all stream crossings. We found 28 stream crossings that blocked fish passage. Those stream crossings are listed in Table 38 and are in need of inspection and repair.

Hydrologic connection on both open and blocked roads is relatively low. Open roads have a higher percentage of hydrologically connected segments than blocked roads. Managers should evaluate hydrologic connectivity while upgrading and repairing roads. Significant storms may change the hydrologic connectivity of a road. Therefore, monitoring roads after storms to determine hydrologic connectivity is critical.

Considering hydrologic connectivity alone does not tell the complete story of forest roads and sediment delivery to streams. We found that while hydrologic connection of blocked roads was relatively low, the majority of hydrologically connected blocked roads actively loaded sediment to streams. Segments identified as actively loading sediment to streams are identified in Appendix X – List of Priority Inspection Roads. These roads should be inspected and repaired if needed.

The proportion of open roads in higher resource risk critical locations in the Wilson River watershed is similar to other nearby watersheds. The percentage of blocked road segments determined to have cut and fill slides (i.e., high slope severity) was 10 times greater than the percentage of cut and fill slides for open road segments. Blocked roads were determined to have 3 times more of their total length that contained fill slides than did open roads (Table 30). Table 42 identifies specific road segments that may pose a long-term risk where slope severity intersects with high potential for landslide delivery to fish bearing streams. These road segments should be inspected to determine if maintenance is needed to prevent future delivery to fish-bearing streams.

Open roads in the Wilson River watershed typically have stable prisms. Blocked roads are less stable and pose a greater risk to the aquatic resource. (Table 32). Road segments that are unstable and have a high potential for landslide delivery to fish-bearing streams should be inspected in order to prevent future delivery to fish bearing streams (Section 7.4.9 Long-term Risk Analysis).

In all, the road system has been designed to limit impacts to aquatic resources. Yet, problems persist, especially at stream crossings where wash out potential is high and where fish passage is blocked . The data summarized in this analysis directs managers to road segments that are a high priority for inspection, repair or removal.

7.5 Recreation-Related Issues

7.5.1 Off-Highway Vehicle Trails

7.5.1.1 Methods

During the 2006 road inventory, approximately 42 miles of trails were surveyed by Duck Creek Associates on the basis of the OHV-Designated trail map and field-based convenience sampling. Queries were made to determine which of the surveyed trails segments were hydrologically connected, parallel to streams or exhibiting erosion. For the purpose of this study, trails were determined to be hydrologically connected when water intercepted by the *trail* prism flows down the *trail* directly to a stream, road drainage feature or culvert that flows to a stream (after Mills et al. 2007). A sample of 13 hydrologically connected trails was selected from the Duck Creek Associates inventory and recommendations from ODF staff during field reconnaissance trips. These hydrologically connected trails were assessed for washout risk using 1) trail grade, 2) slope alignment angle, 3) distance to steam/road drain, 4) water drainage off trail, 5) topographic position, and 6) soil texture. Attempts by ODF to prevent or repair problems were also noted.

7.5.1.2 Results

Sedimentation is most acute where eroding trails intersect adjacent streams or road drainage systems linked to streams. Trail intersections that are then indirectly linked to streams should be considered high priority for management actions. ODF estimates that the Wilson River watershed has approximately 150 miles of designated trails but undesignated trails have not been systematically surveyed except where they intersect roads (noted as a "feature" during the Duck Creek Associates road survey; refer to Appendix M – ODF Roads Protocol). Table 46 below indicates that of the trails surveyed (42.7 total miles) by Duck Creek Associates, 2.1% had hydrologic connectivity and 2.1% ran parallel to streams (Map 55). Data were unavailable for determining the percentage of other unsurveyed user-created trails that were connected or parallel to streams and more accurate figures, therefore, were not available. A limitation of method is that it may vastly underestimate the impact of OHV trails because the Duck Creek Associates survey was not a census, but a selection of 28% of designated trails and ~5% of undesignated trails. Undesignated trails are not maintained or repaired and tend to have steep gradients, high erosion, and impaired drainage.

Table 46. Incidence of hydrologically connect trails. The table shows the percentages of trails found during the Duck Creek Associates road survey to be associated with sedimentation risks.

Trails	Total # Feet Surveyed	Total Miles	% of Crossings Surveyed
150* miles of designated OHV trails	225,580	42.7	28.4
Hydrologic Connectivity	16,065	3.1	2.1
Parallel To Streams	17,030	3.2	2.1
Prism AP 1**	0	0.0	0.0
Prism AP 2**	5,020	1.0	0.01
Prism AP 3**	25,130	4.6	3.1

Stream Crossing Washout Potential (N=74)	Rating	# of Crossings	% of Crossings
	High	18	24.3
	Moderate	17	23
	Low	39	52.7

* exact total OHV mileage within the watershed has yet to be confirmed (does not include all user-created trails

** **AP** Attention Priority Code (see Appendix M – ODF Roads Protocol and a discuss in this chapter, section 7.4 Road-Related Issues)

1 – surface drainage not controlled; surface water is causing <u>severe erosion</u> of road prism and needs immediate attention; unsafe to drive
2 – surface drainage not controlled; surface water is causing <u>moderate erosion</u> of road or onto steep fill; needs attention in next dry period
3 – surface drainage poorly controlled, <u>potential</u> to cause <u>erosion</u> of road prism or weakness in road surface; needs attention within a year
4 – road surface is <u>not draining fully</u>, damage not observed, drainage water not flowing into potentially unstable locations
5 – surface drainage is <u>functioning properly</u>

7.5.2 OHV Trail-Stream Intersections Affecting Water Quality

Data from the field assessment of hydrologically connected trails indicate a high likelihood of water quality effect on trail-stream intersections that have had no mitigating trail drainage engineering, bridging, and/or that exhibit trail grade/slope alignment in excess of trail standard maximums. This question cannot be fully answered without a full census of the designated and undesignated trail system. The Duck Creek dataset of designated trails identify hydrologically connected trails, including those that were parallel, and those with prism stability concerns. From the table above only 3.11 miles of sampled trails were found to have Prism Stability Priority Codes of 1-3 and were mostly concentrated in the Devil's Lake Fork and South Fork subwatersheds (Map 56). Almost half of the stream crossings were found to have "high" or "moderate" washout potential. The dataset only recorded hillslope, not slope alignment or trail grade; two important predictors of washout risk. While "hillslope" is a good indicator, to identify washout risk, all three characteristics need to be recorded.

7.5.3 OHV Trail-Road Intersections Affecting Water Quality

The results of Duck Creek Associates road survey provide an indication of the degree to which hydrologically connected trails may be a problem. To further understand the impacts of hydrologically connected trails, 13 hydrologically connected trails (identified during the road survey) were field-surveyed and the results are presented in Table 47. Results indicate that trail-stream and trail-road intersections are very likely to adversely affect water quality due to the predominance of steep grades, fall line slope alignment and poor drainage (see Photographic Plates Photographic Plate 19, Photographic Plate 20, and Photographic Plate 21 for some examples). Trail construction guidelines from the AMA[60] and IMBA[61] recommend trail grades that average 10% and slope alignment that is no greater than half the grade of the sideslope.

The majority of hydrologically connected trails sampled at trail-road and trail stream intersections violated these recommended maximums. For example, 77% of sample trails exhibited an alignment in the 0-22 degree range which means they run directly down the fall line. When trails follow the fall line, water can't be directed off the trail with normal outslope of the tread path or with drainage dips placed at intervals. Rolling grade dips (RGDs) that reverse the trail grade can divert water but the dip needs to be constructed and maintained so that water and eroded material has a place to go to. Sump holes are typically used along

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[60] Off Highway Motorcycle & ATV Trails Guidelines for Design, Construction, Maintenance and User Satisfaction 2nd Edition. Joe Wernex American Motorcyclist Association 1994

[61] Trail Solutions: IMBA's Guide to Building Sweet Singletrack. International Mountain Bicycling Association 2006

designated OHV trails to serve this function but rainfall and erosion patterns often make these a short-lived solution.

Many of the worst hydrologically connected trails are undesignated or user-created with no regard for design standards. Furthermore, none of the undesignated trails are maintained as they are not part of ODF's OHV-designated trail system. These undesignated trails have high impacts on water quality and are common enough throughout the watershed to be a concern. Given the quantities of sediment originating from trails indicated by the CSA profiles, sediment delivery is likely across the trail system especially on high-gradient hydrologically connected trails. Designated OHV trails should continue to be given maintenance/correction action priority as they likely receive the most use. However, the undesignated trails identified by the Duck Creek Associates dataset should also be assessed.

Table 47. Washout potential of hydrologically connected trails showing the results of 13 trails assessed using parameters that indicate the degree of washout risk.

Inventory Indicator	Sample Points	Percent
Trail Grade		
0-2%	1	8
3-6%		
7-10%	1	8
11-15%	1	8
16-20%	1	8
21-30%	4	30
>31%	5	38
Slope Alignment Angle (degrees)		
0-22	10	77
23-45		
46-68	3	23
69-90		
Distance to Creek or Road Drainage Features		
Within 25 ft	10	77
Within 26-50 ft	1	8
Within 51-75 ft		
Within >75 ft	2	15
Water Drainage off Trail		
0%	4	30
25%	6	46
50%	1	8
75%	1	8
100%		
Topographic Position		
Valley	5	38
Midslope	5	38
River edge	3	23
Soil Texture		
Sandy Clay Loam	11	85
Clay Loam		
Silty Clay	2	15
Sandy Loam		
Loam		
Silt Loam		

An additional OHV trail problem included Table 47 results are the predominance of trails within 25 feet of streams or road drains that also have poor drainage. Soil texture also presents a picture of trails that are easily eroded, don't absorb water very well and compact readily – not good characteristics for sustainable trails.

7.5.4 Hydrologically Connected Trails

The Road Survey conducted by Duck Creek Associates assessed approximately 28% of the total trail system (of an estimated 150 miles) and found that 7.3% was hydrologically connected (Map 55). Because the exact number of OHV trails in the basin are unknown, this may not be a representative sample of the whole designated and undesignated trail network.

7.5.5 Trail Erosion Condition

While ODF is undertaking a program of trail realignment and drainage construction, many of the trails are on legacy routes – logging skid roads and firebreaks – that are steep, fall-line and without drainage structures. This makes the high use levels produce active erosion conditions on most trail surfaces (Map 56). The field assessment of trails found more highly eroding, hydrologically connected trails than were identified by the Duck Creek Associates survey, suggesting a greater degree of erosion than previously indicated.

7.5.6 Recreational Trail Network and Streams

Preliminary results from the Duck Creek Associates database (summarized in Table 46) show that 3.1 miles of the 42.7 DCA-surveyed miles of trails are located parallel to streams. ODF estimates that there are 150 miles of OHV trails in the basin. Using this estimate, we can extrapolate to the entire basin and surmise that about 10 miles of designated trails are hydrologically connected. However, it is yet to be calculated as a percentage because of the total user-defined, designated AND undesignated trail length as it is still unknown.

7.5.7 Recreational Trail Washout Risk

Trail impact studies indicate that rainfall intensity and slope gradient are key factors explaining variations in soil loss on trails[62]. Two additional key indicators of washout potential are slope alignment and the length of trail following the fall line. Field data within the Wilson-Trails geodatabase does not contain these indicators so they were included in the field assessment of a sample of 13 hydrologically connected trails. During the field surveys of an additional seven

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[62] Wilson and Seney. 1994. Mountain Research and Development, Vol. 14, No 1, 1994, pp77-88. Erosional Impacts of Hikers, Horses, Motorcycles and Off-Road Bicycles on Mountain Trails in Montana.

(7) hydrologically connected OHV trails, trail segments were quantified using cross-sectional area to estimate soil loss from the tread at the sample point since trail creation. Accurate and precise cross-sectional area measures require different procedures based on the type of trail, relationship to terrain and erosion. The cross-sectional area surveys differentiate between historical soil loss episodes (legacy road washouts), more recent recreation-related erosion and washouts.

7.5.7.1 Methods

Oregon Department of Forestry OHV maps, district recreation staff advice and survey records from the Wilson-Trails geodatabase were used to identify a small sample of hydrologically connected trails to measure washout risk and soil loss. The size of the watershed, the number of trail miles, and limitations on fieldwork did not allow for a statistically representative sample or a census of all trails in the watershed. The convenience sample was drawn from the trail system to represent potential washout sites based on a representative set of designated trails around the watershed and of each kind of use, including 1) Motorcycle (MC), 2) Motorcycle/Quad (MC/Q) and four-wheel drive (4WD).

Upon locating the target hydrologically connected trail segment, a GPS device was used to document each trail's location and the length of hydrologically connected trail was determined by ground inspection. The assessment followed trail monitoring standards developed by Marion[63] and were modified to measure just the length of trail with hydrological connectivity. Trail conditions were assessed using point sampling procedures, and included measurement of trail length, width, and soil loss since trail creation using a cross-sectional area procedure. Trail condition measurements were taken at transects spaced at fixed intervals along each sample section of trail. Vertical measurements taken at 0.3 foot intervals along each trail transect were recorded on a field datasheet, and then the cross-sectional area was calculated using Microsoft Excel spreadsheet formulas. The number of transects for each trail was dictated by the length of the hydrologically connected section (normally, the number is proportional to the trail's full length).

Sample point locations were measured at intervals. At each sample point, string-line transect were established perpendicular to the trail tread as illustrated in Figure 36 and Photographic Plate 22 and Photographic Plate 23. The tread width was defined by boundaries at the edge of the obvious wear pattern (vegetation loss, soil exposure) capturing about 95% of all trail traffic. Trail width was

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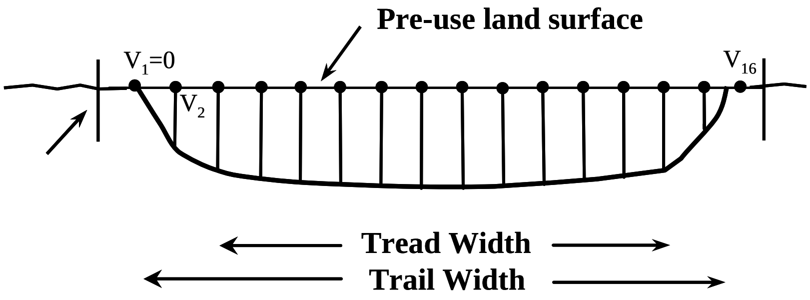
[63] Trail Monitoring Manual – Daniel Boone National Forest Dr. Jeff Marion, USDI, US Geological Survey, Patuxent Wildlife Research Center, Virginia Tech/Department of Forestry (0342) Blacksburg, VA 24061.

assessed only across the bottom of the eroded tread, excluding the steep sides that are not actively impacted by tires. The key characteristic of OHV wear and tear is that travel patterns on active trails can be all the way across the available tread path and beyond depending on the individual (speed, skills, momentum). Measures were taken to avoid including historical wear that had previously incised a trail (old skid road or wear episode) by not including recently undisturbed organic surfaces or re-vegetated edges or old cutbanks.

Figure 36. Cross-sectional area diagram illustrating measurement procedures. (from Marion, 2004)



Vertical distances from the string line down to the trail tread provided the trail depth measures. Trail condition measures were calculated for each trail and for all trails combined, including area of disturbance, cross-sectional area, and mean trail width, depth, and cross-sectional area (Table 48). The "area of disturbance" is an estimate of the land area intensively disturbed by OHV traffic, and was calculated by multiplying trail length by mean trail width. cross-sectional area volume, an estimate of aggregate soil loss (cross-sectional area ft^3), was calculated by multiplying mean cross-sectional area (converted to ft^2) first by sample segment then by total trail length (See Table 49).

Table 48. Description of trail impact indicators and calculation methods.

Variable	Description
Trail Length	Length of informal trail, summed to obtain an aggregate measure for each study area.
Tread Width	Width of tread that captures about 95% of all traffic. Assessed at sample points along each informal trail and averaged for each trail to obtain mean trail width.
Trail Width	Width of trail, including tread and trail-sides up to pre-use land

Variable	Description
	surface. Assessed at sample points along each informal trail and averaged for each trail to obtain mean trail width. Mean trail width for study areas was calculated as the area of disturbance for each trail divided by total length.
Area of Disturbance	The mean trail width times the trail length.
CSA	The cross sectional area from the pre-use land surface to the tread surface. Assessed at sample points along each informal trail and averaged for each trail to obtain mean cross-sectional area. Mean cross-sectional area for study areas was calculated as area of disturbance times mean trail depth
CSA Volume	The mean cross-sectional area for a trail times trail length – an estimate of the total volume of soil lost from a trail.
Mean Trail Depth	Calculated by dividing mean cross-sectional area by mean trail width.

7.5.7.2 Results

Seven sample segments of trail were measured for mean trail width and length to provide estimates of soil disturbance (area in ft^2) shown in Table 49 below. This was then multiplied by the trail length (from OHV map data) and then summed across all types indicating an average disturbance area of 2 acres per mile of trail.

Table 49. OHV erosion quantities (area) along hydrologically connected (HC) trails showings erosion quantities (area) for select OHV trails.

Sample HC Trail Segment	Sample HC Trail Length (ft.)	Mean Trail Width (ft.)	Sample HC Trail Area of Disturbance (ft^2)	Total Trail Length (ft.)	Total Trail Area of Disturbance (ft^2)
1. Quarry #44	225	8.4	1,890	1,742	14,633
2. Military #43	475	8.5	4,038	10,560	234,766
3. Beaver Dam MP 5 (renegade)	240	6.1	1,464	2,640	16,104
4. Cobmaster #66 drop off	200	5.9	1,180	200	1,180
5. Firebreak Five #14	520	17.1	8,892	9,504	162,518
6. University Fire Power #10	1,300	14.4	18,720	6,336	91,238
7. Highway Access #80	910	6.5	5,915	910	5,915
Totals:	3,870		42,099	31,892	526,354
Sample HC length is 12 % of total trail length (6 miles)			**Totals in Acres**		12.1
			Acres/Mile		2.0

Seven sample segments of trail were measured for mean cross-sectional area, mean trail depth and length to provide estimates of soil disturbance (volume in ft^3) shown in Table 53 below. The estimate of soil erosion volume per mile was also derived for each sample trail. Volumes were totaled across all types indicating a combined disturbance volume of 22,893 cubic feet over a combined sample trail length of 3,870 feet. This results in a combined total of 1,157 cubic yards of soil loss extrapolated to estimate volume per mile of trail. It is suspected that the variability of the trail conditions makes extrapolation beyond the sample length difficult to do especially across different types of trail. However, this indicates that hydrologically connected OHV trails are a significant source of sediment, especially considering the year round nature of use and the back log of repair and closure facing ODF staff. Where ODF has placed and maintained drainage features on designated trails, the sediment is diverted to the forest, but on unmaintained hydrologically connected trails, sediment can flow down to drainages (stream and/or road drainage systems).

Table 50. OHV Erosion Volume along hydrologically connected trails. This table shows erosion quantities (volume) for select OHV tails (based upon mean cross-sectional area [CSA] measures).

Hydrologically Connected Sample Trail Segment	Mean Trail Depth* (in)	Mean Trail Width (in)	Mean CSA (in^2)	Trail Erosion Volume		
				Length(ft)	**(ft^3)**	**(ft^3/mi)**
1. Quarry #44	8.3	100.5	832	225	1,300	30,507
2. Military #43	4.5	102	461	475	1,520	16,896
3. Beaver Dam MP 5 (renegade)	3.6	73.5	264	240	432	9,504
4. Cobmaster #66 drop off	4.5	70.5	320	200	440	11,616
5. Firebreak Five #14	9.2	205.5	1,886	520	6,812	69,168
6. University Fire Power #10	6.8	173	1,182	1,300	10,660	43,296
7. Highway Access #80	3.5	79	269	910	1,729	10,032
Totals:				3,870	22,893	31,241
				Totals in yards^3	848	1,157/mile

* Mean trail depth for all vertical measurements. NOT the average of profile mean trail depth.

ft^3 = length x Mean cross-sectional area

ft^3 /mile = (5,280/Length) X ft^3

The average trail depth was also calculated per sample segment.

CSA Volume: The mean CSA for a trail times trail length – an estimate of the total volume of soil lost from a trail.

e.g., Quarry Trail: 225 x 12 = 2700 (trail length in inches) x 832 = 2,246,400 (in^3) x .0005787 = 1,300 ft^3 for estimated erosion volume in cu ft. Expressed in volume of soil loss per mile as (1300 x 5280)/225 = 30,507 ft^3/mi.

Erosion associated with old road/skid trails was effectively accounted for by not measuring early era incision profiles (explained, previously, in the methodology). It would be helpful in future trail assessments, however, to differentiate between trails on old logging roads/skids and those newer ones that have been established by users or by ODF. Trails 1, 2, 3, 4 and 7 in table 51 are sample segments of trails established by users or ODF and recorded a combined soil loss total of 515 cubic yards per mile.

Table 51 below summarizes two other measures of trail condition that are associated with sedimentation and washout risk: fall-line slope alignment and the presence of secondary or braided trails. The presence of secondary or braided trails indicates problems in the trail section itself that could be from other factors (e.g., rutting or obstacles). They are, however, intuitively related. No statistical tests were performed to determine if these two factors were significantly related.

The ODF trail layer did not include braided trail length which could multiply the mileage of actual trail on the ground by a factor of seven[64]. Future trail mapping should include the length of secondary or braided trail sections associated with the main route.

Table 51. OHV sample of hydrologically connected trail braiding and fall-line showing the percent fall-line and the number of secondary tails associated with the select OHV tails (secondary trails indicate problems).

Hydrologically Connected Sample Trail Segment	Secondary Trails (#)	% of Trail Direct Ascent (Fall Line)
1. Quarry #44	13	22.0
2. Military #43	14	26.0
3. Beaver Dam MP 5 (renegade)	6	100.0
4. Cobmaster #66 drop off	4	87.5
5. Firebreak Five #14	5	91.0
6. University Fire Power #10	6	85.0
7. Highway Access #80	3	58.0
Total	51	

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[64] The total number fo secondary trails across the 7 assessed trails was 51 (a bit over 7 times). Therefore, this is a rough indicator of the degree of braiding among these 7 samples segments. However, not enough trail segments were able to be measured to make an estimate for the entire system.

7.5.8 Overall Condition of OHV Trails

Fieldwork and database inventory analysis results indicate that OHV trails in the watershed exhibit a variety of conditions that are having low to severe impacts on water quality. Although the total number of miles of all trails (both designated and undesignated) in the forest is unknown (see the Data Gaps and Limitations section, below), data from the Duck Creek Associates road survey, combined with data in the OHV trails database, indicate that at least 22% of the currently-used OHV trail system in the forest could be user-created[65]. Such undesignated trails are currently not managed by ODF and, therefore, are more likely to be negatively impacting water quality.

Field surveys of the OHV trails found that designated OHV trails also are contributing to water quality problems either directly at road or stream intersections or indirectly by contributing sediment to hydrologically connected drainage systems. Of the 42 trail miles assessed by Duck Creek Associates, 28% were found to be at risk of sedimentation. Extrapolated to the entire watershed, this would indicate that as much as 41 miles of the 150 designated OHV trail miles pose a sedimentation risk. Of the hydrologically connected trail segments that were assessed in the field, extremely high levels of disturbance and erosion were noted with an average soil loss of 2 acres and 1,157 cubic yards of soil loss per mile. Additionally, all the soil loss resulted from relatively recent activities as the cross-sectional area measures were taken only on the active tread wear area. For reference, a 4 foot wide motorcycle trail should only have a disturbed area of 0.485 acres/mile, a 6 foot wide motorcycle/quad trail should have a disturbed area of 0.728 acres/mile and a 10 foot wide four-wheel drive trail should have a disturbed area of 1.214 acres/mile. The Firebreak Five four-wheel drive trail ("FB5" in the Duck Creek Associates road assessment GIS layer), on the other hand, a ridgetop boundary road located between the Little North Fork and Middle Wilson subwatersheds, had a footprint of 3.74 acres/mile. In order to calculate an annual estimate of soil loss, yearly monitoring would be required.

7.5.8.1 Data Gaps and Limitations

Off-highway vehicle trails, both designated and undesignated, in the Wilson River watershed are not accurately mapped or, in the case of the undesignated trails, not mapped at all. ODF has a GIS layer representing trails mapped over the last 15 years, but staff stated it is not up to date and only covers main routes, not all the myriad of user-created trails, braiding and "play" areas. An accurate calculation of the total number of miles of OHV trails currently utilized,

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[65] Estimate derived from the DCA road survey showing that 36 points in the Forest Grove and 56 points in the Tillamook districts had trail/road crossings that could not be accounted for in the ODF OHV trail database (92 of 413; 22.3%).

therefore, is not possible and field assessments conducted for this watershed analysis were only able to provide a rough estimate.

7.5.8.2 Recommendations

- Management of the system is being hampered by a lack of accurate and up-to-date inventory data. Therefore, we recommend an immediate and full inventory of the OHV trail system with a particular focus on the undesignated trails.

- The inventory should include a trail census, sample sites and permanent monitoring points where erosion quantity and rate data can be calculated. In order to get an accurate system-wide estimate of erosion, trail impact measures (e.g., cross-sectional area profiles) should be taken at intervals along the length of the trail.

- Because data from the detailed road assessment indicate that hydrologically connected sections are most likely to impact water quality, the inventory strategy should place priority on hydrologically connected trails and trail segments.

- Additionally, for each type of trail (e.g., motorcycle, motorcycle/quad, four-wheel drive), ODF should develop acceptable targets for average maximum soil loss (ft^3/mile) and disturbed area (acres/mile). These targets could then be used as indicators of overall trail "health" and sustainability.

7.5.9 High Priority Trail Segments

Trail design guidelines and impact studies indicate that certain key characteristics create the highest potential for washouts and erosion problems. Duck Creek Associates trail survey data revealed that almost half of the designated OHV trails had moderate to high stream crossing washout potential. An additional field erosion assessment sample (representing all OHV types) found that a majority of trail segments were exhibiting key washout risk indicators. For example, 77% of trails segments surveyed ran down the fall line and 84% had trail grades in excess of 11 degrees.

Recreation staff and volunteers have taken on and accomplished a massive amount of work dealing with a trail system that included many ill-sited legacy roads and trails used by an increasing number of OHV users. The problem trails focused on in this report are those near streams and while ODF has managed to divert and or bridge all of the designated trail/stream crossings, the field work indicated much work still to be done on user created trails. Steep gradient trails on steep slopes following the fall-line are very problematic, regardless of how many rolling grade dips are placed. Rolling grade dips that are placed on problem trail sections are not as effective as rolling grade dips designed into new trails. ODF has placed drainage features on much of the designated trail system and water is effectively diverted off trail to deposit into the forest. Where trails are hydrologically connected, sump holes can be effective in trapping sediment, but without maintenance they become filled and overflow. It is good start, but Rerouting the trail away from road drains and streams or off the steep side slope is a better long-term solution.

7.5.9.1 Data Gaps and Limitations

A lack of geographic data in the OHV trail inventory database resulted in difficulties in identifying the geographic locations of problem trail segments. Field assessments conducted for this watershed analysis, however, provided insight into the trail characteristics that are causes for concern within the Wilson River watershed (discussed in greater detail in the Recommendations section, below). Additionally, the ODF OHV trail inventory database provided good baseline data on site conditions but lacked numerical measures useful for determining specific site priority (also discussed in greater detail, below).

7.5.9.2 Recommendations

- The following core washout risk indicators should be used to determine priority for corrective action for problem trail segments. The trail:
  - is hydrologically connected,
  - follows the fall line (low slope alignment angle),
  - has gradients in excess of 12%,
  - lacks proper drainage of water from the trail surface,
  - exhibits active erosion and delivery of sediments to the drainage, and
  - is located on unusually erosion-prone soils located on steep slopes.
- Any hydrologically connected trail segment in the watershed that exhibit the above attributes should receive the highest priority for corrective

action (closure and rerouting) as they are generally difficult to drain, maintain, and prevent erosion[66].

- There are a number of trails that are not yet designated but have been identified as “proposed” for inclusion. We recommend that the washout risk indicators listed above be used to screen proposed trails or segments of trails from becoming designated until the trail is rerouted or upgraded.

7.5.10 High Priority Dispersed Camping Sites

7.5.10.1 Data Gaps and Limitations

The ODF inventory of dispersed camping sites provided a good baseline for data in site conditions but lacked numerical measures useful for determining site-specific priorities. Data were instead used to provide direction on setting priority based on site conditions.

7.5.10.2 Recommendations

7.5.10.1.1 Highest Priority for Upgrade or Closure

- To reduce impacts to riparian vegetation, water quality, and tree vigor, any campsite currently located within 25 feet of the water should be removed or set back to at least 25 feet from the water because it is in violation of ODF Administrative rules for campsite proximity to streams. A more conservative approach would be to use tree length (100 feet) but people are naturally drawn to water and availability of flat ground is limited. Appendix W – List of Priority Dispersed Recreation Sites for Upgrade or Closure lists these sites and they are identified on Map 43.

- In addition, 62% of sites exhibited moderate to very high overall impact ratings and should also be high priority for action as these sites exhibit an array of problems impacting water quality and the achievement of properly functioning local riparian conditions.

- Sites documented during the Duck Creek Associates road survey that exhibited moderate to very high impacts and complete vegetation loss of over 1,000 square feet are on the Forest Grove District (FG088, FG101, FG060, FG073, FG092, and FG100; as labeled in the Duck Creek Associates road survey GIS layer). Two sites exhibited impacts that covered 10,000 square feet (FG029, FG039) and exhibited severe soil exposure and compaction. These campsites should be a high priority for

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[66] Except for those short trail sections with built-in grade reversals and/or sediment traps that isolate runoff.

remediation as they all exhibited heavy OHV use, sedimentation and canopy impacts.

7.5.10.1.2 Actions to Address Impacts

- While Leave No Trace[67] and other common mitigation guidelines for campsites on federal land recommend a 100-200 foot set back. However, it is recommended to set back all campsite boundaries to 50 feet from streams because of the impracticality of buffering at a greater distance on the narrow streamside benches typical of this watershed.

- Restrict vehicle access to sites within the inner riparian zone (inner riparian zone) by making these sites “walk-in” only.

- Block and revegetate dispersed sites that are currently used by OHVs for circuit riding.

- Remove or reroute access roads and trails that run down the fall line.

- Remove or upgrade eroding trails that link the campground to the water.

- For the summer season (e.g., high use season), place portable toilets at the most popular sites.

- Institute a dispersed camp permit and fee program to:
    - ➢ hold users accountable for damage
    - ➢ inform users of best practices, and
    - ➢ help pay for site maintenance, mitigation and restoration.

The emphasis on removing vehicle access and pit riding by OHVs from campsites results from these problems being present in all of the high impact campsites. Setting back the edge of the campsite from the water adds a measure of prevention and buffers impacts from the stream edge.

7.5.11 Future Inventory and Monitoring

The dispersed campsite inventory undertaken by ODF provided a good baseline for data on the general conditions and locations of dispersed campsites in the watershed. The sample of sites reassessed for this analysis indicated that many of

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[67] Leave No Trace guidelines can be found online at www.lnt.org.

the impacts reported by ODF were underestimated and/or were subjective measures that lack numeric values (refer to Table 26).

7.5.11.1 Recommendations

- Use a set of metrics for future inventory and monitoring that provides more accurate and quantifiable data. We recommend that the USFS campsite monitoring protocol[68] be used.
- Update the current ODF dispersed campsite inventory form. The metrics listed in Table 52 could be added and adjusted for greater utility in future monitoring and assessment projects.

Table 52. Recommended ODF dispersed campsite inventory form changes. Note: the presence of a question mark indicates that the inclusion of this field's measurement/metric is open ended.

Form field	Measure/Metric	Changes
Site Characteristics	ODF index *? = open ended*	Recommended upgrade
site code	FG### or TL###	
GPS	lat, long, altitude	
Dimensions	In feet (XbyY)	***DA 0,1,2,3 & Sq feet
Number of access roads	#	Mgt or social
Forest canopy	open/closed	% closed
surface type	veg type	FGI see below*
logging landing or draft road	?	Active landing/road
multiple campsites	?	#
fire pits	?	#
Trail access? name/type	?	
Water access?	?	
Distance in ft	?	actual distance in feet
Water body name	?	
Access (social) Trails	?	#
Site improvements	?	
effectiveness comments	?	ineffective, partially effective, effective
Photos & Reservations of access	?	
Site Use Info.	Check all that apply	
day use or overnight use		
target shooting		
swimming		
fishing		
pit riding		Rename "OHV use" & add type (4wd, mc, quad)
other		
Human Impacts	Check all that apply	
Litter/garbage		

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[68] Recreation Site Monitoring Procedures and Protocols: David Cole, Aldo Leopold Wilderness Research Institute.

Form field	Measure/Metric	Changes
Road damage Dumping Fire hazards human waste erosion soil compaction water quality issue vehicle damage streamside damage tree damage firewood gathering number of affected trees		Access road damage Sediment delivery to stream Regular or OHV Impacts <25 ft of stream TD**+ damaged and undamaged tree count within campsite
Comments *other impacts, largest impact* *Overall impact*	Low, mod, high, very high	Use total score from adding FGI + TD + DA

*Frissell Ground Cover Impact **(FGI)**	1 – Ground vegetation flattened but not permanently injured	2 - Ground vegetation worn away in activity center	3 – Ground vegetation lost on most of the site	4 – Bare mineral soil widespread, exposed roots	5 – Soil erosion obvious, trees reduced in vigor or dead
Tree Damage **(TD)	0 – No more than 3 severely damaged trees.	1 – 4 to 10 severely damaged trees.		2 – More than 10 severely damaged trees.	
***Disturbed Area **(DA)**	0 – No more than 25 m^2 (0-250 ft^2).	1 – 26 to 100 m^2 (251 – 1,000 ft^2).	2 – 100 m^2 to 1,000 m^2 (1,000 ft^2 to 10,000).	3 – More than 1,000 m^2 (more than 10,000 ft^2).	

- Future monitoring protocol to address tree damage could include additional data gathering to produce better accuracy and enhance long term monitoring of impacts on riparian vegetation. If time and staff are available, additional data on tree damage could be gathered by census of trees within the site boundary to account for existing density, % damaged and severity of damage. Below is a USFS example of monitoring protocols for this level of data collection for campsites (Glidden 2005)[69]

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[69] Glidden, N. 2005. Impact Indicators and Methodology for Wilderness Campsite Inventory and Monitoring Unpublished report from Dixie National Forest, US Forest Service. May 2005 (provided by Jeffery Marion, Virginia Tech).

> If long term LW recruitment impacts from dispersed camping become a concern, species data should also be collected.

Marion and Cole (1996)[70] recommend all trees within the boundaries of the campsite area be censused according to these criteria. Trees <4.6 feet (<140 cm) tall but at least 0.5 years old should be counted as tree reproduction. Trees >4.6 feet (>140 cm) tall be classified and counted as either damaged by humans (e.g., nails, broken branches, trunk scars) or undamaged by humans. Felled trees (tree stumps) should also be counted.

Table 53. Example of USFS Tree Damage Monitoring Protocol.

Damage	Categorical Rating	Numerical Rating	Notes
Tree Impacts or mutilations	Percent Tree Damage (On-site)	(0-5%, 6-25%, 26-50%, 51-75%, 76-100%)	Determine the percentage of trees within the site's boundary that have visual damage that can attributed to human use and record the appropriate attribute choice on the data sheet or in the GPS.
	Percent Tree Damage (Site related)	(0-5%, 6-25%, 26-50%, 51-75%, 76-100%)	Determine the percentage of trees in and around the site that have visual damage that can attributed to human use of the site and record the appropriate attribute choice on the data sheet or in the GPS.
	Number of Damaged Trees (On-site)	(No trees, No damage, broken branches/1-2 scarred tree, 3-7 scarred trees, >7 scarred trees/# of trees) or (Number of damaged trees)	Determine the amount of trees within the site's boundary that have visual damage that can attributed to human use and record the appropriate attribute choice or number on the data sheet or in the GPS.
	Number of Damaged Trees (Site related)	(No trees, No damage, broken branches/1-2 scarred tree, 3-7 scarred trees, >7 scarred trees/# of trees) or (Number of damaged	Determine the amount of trees in and around the site that have visual damage that can attributed to human use of the site and record the appropriate attribute choice or number on the

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[70] Marion, J. and D. Cole. 1996. Spatial and temporal variation in soil and vegetation impacts on campsites. *Ecological Applications,* 6(2):520-530.

Damage	Categorical Rating	Numerical Rating	Notes
		trees)	data sheet or in the GPS.
	Number of Damaged Trees and Severity of Damage.	(Number of trees damaged in each classification: Slight, Bad, Felled)	Determine the amount of trees within the site's boundary that have visual damage that can attributed to human use and record the number of trees in each category of damage on the data sheet or in the GPS.
	Percent Canopy Cover (Rapid Inventory)	(0-25%, 26-50%, 51-75%, 76-100%)	Estimate percent cover by mentally "lumping" the canopy cover on the site into one part of the site and record the appropriate attribute range on the data sheet or in the GPS. Note: Remote sensing may be used in some cases to determine canopy cover of a site.

7.5.12 Effectiveness of Recent (post-1994) Recreation Site Upgrades

ODF recreation staff have undertaken the monumentous job of trying to mitigate years of unrestricted and damaging recreational impacts while not having adequate or comprehensive inventories of the areas needing attention. Districts have enlisted volunteers, secured grants and in-kind services and developed considerable capacity to manage the heavy demand placed on the forest by recreation users and events. Heavy year-round use, too many events, and eroding trails and sites, however, still outstrip ODF's capacity to effectively manage and mitigate impacts to the watershed.

7.5.12.1 General Recommendations

- Drastically reduce the event schedule until the trail system is better mapped, mitigated and under control.
- Close the forest completely to OHV use in the winter.
- For OHV events, stop using trails that exhibit the washout risk indicators identified by this analysis (refer to section 7.5.8 Overall Condition of OHV Trails and 7.5.9 High Priority Trail Segments, above).

- Introduce a minimum annual number of hours OHV clubs must volunteer on trail work before they can hold an event, preferably on the route they wish to use.

- Introduce and enforce an event bond to repair and upgrade failing trails.

7.5.12.2 OHV site upgrades

Key staging areas such as Rogers camp, Brown's camp and Jordan Creek have been successfully upgraded within the campsite or day-use area boundaries. However, outside those boundaries, efforts to mitigate impacts have been much less effective, not consistent and not monitored or maintained. ODF staff and volunteers have undertaken repair work on a variety of different sites often using differing techniques. Results have been mixed and many mitigation attempts have been ineffective at stopping or reducing the worst impacts.

7.5.12.1.1 Recommendations

- Step up enforcement, trail patrol and signage efforts to help educate OHV users about appropriate behavior, trail etiquette and places to ride.

- Close or treat satellite staging areas with the same site hardening and delineation techniques used at the main OHV sites.

7.5.12.3 OHV Trail System upgrades

A significant proportion of the trail system is built on legacy pre- and post-fire logging roads, skids trails and fire breaks. These were all placed during a period of forest management where environmental (Forest Practices Act) standards were undeveloped or absent. Future use of the network for OHV recreation was not anticipated but OHV users have "adopted" this network and continue to do so today, long after the roads were closed. Mitigation of eroding trails, poor drainage areas and inappropriate location cannot realistically be carried out until the trail system is rationalized back to a more manageable level. Some upgrades of popular designated trail segments are progressing but the work load is not currently matched by the staffing capacity. Undesignated trails receive the least attention but still get heavily used and may be seriously impacting water quality.

OHV use is increasing in spite of higher gas prices and travel distances, meaning increased and sustained OHV use can be expected across the watershed. Furthermore, club membership is dropping leading to fewer opportunities for young and new users to learn appropriate behaviors and to be involved in volunteerism.

7.5.12.1.1 Recommendations

- Place a moratorium on new trail construction until the existing system is inventoried, upgraded and reduced to a more manageable size.
- Institute a monitoring program to assess the effectiveness of upgrade projects and the rate of degradation.
- Institute a "Closed Unless Posted Open" policy for trails to limit the use of unrestrained riding through the forest and on undesignated trails or in riparian areas.

7.5.12.4 Dispersed campsite upgrades

ODF Recreation staff have attempted site improvement at 22% (n=43) of the sites to mitigate or prevent user impacts. Of those sites, 44% were rated by ODF recreation technicians as effective, 37% as partially effective and 18% as ineffective. During the site improvement survey, an ODF technician suggested a range of management actions useful in guiding future efforts. Improper vehicle access and pit riding by OHVs, however, remain the two biggest factors in failed improvements. Persistent re-entry and unblocking of closed access trails requires more robust measures to be effective. OHVs were consistently listed as factors associated with site upgrades that were rated as ineffective or partially effective, and, therefore, OHV access should be targeted.

An example of recent progress on a larger scale addressing this issue is the Wilson River Vehicle Management Plan (ODF Internal draft 2/2007). ODF staff recommend a number of actions based on the Wilson River Corridor Dispersed campsite inventory. The strategy chosen by ODF, however, appeared to be the least aggressive option, which past experience and this analysis have shown to be ineffective.

Recreation management principles caution that whatever conditions are tolerated will become the normally accepted mode of operation. Dispersed campsite impacts that have occurred across the watershed for the last two decades may have set up an expectation among users that ODF accepts the high impacts and poor conditions. Allowing this expectation to continue makes future recreation site upgrade/mitigation work less likely to succeed and be appreciated or respected by users.

7.5.12.1.1 Recommendations

- Overhaul and tighten the dispersed camping rules on the forest to better announce and enforce impact-related regulations.
- Develop an overnight camping fee permit to obtain user data, revenue and establish a "point of sale" opportunity for an education program to

inform dispersed campers of appropriate behaviors including OHV use, waste disposal, firewood selection and live tree protection.

- Apply trenches, boulders, root wads and fences (in combination) to more effectively block OHV and other vehicles from going beyond access blockades. A series of campsites along Cedar Creek have successfully received this kind of robust and effective upgrade (see Photographic Plate 24 for an example of an effective barrier). The target sites for this action are listed below in Table 54.

Table 54. High priority dispersed camping sites recommended for upgrade or closure based on ODF-recorded human impact ratings of “High/Very High” (n=62).

Site Code	Human Impact Comments	Overall Impact
TL008	Largest impact: pit riding.	Very High
TL016	Largest impacts: garbage, access road next to stream with no buffer.	Very High
TL019	Largest impact: stream running through site, carrying sediment and garbage directly into W. Fork Wilson River.	Very High
TL032	Largest impacts: heavy use, garbage dumping, and unmanaged OHV trail.	Very High
TL033	Largest impact: dumping of large items.	Very High
TL040	Largest impact: campsite on cliff over stream with no buffer.	Very High
TL050	Largest impacts: heavy use, vehicular erosion and rutting, and unnecessary road network.	Very High
TL051	Largest impacts: draft road to Wilson River, fire ring under high water mark, heavy use, vehicular erosion and rutting, and unnecessary road network.	Very High
TL052	Largest impacts: hazard trees, heavy use, vehicular erosion and rutting, and unnecessary road network.	Very High
TL061	Largest impacts: road to site crosses small stream and also provides unsecured access to the back of the forestry center. In addition, severe tree damage.	Very High
TL067	Largest impact: heavily rutted road with direct sediment drainage into river. Also, heavy use as a party spot with lots of garbage.	Very High
TL068	Largest impact: heavily rutted road with direct sediment drainage into river. Also, heavy use as a party spot with lots of garbage.	Very High
TL069	Largest impact: water traveling down road, pooling in camp site, and draining with sediment directly into river. Heavy use site.	Very High
TL070	Largest impacts: no buffer to stream, garbage. Safety issue: fire ring only a few feet from cliff being undercut by stream.	Very High
TL071	Largest impact: small stream running through campsite carrying sediment.	Very High
TL072	Largest impact: no buffer to stream.	Very High
TL076	Largest impact: 2 fire rings directly next to stream.	Very High

Site Code	Human Impact Comments	Overall Impact
TL077	Largest impacts: lots of garbage, no buffer to stream, heavy use.	Very High
TL081	Largest impact: no buffer on steep bank to stream and waterfall.	Very High
TL092	Largest impacts: garbage, human waste, tree damage, OHV riding, little buffer to creek.	Very High
TL104	Highest impact: erosion and severe rutted condition of access roads.	Very High
TL105	VERY HIGH IMPACT: 4wd tracks crossing creeks in at least 3 places. Road drainage not functioning. Deeply rutted meadow and unmanaged OHV access to forest. High volume of garbage.	Very High
TL117	Highest impact: fire rings under high water mark; camping right next to active salmon spawning stream. Also, plenty of garbage.	Very High
TL119	Largest impacts: heavy use, no buffer to stream, damaged trees, garbage.	Very High
TL128	Largest impacts: major access road rutting from vehicle traffic.	Very High
TL147	VERY HIGH IMPACT: severe rutting from vehicle traffic. Extensive section of road and campsite were flooded. Draft road provides OHV access to river bed.	Very High
TL148	Largest impact: access road and campsite on cliff edge above stream with no buffer. Also, can park on stream's edge because of draft road.	Very High
TL150	Largest impact: campsite on cliff's edge over stream at end of draft road. Safety concern.	Very High
TL126	Largest impacts: close proximity to stream and garbage.	High
FG029		High
FG039	largest impact = user created trails and mud pits	High
FG053		High
FG070		High
FG073	Largest impact = motorized user-created trail network	High
FG074	Lots of user created motorized trails surrounding the site.	High
FG092	Lots of garbage. Heavy amounts of tree damage. A little streamside erosion occurring.	High
FG101	Ax marks in trees. Many user created hiking and OHV trails on North side of site	High
TL009	Largest impact: pit riding.	High
TL011	Highest impact: fire ring under high water mark.	High
TL012	Highest impact: easy vehicle access to stream on legacy draft road.	High
TL024	Largest impact: 2 OHV access paths.	High
TL030	Largest impact: < 25 ft. from stream, heavy use.	High
TL039	Largest impact: heavy use.	High
TL041	Largest impacts: damaged trees, garbage, draft road access to streamside.	High
TL046	Largest impacts: unnecessary road network.	High
TL049	Largest impacts: heavy use, vehicular erosion and rutting, and unnecessary road network.	High
TL054	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High

Site Code	Human Impact Comments	Overall Impact
TL055	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL056	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL057	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL058	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL059	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL060	Largest impacts: garbage, access to 2 unmanaged motorcycle trails up the creek drainages.	High
TL087	Largest impacts: garbage, vehicular rutting.	High
TL096	Highest impact: heavy use and close proximity to stream.	High
TL097	Largest impact: heavy use, close proximity to stream, and OHV trails.	High
TL101	Largest impact: garbage and highly rutted condition of access road.	High
TL103	Largest impacts: unbuffered access to stream and garbage.	High
TL107	Largest impact: access to multiple unmanaged OHV trails.	High
TL112	Fire hazard: nearby slash piles. Largest impact: pit riding.	High
TL139	Other impacts: large amount of spray-paint graffiti on trees and boulders, as well as carved graffiti on trees.	High
TL156	Largest impacts: no buffer to stream, damaged trees.	High

8 Water Quality

8.1 Introduction

The 2001 Wilson River Watershed Assessment (E&S Environmental Chemistry 2001) provided an extensive analysis of water quality conditions in the Wilson River watershed. The purpose of this current effort is to briefly summarize the findings of the 2001 assessment to answer the OWEB critical questions, updating the existing information as appropriate with new data available from the intervening five years.

The primary focus of the current effort is to evaluate current and likely historic stream shading conditions along the principal streams within the Wilson River watershed, and to assess water temperatures within the forested portion of the basin. The effects of dispersed recreation upon water quality are discussed in the Recreation portion of this assessment.

8.2 Water Quality Criteria, Limited Sections, and Status

The conclusions of the 2001 Wilson River Watershed Assessment (E&S Environmental Chemistry 2001) were that, based on the frequency of exceedance of the evaluation criteria, water quality in the major streams of the Wilson River watershed would be considered impaired for temperature, nitrogen, bacteria, and (in the lower reaches of the river near the mouth) dissolved oxygen. The authors concluded that there was no reason to suspect impairment with respect to pH, total phosphorus concentration, turbidity, or trace metals; and that there was insufficient data to make a determination with respect to organic contaminants.

The federal Clean Water Act (CWA) requires that states maintain a list of water bodies that are “water quality limited,” i.e., do not meet water quality standards. The listing of water quality limited streams is referred to as the “303(d) list.” In Oregon, the Department of Environmental Quality (ODEQ) is responsible for maintaining the state’s 303(d) list. The ODEQ periodically revises the 303(d) list.

Temperature and bacterial contamination issues have been addressed as part of the Tillamook Bay Watershed Total Maximum Daily Load (TMDL), completed by the Oregon Department of Environmental Quality (ODEQ 2001). Consequently, the stream segments identified on the 1998 303(d) list for temperature (the Wilson River mainstem from the mouth to the confluence with the South Fork), and bacteria (the Wilson River mainstem from the mouth to the confluence with Little North Fork) have been removed from the 303(d) list.

The 2002 303(d) list included the Wilson River from river mile 3.5 to 10.1 (Highway 101 to the confluence with Little North Fork) as water quality limited for Dissolved Oxygen, for the September 15 - May 31 period, impacting salmonid fish spawning.

The latest iteration of the 303(d) list was prepared as part of ODEQ's 2004/2006 Integrated Report, which was approved by the U.S. Environmental Protection Agency (EPA) Region 10 office on February 26, 2007. Currently the Wilson River, RM 5.8 to 27.2 (approximately 4 miles downstream of the confluence with Little North Fork to Lee's Camp), is listed as water quality limited for dissolved oxygen for the period September 1 - June 15 (Table 55).

Table 55. Current 303(d) list status of streams within the Wilson River watershed. All records are for Dissolved Oxygen; all were added in 2004.

Location	Season	Criteria	Beneficial Uses	Status	Supporting Data
Wilson River, RM 0 to 3.5	Year Around	Estuarine: Not less than 6.5 mg/l	Estuarine water	Attaining some criteria/uses	ODEQ/ODA LASAR[71] database
Wilson River, RM 0 to 5.8	Year Around (Non-spawning)	Cold water: Not less than 8.0 mg/l or 90% of saturation	Cold-water aquatic life	Insufficient data	ODEQ/ODA LASAR database
Wilson River, RM 3.2 to 5.8	October 15 - May 15	Spawning: Not less than 11.0 mg/L or 95% of saturation	Salmon and steelhead spawning	Insufficient data	ODEQ/ODA LASAR database
Wilson River, RM 5.8 to 27.2	September 1 - June 15	Spawning: Not less than 11.0 mg/L or 95% of saturation	Salmon and steelhead spawning	Water quality limited, 303(d) list, TMDL needed	ODEQ/ODA LASAR database
Wilson River, RM 5.8 to 34.5	Year Around (Non-spawning)	Cold water: Not less than 8.0 mg/l or 90% of saturation	Cold-water aquatic life	Attaining some criteria/uses	ODEQ/ODA LASAR database
Wilson River, RM 27.2 to 34.5	October 15 - June 15	Spawning: Not less than 11.0 mg/L or 95% of saturation	Salmon and steelhead spawning	Insufficient data	ODEQ LASAR database

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[71] Laboratory Analytical Storage and Retrieval (LASAR) database

8.3 Stream Shading

8.3.1 Distribution of Effective Shade

8.3.1.1 Methods

Stream shading was estimated as the combined function of riparian vegetation, topography, and active channel widths (i.e. *effective shade*) for the current and potential future conditions[72] (50- and 100- year scenarios). Our approach in estimating future effective shade levels assumed no management within riparian areas. Future riparian stand conditions (i.e., years 2056 and 2106) were modeled using the Pacific Coast variant of the Forest Vegetation Simulator (FVS) as described in section 6.2.1 above.

Effective shade values were estimated using the HeatSource version 7.0 temperature model (Boyd and Kasper 2003). Effective shade was estimated within a GIS using the ArcView 3.x TTools extension[73]. Input data is assembled within T-tools at sampling points located along a given stream. Sample data was assembled at a 100-meter interval along 12 principal streams in the Wilson River watershed. Location elevation, channel gradients, and topographic characteristics were calculated using the finest-resolution DEM available (i.e., 1/3 arc-second; ~7.3 meter)[74]. Active channel widths were associated with each shade sample point based on contributing drainage area, using the equations of Clarke and others (unpublished) and Lorensen and others (1994)[75].

The TTools extension was also used to sample riparian stand conditions, and assemble these data for evaluation within HeatSource. Several stand metrics are needed by HeatSource in calculating effective shade, these include stand height, canopy density, and canopy overhang. Values used for current (year 2006) and future (years 2056 and 2106) scenarios are given in Table 56. Values for all stand types were derived from SLI data (described in Chapter 6, section 6.1.3, Field Reconnaissance); with the exception of "unsampled forest" which were estimated using professional judgment.

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[72] The development of the potential future conditions is described in the riparian vegetation section of the assessment.

[73] http://www.deq.state.or.us/wq/tmdls/tools.htm

[74] http://seamless.usgs.gov/

[75] Estimating active channel width is discussed in detail in the Hydrology section of this report.

Table 56. Riparian stand metrics used in estimating effective shade. Values are for current (2006) and modeled future (2056 and 2106) conditions.

Year	Land Cover Name (optional)	Code	Height (m)	Density (%)	Overhang (m)
2006	Hardwood	1	31.7	89%	2.0
	Mixed – Conifer	2	35.6	89%	2.5
	Hardwood	3	31.2	89%	2.2
	Mixed – Conifer	4	38.5	89%	3.3
	Hardwood	6	33.8	89%	2.6
	Hardwood	8	31.0	66%	2.1
	Hardwood	9	30.3	89%	2.4
	Conifer	26	36.3	89%	3.4
	Unsampled Forest	100	33.6	25%	2.6
	Non Forest	999	10.0	1%	0.5
	Non Forest with Trees	101	24.5	5%	1.2
2056	Hardwood	1	45.4	89%	2.6
	Mixed – Conifer	2	46.2	89%	3.3
	Hardwood	3	45.4	89%	2.9
	Mixed – Conifer	4	46.7	89%	4.3
	Hardwood	6	44.9	89%	3.0
	Hardwood	5	45.6	89%	2.5
	Hardwood	34	45.3	89%	2.9
	Unsampled Forest	100	33.6	25%	2.6
	Non Forest	999	10.0	1%	0.5
	Non Forest with Trees	101	24.5	5%	1.2
2106	Hardwood	1	51.0	89%	3.2
	Mixed – Conifer	2	50.7	82%	4.2
	Hardwood	3	50.7	89%	3.1
	Mixed – Conifer	4	50.4	73%	5.3
	Hardwood	6	50.5	80%	3.6
	Hardwood	8	50.5	77%	3.2
	Hardwood	34	50.8	89%	3.5
	HW Mix transition to Conifer	12	50.4	80%	3.9
	Unsampled Forest	100	33.6	25%	2.6
	Non Forest	999	10.0	1%	0.5
	Non Forest with Trees	101	24.5	5%	1.2

8.3.1.2 Results

Current and potential future shade levels for the principal streams in the Wilson River watershed are shown in Figure 37 and summarized in Table 57. With the exception of the Wilson River mainstem, the sampled streams had high levels (>90%) of effective shade for all modeling scenarios. Modeled effective shade generally increases from the current (2006) condition to 2056, but declines over the following 50-year period in most of the streams.

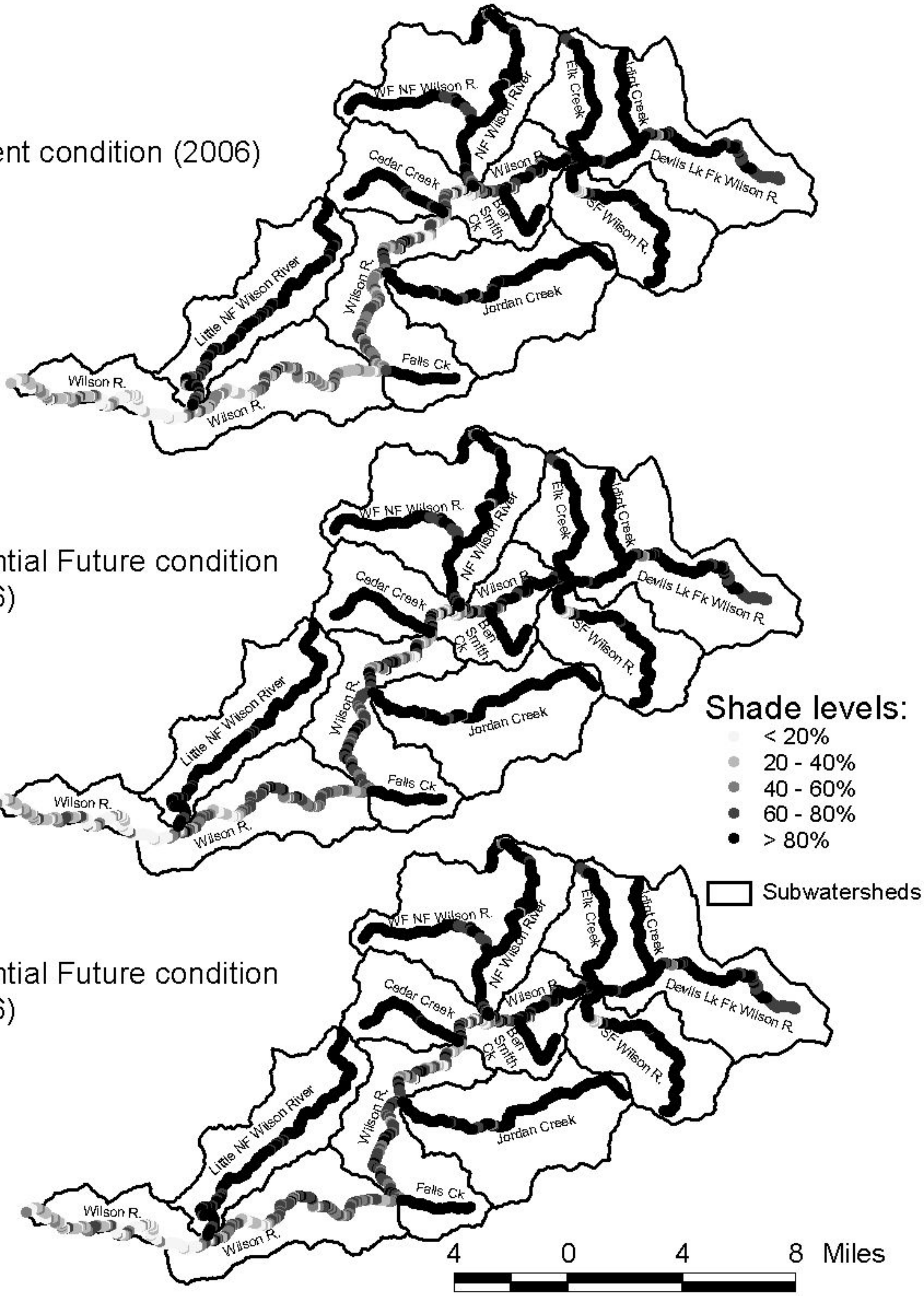

Figure 37. Current effective shade (top), and potential future shade conditions in 50 (middle) and 100 (bottom) years along principal streams, Wilson River watershed.

Table 57. Stream Shade Summary. Modeled average (minimum-maximum) effective shading (%) for 12 principal stream systems in the watershed in 2006 and projected 50 and 100 years in the future.

Stream	Current (2006)	Potential Future (2056)	Potential Future (2106)
Ben Smith	97% (95% - 98%)	98% (97% - 98%)	97% (96% - 98%)
Cedar	95% (69% - 98%)	97% (81% - 98%)	96% (80% - 98%)
Devils Lake Fork	86% (29% - 98%)	87% (29% - 98%)	86% (28% - 98%)
Elk	96% (68% - 98%)	96% (68% - 99%)	96% (68% - 98%)
Falls	96% (80% - 98%)	97% (96% - 98%)	97% (95% - 98%)
Idiot	97% (84% - 98%)	97% (85% - 99%)	97% (85% - 98%)
Jordan	95% (51% - 98%)	96% (54% - 98%)	96% (54% - 98%)
Little N. Fk. Wilson	90% (34% - 98%)	94% (63% - 98%)	93% (67% - 98%)
N. Fk. Wilson	94% (28% - 98%)	95% (28% - 98%)	95% (28% - 98%)
S. Fk. Wilson	93% (8% - 98%)	94% (8% - 98%)	94% (8% - 98%)
W. Fk. N. Fk. Wilson	91% (64% - 98%)	92% (65% - 98%)	91% (65% - 98%)
Wilson	47% (2% - 98%)	54% (2% - 98%)	55% (2% - 98%)

The largest and most widespread differences between current and potential shade scenarios were in the Wilson River mainstem. Overall, the Wilson River currently provides an average shade value of 47% as compared with 54% (2056) and 55% (2106) in the potential future conditions (Table 57). The largest differences occurred in the middle reaches (~RM 12-22); on ODF managed lands, the key opportunities for shade enhancement are between RM 20 and 30, approximately between the confluence of Jordan Creek and the North Fork Wilson River (Figure 37 and Figure 38).

Figure 38 illustrates the modeled changes in effective shade along the mainstem Wilson River. Values indicate the increases in effective shade that the potential future conditions would likely provide assuming no management. Areas with high values are likely areas for protection and passive restoration. Areas with no or only minor changes may be either fully functioning (in terms of shade), or have a natural or human-caused impediment to stand development; in either case they represent areas where enhancement opportunities could be investigated. Areas with negative or declining values represent areas where shade conditions are expected to deteriorate in the absence of active management.

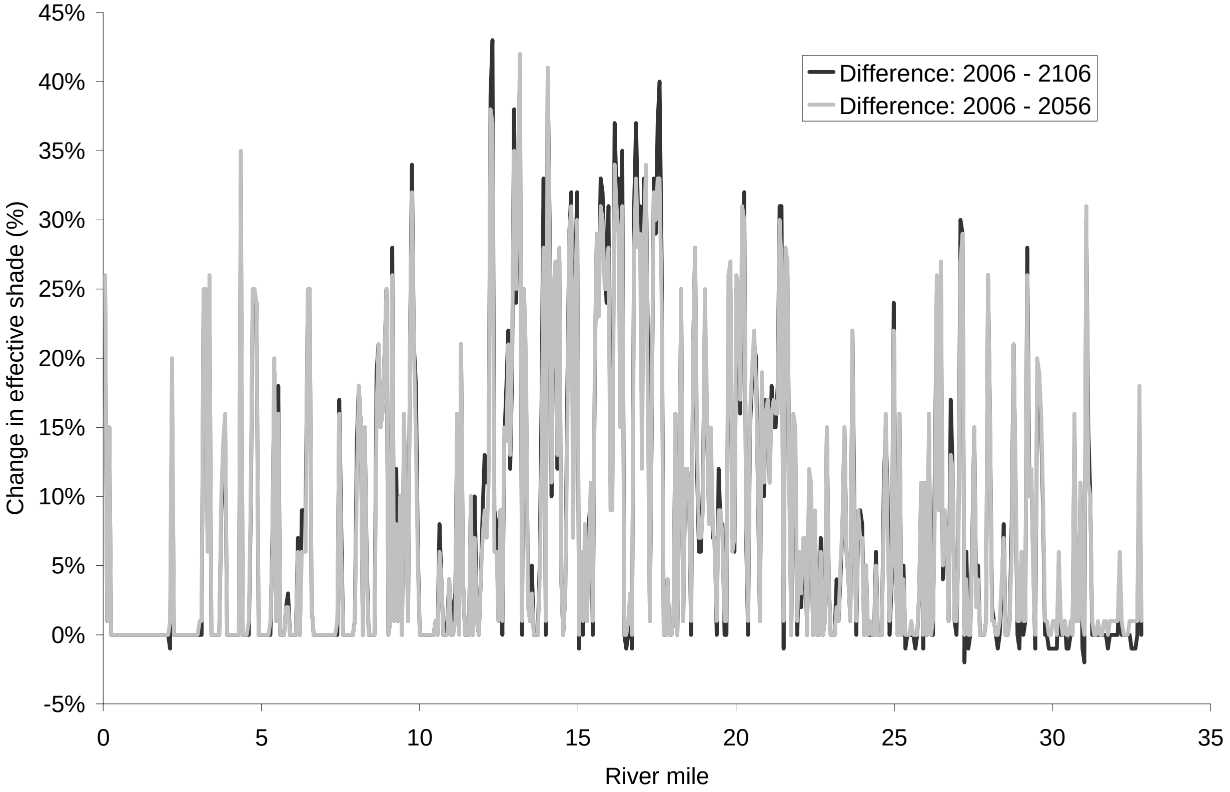

Figure 38. Changes in Effective Shade. The estimated changes in effective stream shading between the current (2006) and potential future (2056 and 2106) conditions for the Wilson River. Values indicate the increases in effective shade that the potential future conditions would likely provide assuming no management.

8.4 Stream Temperatures, Reasonable Achievable and Compared to Potential Levels

8.4.1 Methods

We conducted an analysis to evaluate what stream temperatures are reasonably achievable under natural conditions in the Wilson River watershed using empirical stream temperature data and site conditions for 24 monitoring sites in the Wilson River Watershed (Figure 39 and Table 58). Regression analysis was used to determine the relationship between the annual maximum seven-day moving average of the daily maximum water temperature ($\mathbf{T_{max}}$)[76] and the environmental variables most likely to affect water temperatures. The variables considered in the regression analysis were:

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[76] OAR 340-04l-0006 (54) defines the numeric temperature criteria as the seven-day moving average of the daily maximum temperatures.

- ***Solar radiation.*** The seven-day moving average of total solar radiation received (in Langleys) at the Forest Grove Agrimet climate station[77] on the day of the annual $\mathbf{T_{max}}$.

- ***Streamflow index***. The flow exceedance percentile[78] (expressed as a decimal) for mean daily streamflow at the Wilson River USGS stream gage on the day of the annual $\mathbf{T_{max}}$.

- ***Air temperature***. The seven-day moving average of daily maximum air temperature (degrees F) at the Tillamook 1W weather station[79] on the day of the annual $\mathbf{T_{max}}$.

- ***Site elevation (E).*** The elevation at the stream temperature monitoring site (in units of feet; determined from digital elevation model data)

- ***Effective shade (S).*** Average 2006 effective shade levels (expressed as a decimal) for the entire stream upstream of the temperature monitoring site. Values for effective shade calculated for the current condition (as discussed in the previous section, Stream Shading) were used in developing the initial regression equations.

- ***Distance from watershed divide (D).*** The final variable used in the regression analysis was distance from watershed divide (in units of miles). Distance from the watershed divide provides an index of the time that water has been exposed to ambient air temperatures. The implication is that streams that have a shorter distance to the watershed divide would be expected to have lower water temperatures

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[77] Data from the Forest Grove station were used because it is the only data set that covers the entire time period of stream temperature data. July and August total solar radiation values are well correlated ($r^2 = 0.85$; n=60, $p<0.00001$) with the short period of record available from the South Fork station which is located within the Wilson River watershed.

[78] Calculated using combined July and August mean daily flow values

[79] http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or8494

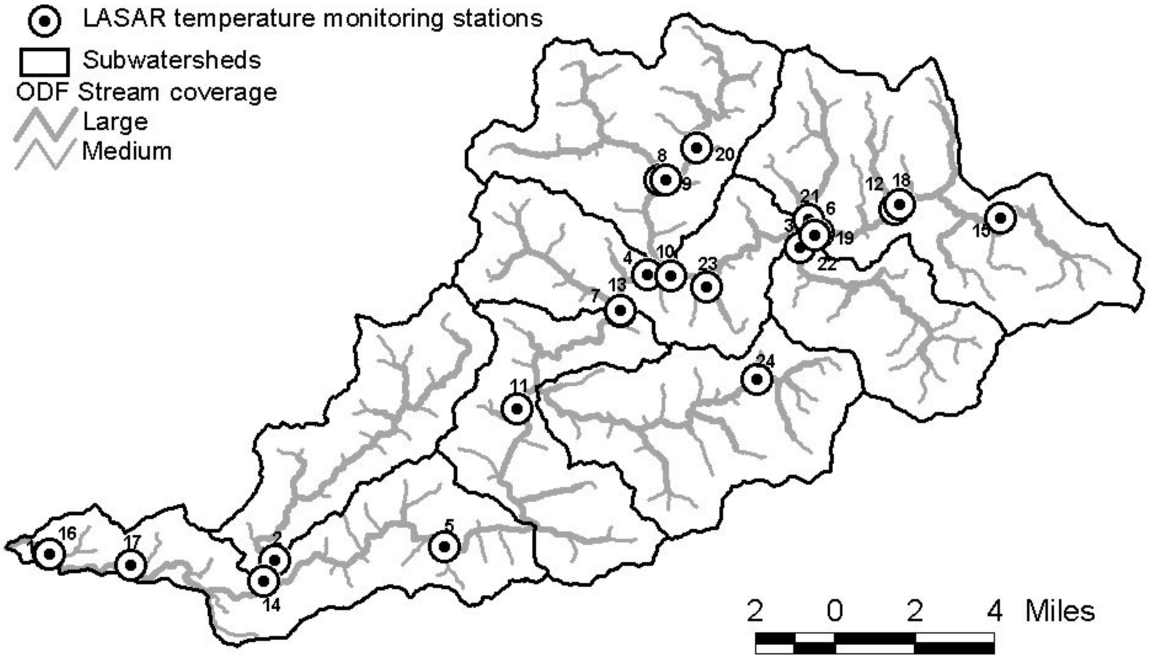

Figure 39. LASAR temperature stations within the Wilson River watershed.

Table 58. Site description and period of record for LASAR temperature monitoring stations in the Wilson River watershed.

Map ID	ODEQ ID	Description	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	10572	Tillamook Creamery (TCCA) outfall at Wilson River		a								
2	11845	Little North Fork Wilson River at River Mile 1.5			■							
3	12865	South Fork Wilson River at 1st bridge on South Fork	b									
4	12943	Wilson River downstream of North Fork Wilson River	■	■								
5	12944	Wilson River downstream of Kansas Creek	■									
6	12945	Wilson River downstream of Devils Lake Fork		■								
7	12946	Wilson River downstream of Cedar Creek	■	c		■						
8	12947	West Fork of North Fork Wilson River at mouth		■								■
9	12948	North Fork Wilson River upstream of West Fork Wilson		■								■
10	12951	Wilson River at Hwy 6 (Lee's Camp)	■	■		■						■
11	12952	Wilson River downstream of Jordan & Keening Creeks	■									
12	12954	Idiot Creek at mouth		■								
13	12956	Cedar Creek at mouth (to Wilson River)	■	■		■						
14	13027	Little North Fork Wilson River at mouth		■								
15	13102	Devils Lake Fork Wilson River at Saddle Mountain Rd		■								
16	13266	Wilson River Mid channel 100 feet upstream of TCCA		■								
17	13422	Wilson River at Sollie Smith Road (River Mile 3.5)		■								
18	20362	Devils Lake Fork Wilson River upstream of Idiot Cr		■								
19	20363	Devils Lake Fork Wilson River at mouth		■		■						■
20	20364	North Fork Wilson River 1.4 miles upstream of WFNF		■								
21	20365	Elk Creek upstream of Elk Creek Forest Park		■								
22	20366	South Fork Wilson River at mouth		■		■						
23	21811	Ben Smith Creek at River Mile 0.44			■	■	■	■		■	■	■
24	21812	Jordan Creek at River Mile 7.52			■			■				

a. Data not used; site is not a creek

b. Data not used; record didn't start until 9/2/1997

c. Data not used; record didn't start until 10/14/1998

8.4.2 Results

A stepwise approach was taken to eliminate those variable from the regression equation that were not statistically significant at the $p \leq 0.05$ level. Effective shade alone showed a significant ($p< 0.001$) relationship with maximum 7-day water temperature (Figure 40). Distance to watershed divide also showed a strong correlation with $\mathbf{T}_{\mathbf{max}}$ (Figure 41). However, when effective shade and distance to watershed divide were both included as variables, distance to watershed divide was no longer significant, due to the high correlation between effective shade and distance to watershed divide (Figure 42). Site elevation was also dropped from the final equation. The final form of the regression included the following variables:

- *Effective shade,*
- *Solar radiation,*
- *Streamflow index,* and
- *Air temperature*

Regression statistics for the final equation are presented in Table 59.

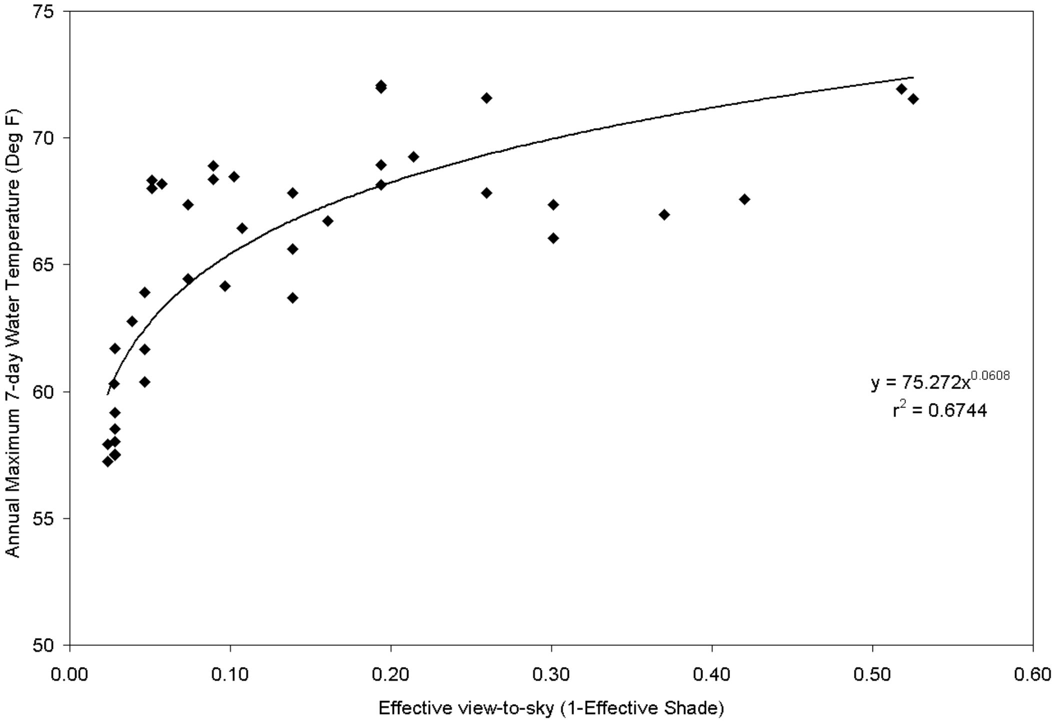

Figure 40. Relationship between annual maximum seven-day water temperature and effective shade. For this analysis effective shade was expressed as effective view to sky, which is 1 – effective shade.

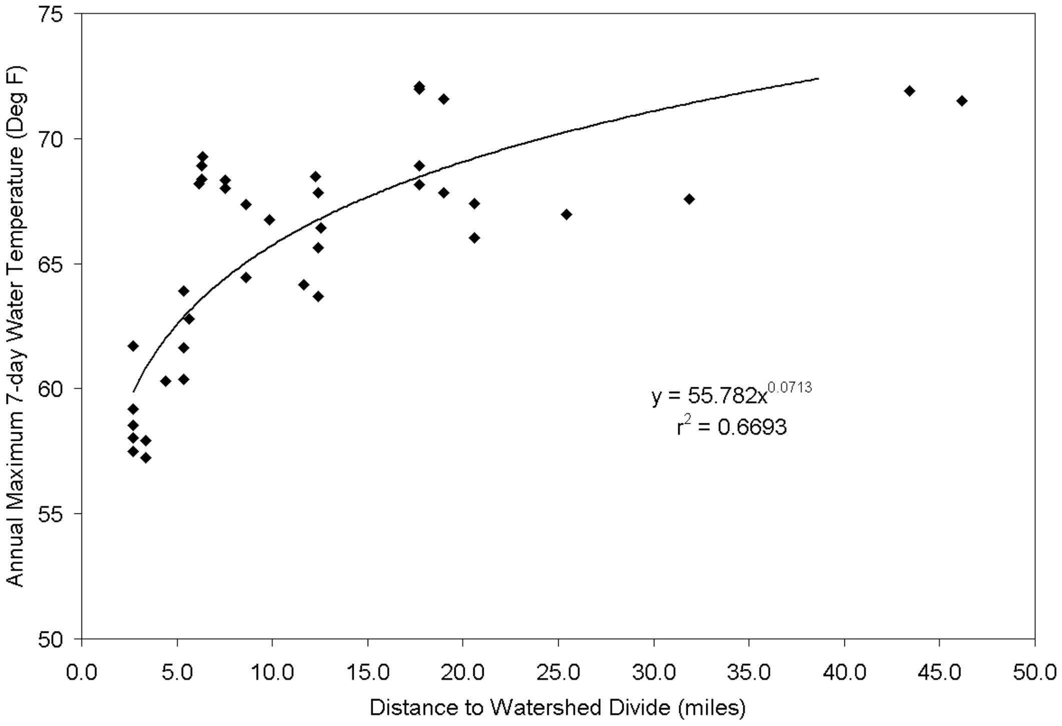

Figure 41. Relationship between annual maximum seven-day water temperature and distance to watershed divide.

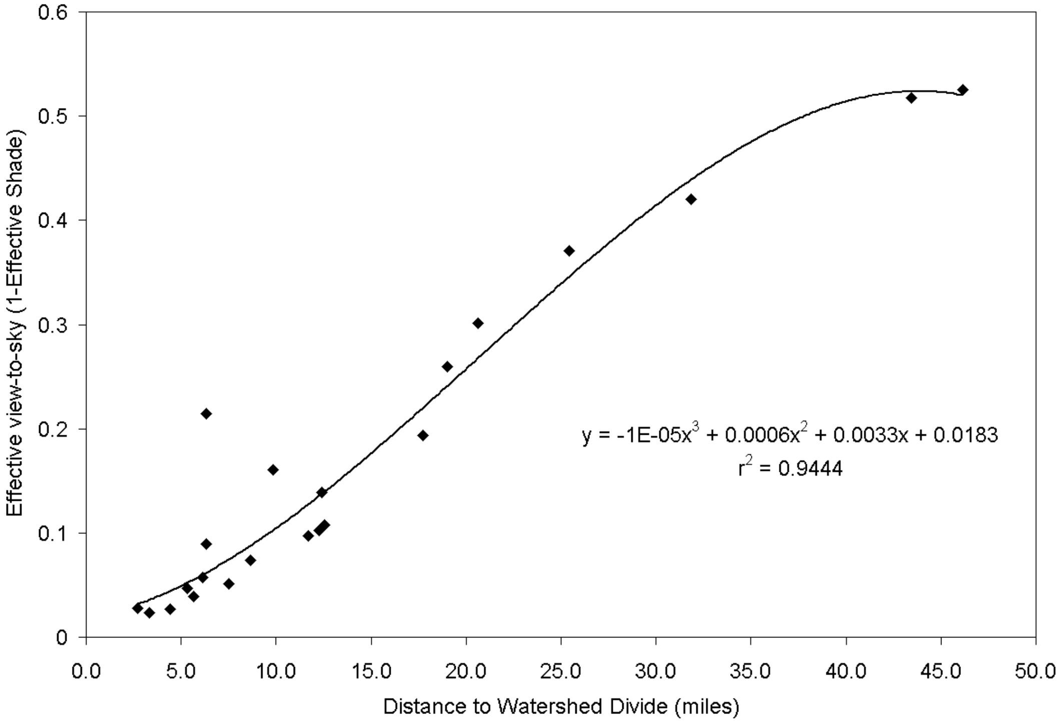

Figure 42. Correlation between distance to watershed divide and effective shade.

Table 59. Regression statistics for the Wilson River watershed temperature prediction equation.

Adjusted R Square		0.81067
Standard Error		1.99694
Observations		41
	Coefficients	P-value
Intercept	-370794.8517	4.575×10^{-13}
Effective shade (expressed as [1 – effective shade] $^{0.00001}$)	370809.4234	4.588×10^{-13}
7-day mean total solar radiation at Forest Grove	0.063000916	4.643×10^{-6}
Streamflow index	-13.47725843	0.000977
7-day average maximum air temperature	0.37536097	0.037709

We used the Wilson River temperature equation (Table 59) to evaluate the likelihood that stream temperatures and/or shade conditions are a limiting factor in the achievement of proper functioning condition among the principal streams found in the Wilson River watershed. Our approach was to estimate effective shade levels associated with current (2006) riparian conditions, and modeled conditions 50 and 100 years in the future (i.e., 2056 and 2106) while assuming no management within riparian areas. Only effective shade was varied among the modeling scenarios; values for solar radiation, streamflow and air temperature were held constant[80]. Effective shade values were estimated at 100-meter intervals along the principal streams. The Wilson River temperature equation was then used to estimate point $\mathbf{T_{max}}$ values along each principal stream.

Current and future $\mathbf{T_{max}}$ values were calculated at each 100-meter point along principal streams by substituting current and future effective shade values into the Wilson River temperature equation. Current and future $\mathbf{T_{max}}$ values for the mainstem Wilson River are shown in Figure 43 (top graph). Values are plotted from the river mouth upstream. Values for the mainstem Wilson River indicate a predicted ~ 1 degree Fahrenheit drop in temperature along the majority of the river from 2006 to 2056, with little expected change from 2056 to 2106. These scenarios assume no management of riparian stands. To better illustrate predicted changes in $\mathbf{T_{max}}$ values we also plotted the difference[81] between future and current values (Figure 43; bottom graph). The values in Figure 43 are typical for most streams; an overall decreasing trend in $\mathbf{T_{max}}$ values in an upstream

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[80] Average values were used for the days of observed T_{max} at the temperature monitoring locations within the Wilson River watershed.

[81] Future (2056 and 2106) $\mathbf{T_{max}}$ values – current (2006) $\mathbf{T_{max}}$ values

direction. However, some streams (e.g., Ben Smith Creek; Figure 44) had their lowest predicted $\mathbf{T_{max}}$ values occur in the middle portions of the stream. Longitudinal $\mathbf{T_{max}}$ profiles for all principal streams are provided in Appendix V – Longitudinal T_{max} Profiles for all Principal Streams

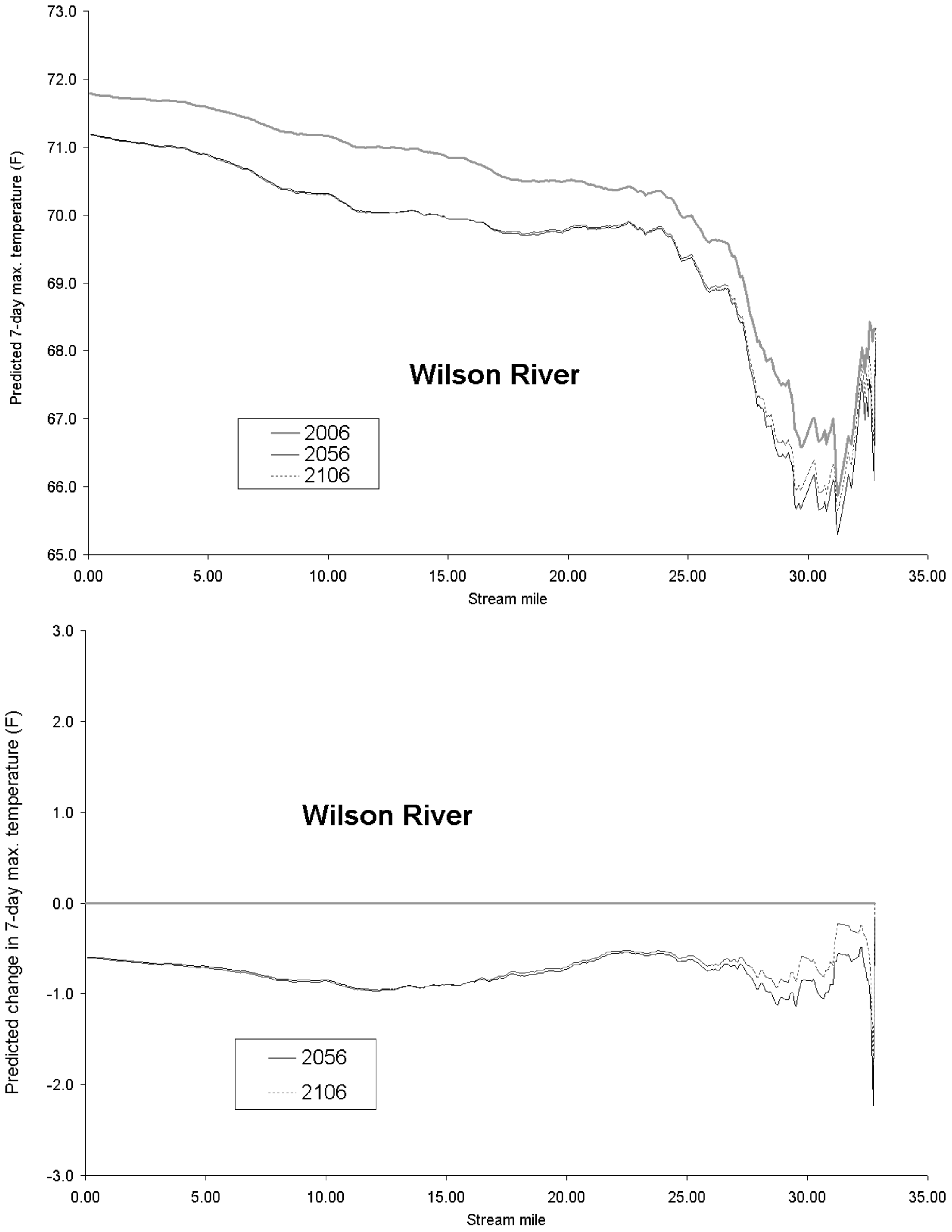

Figure 43. Longitudinal T_{max} profile, Wilson River mainstem. Top graphs shows predicted T_{max} values for current (2006) and future (2056 and 2106) scenarios. Bottom graphs shows difference between future and current scenarios.

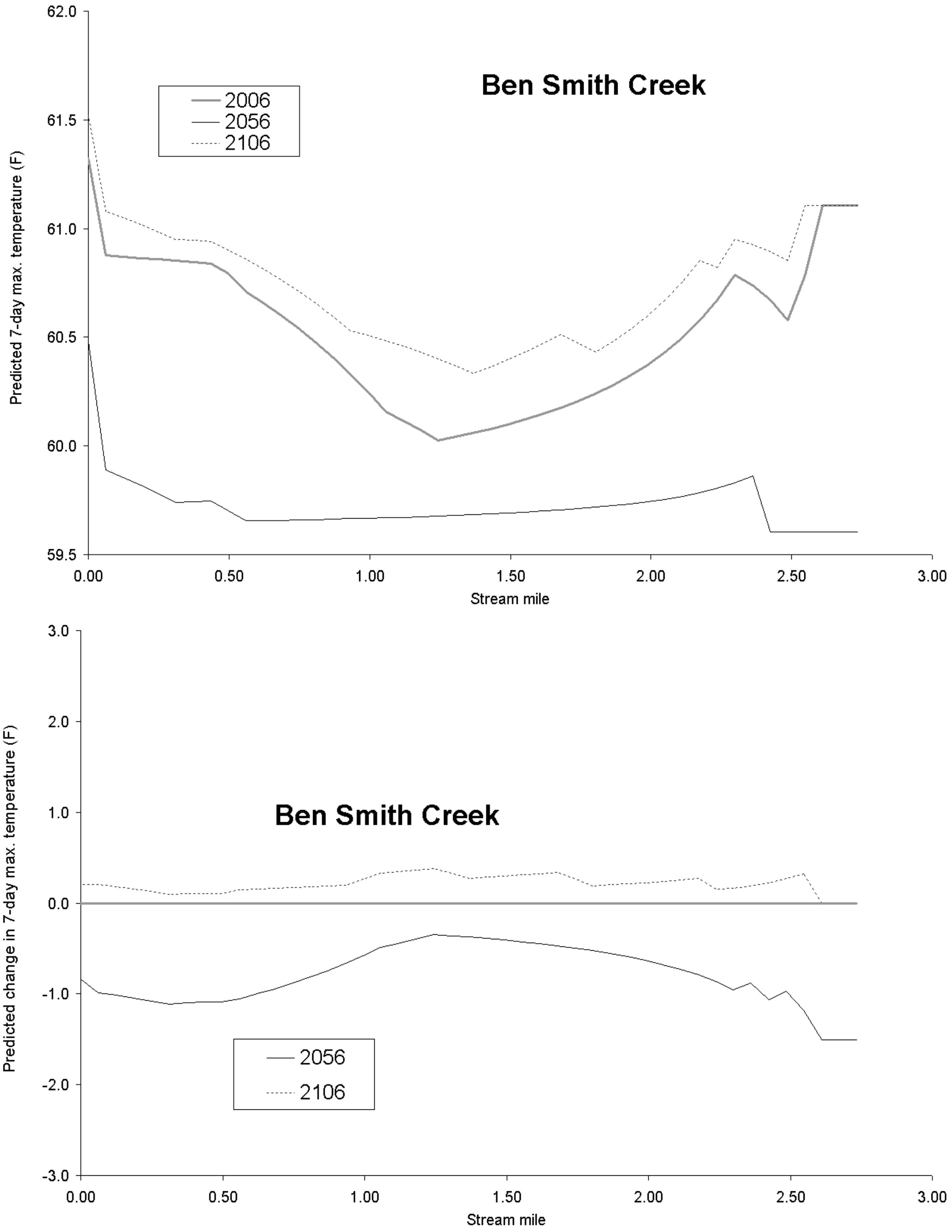

Figure 44. Longitudinal T_{max} profile, Bens Smith Creek. Top graphs shows predicted T_{max} values for current (2006) and future (2056 and 2106) scenarios. Bottom graphs shows difference between future and current scenarios.

Predicted changes between current and future $\mathbf{T_{max}}$ values are summarized in Table 60. Column one in Table 60 shows the average predicted change in $\mathbf{T_{max}}$ for the entire stream between 2006 and 2056; and column two shows the average predicted change between 2006 and 2106. Columns 3 and 4 in Table 60 show the largest point *decrease* in temperature for the two time scenarios within each stream (i.e., the largest at-a-point decrease in $\mathbf{T_{max}}$). Columns 5 and 6 show the largest point *increases* in temperature for the two time scenarios.

Table 60. Summary of predicted changes between current (2006) and future 2056 and 2106) T_{max} values..

	Mean T_{max} change for entire stream		Largest point decrease in T_{max} within stream		Largest point increase in T_{max} within stream	
Stream	**2006-2056**	**2006-2106**	**2006-2056**	**2006 - 2106**	**2006-2056**	**2006 - 2106**
Idiot Creek	-0.1	0.1	-0.2	0.0	0.0	1.5
WF NF Wilson	-0.5	0.6	-0.9	0.0	0.0	1.5
Ben Smith Cr	-0.8	0.2	-1.5	0.0	-0.3	0.4
Devils Lk Fk	-0.1	0.0	-0.1	0.0	0.0	0.0
Elk Creek	0.0	0.3	0.0	0.0	0.0	0.5
SF Wilson	-0.6	0.3	-1.3	-0.7	0.0	2.6
NF Wilson	-0.3	0.1	-0.9	-0.5	0.0	2.6
Cedar Cr	-0.7	0.1	-1.5	-1.0	0.0	1.5
Jordan Cr	-0.7	0.1	-1.4	-0.7	0.0	1.5
Falls Cr	-0.9	0.3	-1.5	-1.1	0.0	1.5
Little NF Wilson	-1.6	-1.2	-2.5	-2.3	0.0	0.3
Wilson River	-0.8	-0.7	-2.2	-1.8	-0.2	0.0

8.5 Stream Temperature Comparison with Adjacent Basins

8.5.1 Methods

We evaluated how water temperatures at sites in the Wilson River watershed compared to other nearby basins with similar flows climate and geology. The purpose of this assessment was to evaluate whether or not temperatures in the Wilson differ much from similar watersheds. Climate and geology are the two variables, independent of land use, that are most likely to affect summertime stream temperatures. We controlled for climate by limiting our comparisons to other watersheds in the North Coast area. We then identified watersheds in the

North Coast area that were similar to the Wilson River watershed in terms of underlying geology, and selected an area for comparison. Annual maximum 7-day temperatures were identified for each temperature site within the selected area, and distance to watershed divide was calculated for each site. Data were pooled with the Wilson data set, and annual maximum 7-day temperature as a function of distance to drainage divide was calculated for the pooled data set. Finally, residual variation in the data set was examined to see if results from the Wilson River watershed were similar to other North Coast sites.

8.5.2 Results and discussion

Geological information for the North Coast area was available from the USGS (Miller et al. 2003 [82] and Walker and MacLeod 1991). The principal lithologies for all fifth-field HUCs in the Wilson-Trask-Nestucca Basin were summarized (Figure 45). The adjacent Trask River watershed was most similar to the Wilson River watershed in terms of principal lithologies. The Trask watershed is also similar in size, and (given its adjacency to the Wilson) climate. Twenty temperature monitoring sites were identified in the Trask River watershed (Table 61 and Figure 46). Three sites had an insufficient record for three individual years, and were not used in the analysis.

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[82] http://geopubs.wr.usgs.gov/open-file/of03-67/

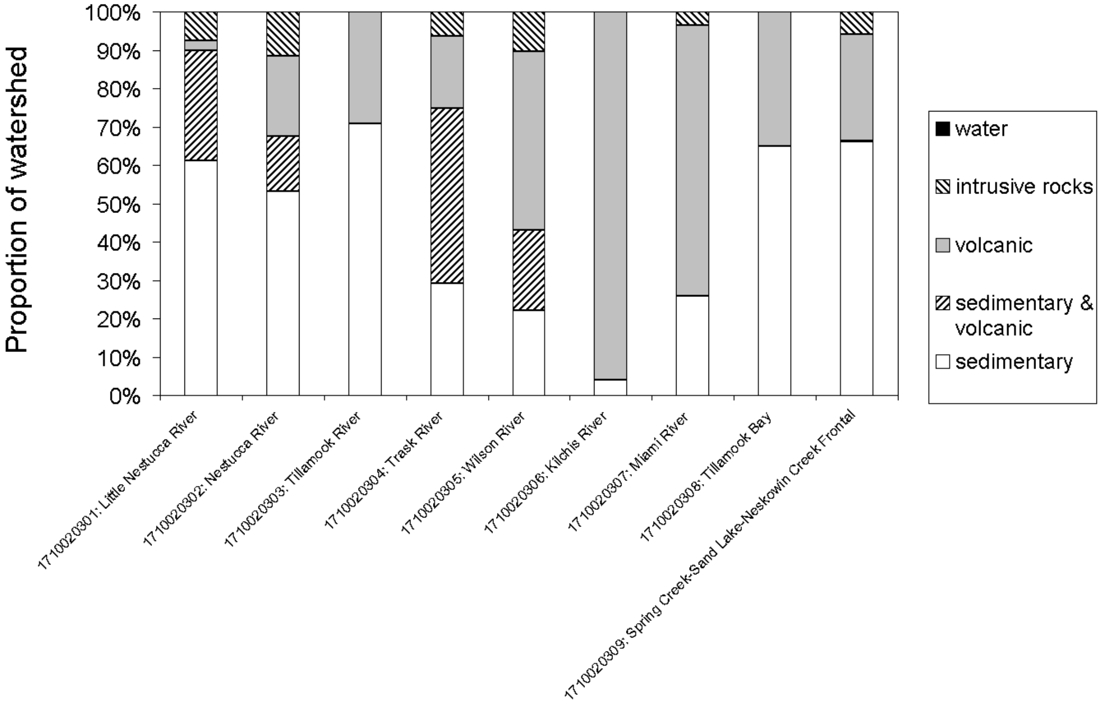

Figure 45. Summary of principal lithologic types for watersheds in the Wilson-Trask-Nestucca Basin. From Miller and others (2003).

Table 61. Site description and period of record for LASAR temperature monitoring stations in the Trask River watershed.

Map ID	Station ID	Description	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	12950	North Fork Trask River upstream of Bark Shanty Creek	a	■								
2	12957	Trask River at USGS Gage	■									
3	12958	Trask River at Trask River Fish Hatchery		b		■				c		■
4	12959	Trask River at Lower Trask Boat Ramp	■									
5	12960	South Fork Trask River at mouth	■	■								
6	12961	South Fork Trask River downstream of Bill Creek	■				■					
7	12962	South Fork Trask River downstream of Edwards Creek	■	■		■						
8	12963	North Fork of North Fork Trask River at mouth	■	■								
9	12964	North Fork Trask River downstream of Clear Creek	■									
10	12965	North Fork Trask River upstream of North Fork of North Fork Trask	■	■								■
11	12966	North Fork Trask River downstream of Bark Shanty Creek	■	■								■
12	12967	Mill Creek at Pot RR Bridge (Trask River)	■									
13	12968	East Fork of South Fork Trask River downstream of Rock Creek	■									
14	12969	East Fork of South Fork Trask River downstream of Steampot Creek	■									
15	12970	Bark Shanty Creek at mouth (North Fork Trask River)	■	■								
16	13478	Trask River upstream of milepost 11		■								
17	13479	North Fork Trask River at Trask River Rd. bridge		■		■						
18	16987	East Fork of South Fork Trask River at mouth		■								
19	23819	Clear Creek at River Mile 0.72 (North Fork Trask River)				■						
20	25324	Laughlin Creek, Trask					■					

a. Data not used; record didn't start until 9/3/1997

b. Data not used; record didn't start until 10/14/1998

c. Data not used; record didn't start until 8/31/2004

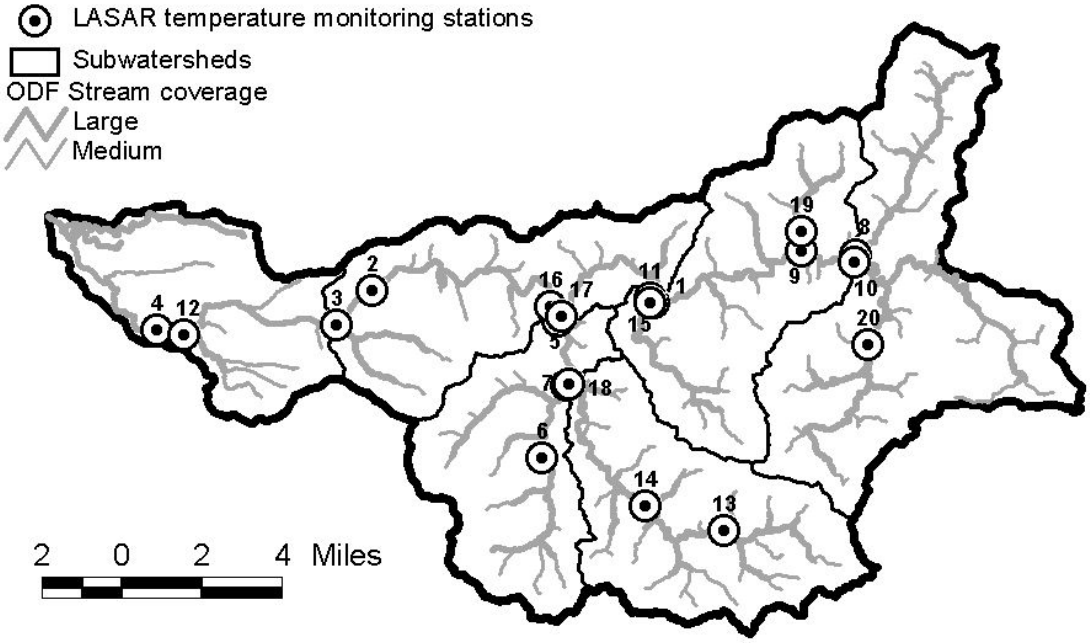

Figure 46. LASAR temperature monitoring sites within the Trask River watershed.

Figure 47 shows the relationship between distance to watershed divide and maximum 7- day water temperatures for the pooled Wilson River Trask River data sets. Distance from watershed divide accounts for approximately 2/3 of the observed variability in the data set. Figure 47 suggests that temperatures in the Trask watershed are lower than values in the Wilson watershed, at least up to approximately 20 miles from the drainage divide. This is also apparent in a plot of the residual variability (Figure 48). Results from a one-tailed t-test indicate that temperatures in the Trask are approximately 2 degrees F cooler than in the Wilson watershed ($p < 0.001$). Possible explanations for relatively lower temperatures in the Trask as compared to the Wilson include differences in riparian shading, due to more aggressive riparian harvest and/or greater riparian disturbance (e.g., flood damage); and cool-water reservoir releases (i.e., Barney Reservoir on the Middle Fork of the North Fork Trask).

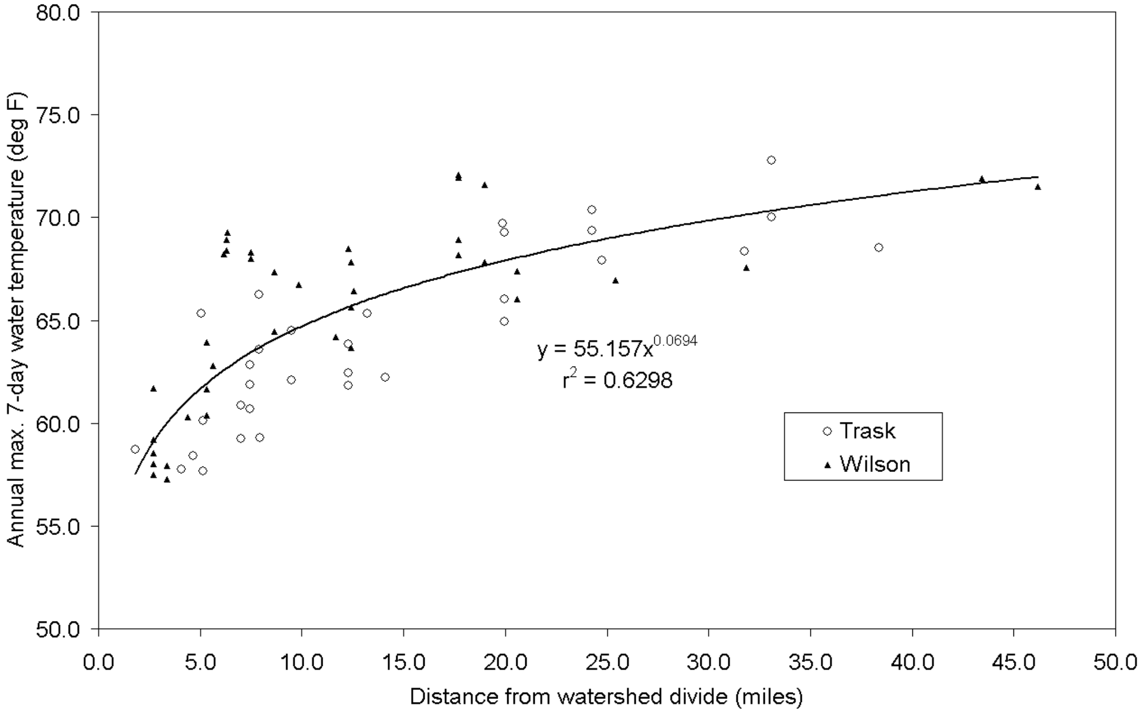

Figure 47. Relationship between annual maximum seven-day water temperature and distance to watershed divide for the pooled Wilson River / Trask River data sets.

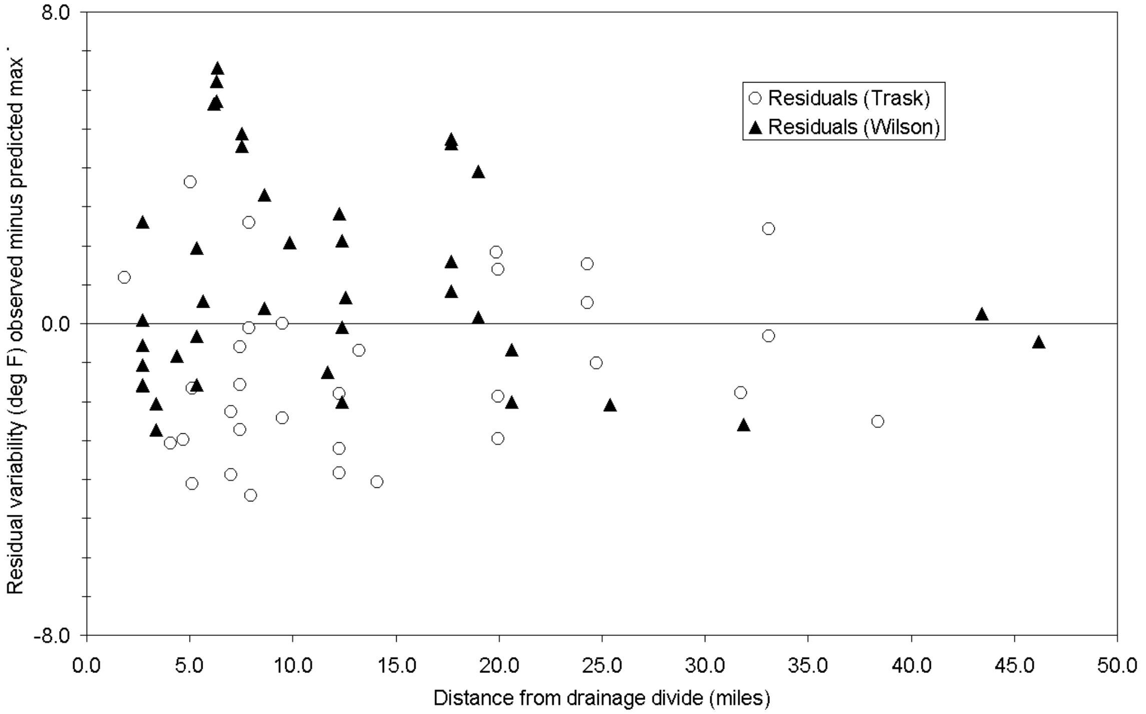

Figure 48. Residual variability from stream temperature regression model.

8.6 Limiting Factors

8.6.1 Stream Temperatures and Shade Conditions

We used the ODEQ "core cold water habitat use" criterion of T_{max} less than or equal to 60.8 degrees Fahrenheit (16.0 degrees Celsius)[83] as the metric to evaluate to what extent stream temperatures and/or shade conditions are limiting the achievement of properly functioning condition in the Wilson River watershed. All of the principal streams within the Wilson River watershed are designated as core cold water habitat[84]. Many of the principal streams are also designated as salmon and steelhead spawning use[85] as well, however, the seasons that this designation apply to are outside of the July and August time period considered for this analysis. We assigned impact ratings using the following approach:

- The proportion of total length for each principal stream that meets the ODEQ core cold water habitat criterion was calculated for each model scenario (i.e., 2006, 2056, 2106; Figure 49),

- Streams having less then 10% of their total length that meet the core cold water habitat criterion under <u>any</u> of the three model scenarios were assigned a "low" likelihood of posing a limitation to properly functioning condition. The reasoning behind this rating is that these streams are unlikely to meet the ODEQ criteria regardless of riparian management actions.

- Similarly, streams where the future proportion of stream length that meets the ODEQ criterion is greater than the current condition were assigned a "low" likelihood of posing a limitation to properly functioning condition (i.e., conditions are getting better).

- Streams where the future proportion of stream length that meets the ODEQ criterion is less then the current condition, but greater than 10%, were assigned a "moderate" likelihood of posing a limitation to properly functioning condition (i.e. worsening trend).

- Streams where the future proportion of stream length that meets the ODEQ criterion is less then the current condition, and less than 10%, were assigned a "high" likelihood of posing a limitation to properly functioning condition.

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[83] http://arcweb.sos.state.or.us/rules/OARs_300/OAR_340/340_041.html
[84] http://www.deq.state.or.us/wq/rules/div041/fufigures/figure230a.pdf
[85] http://www.deq.state.or.us/wq/rules/div041/fufigures/figure230b.pdf

Results are presented for two time periods; 0-50 years in the future, and 0-100 years.

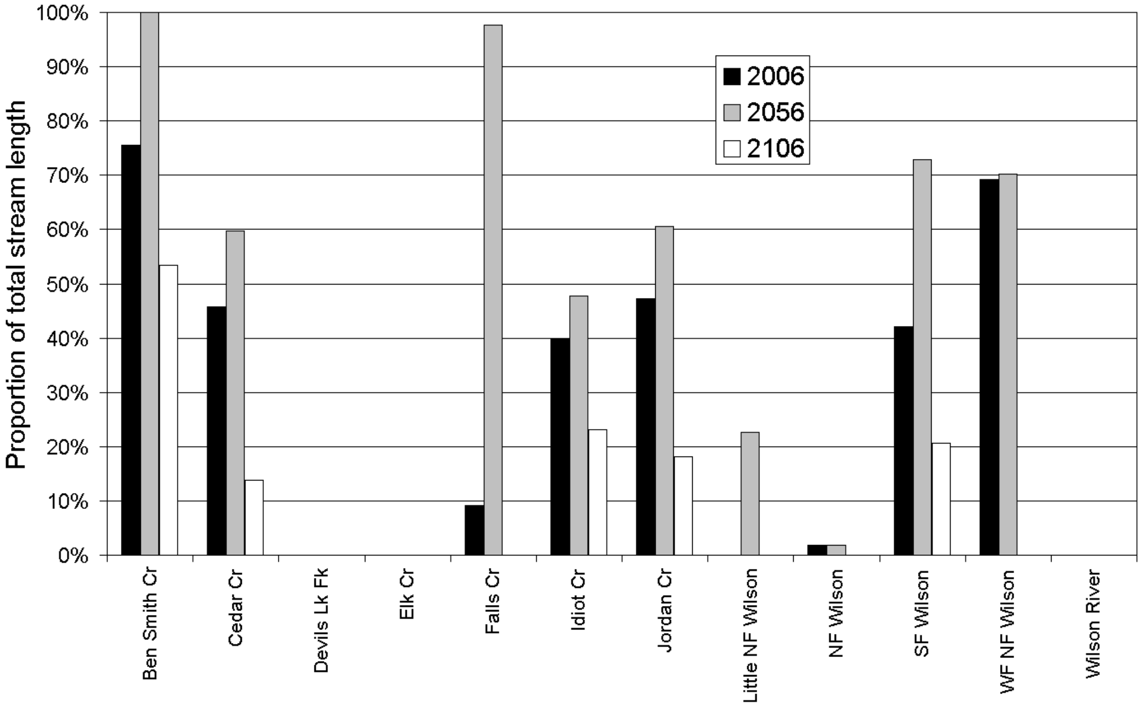

Figure 49. Proportion of total principal stream length that is estimated to achieve the ODEQ "core cold water habitat" criteria ODEQ "core cold water habitat use" criterion is T_{max} less than or equal to 60.8 degrees Fahrenheit. The absence of a bar means that 0% of the stream length is predicted to meet the criteria.

The results indicate that in the mid-term (i.e., 50-year time horizon) shade conditions, and associated stream temperatures, will experience an improving trend, as current stands mature, and riparian shade generally increases. However, over the longer term (0-100 years) we can expect to see shade conditions deteriorate, and temperatures increase, as stands break up and shade conditions decrease (see the discussion on lack of canopy recruitment in Chapter 6 Riparian and Wetlands, section 6.2 Potential Future Conditions).

Table 62. Likelihood that stream temperatures and/or shade conditions are a limiting factor for achieving properly functioning aquatic system. Results are provided by principal stream.

Principal stream	0-50 year time horizon	0-100 year time horizon
Ben Smith Cr	Low	Moderate
Cedar Cr	Low	Moderate
Devils Lk Fk	Low	Low
Elk Cr	Low	Low
Falls Cr	Low	High
Idiot Cr	Low	Moderate
Jordan Cr	Low	Moderate
Little NF Wilson	Low	Moderate
NF Wilson	Low	Low
SF Wilson	Low	Moderate
WF NF Wilson	Low	High
Wilson River	Low	Low

8.7 Confidence in the Assessment/Analysis

Confidence in the above analysis is moderate. The overall approach to estimating temperatures is robust, and follows a methodology similar to other recent state of the art efforts (e.g., Allen et al., 2007). However, the limited availability of recent temperature data from sites within the Wilson watershed limits the overall confidence. Given that stream temperature monitoring equipment is relatively cheap to deploy, and temperature data relatively easy to analyze, ODF is encouraged to increase its temperature monitoring efforts within the Wilson River watershed.

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9 Fish and Fish Habitat

9.1 Introduction

A variety of native and introduced fish species inhabit the Wilson River watershed. Native species, especially salmonids, are of particular interest and, assuming they are the most sensitive species in stream networks, are often used as indicators of overall aquatic health (WPN 1999, Bottom et al. 1998, Carigan and Villard 2002). Other fish species, however, are also increasingly being used to indicate aquatic health (e.g., lampreys) and knowledge about which species inhabit particular areas is important for predicting the types and severity of species interactions and their ecological consequences.

The health of fish populations is intricately linked to aquatic habitat conditions. Habitat conditions that are good for salmonids generally reflect habitat conditions that are good for other species of aquatic biota. In many cases, understanding historic and current aquatic habitat conditions allows resource managers to better predict how various land use practices influence species distributions, relative abundance and population status. Furthermore, understanding how current habitat conditions compare to historic conditions allows land use managers to asses how subwatersheds may be functioning (e.g., meeting proper functioning condition).

In many cases, answers to OWEB questions were sufficiently answered in the 2001 OWEB watershed assessment (e.g., native/introduced species present, fish distributions and life histories; E & S Environmental Chemistry) and are, therefore, only briefly addressed and referenced here. In other cases (e.g., fish population abundance, aquatic habitat conditions, barriers to fish passage), additional surveys/projects have been completed since the 2001 OWEB assessment and have been incorporated below.

9.2 Species, Listings, and Extinctions

Six salmonids (steelhead trout, cutthroat trout, Chinook, chum, pink[86] and coho salmon), three species of lamprey (Pacific, river, Western brook lamprey), two species of sturgeon (Green and White sturgeon), and several species of non-game fish have either been documented in, or, where records are lacking, are presumed to inhabit[87] the Wilson River watershed (Table 63). While all species (with the

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[86] Juvenile pink salmon were documented in a smolt trap on the Little North Fork Wilson in 2003. Dave Plawman (ODFW-Tillamook Fish Biologist), personal communication, July 12, 2007.

[87] Based upon geographic species distributions and/or documented presence in nearby river systems.

exception of the summer steelhead *race*) are native to the Wilson River, not all species and life stages are found throughout the basin. For example, adult and sub-adult sturgeon are found in tidewaters of the Wilson River while adult sockeye salmon[88], but no juveniles, have been documented. The salmonid life history strategies were presented in the 2001 OWEB assessment and are therefore not presented here (E & S Environmental Chemistry 2001).

Several of the species inhabiting the Wilson River watershed have been extensively reviewed by State and/or Federal biologists and listed as *Species of Concern*, *Sensitive*, *Vulnerable*, *Candidate*, *Threatened*, or *Endangered* species (includes both State and Federal listings). The Federal government authority responsible for protecting anadromous species, NOAA Fisheries, recently issued final species listing determinations (2005-2006) and final critical habitat designations (2005) for several species (includes Species Management Units and Distinct Population Segments) of anadromous salmonids found in the Pacific Northwest (Table 63).

As of December 2007, none of the anadromous salmonid species inhabiting the Wilson River watershed are currently listed as *Threatened* or *Endangered* under the federal Endangered Species Act (ESA; Table 63). The Oregon Coastal winter steelhead trout are federally listed as a *Species of Concern* and are listed by the State as *Vulnerable*. In the most recent assessment of Species Management Units (SMUs) of Oregon native fishes (ODFW 2005), the Oregon Coastal winter steelhead trout are listed as Potentially At Risk of extinction (Table 63). Neither the coastal fall and spring Chinook salmon SMUs are listed by the State but the interim assessment for the Spring run is Potentially At Risk and the Fall run Not At Risk of extinction (Table 63). While wild coastal coho populations are still doing poorly, as of December 2007, they were no longer federally listed as *Threatened* – although the official State listing is *Sensitive/Critical* – in part, because the U.S. District court ruled that hatchery fish must be included in counts when assessing population sizes. Nevertheless, counts of wild Coastal coho, aside from a few years with high numbers of adult returns that corresponded with high-productivity ocean cycles, continue to remain and are likely to be re-listed by NOAA Fisheries as *Threatened*. Additionally, chum salmon populations are listed by the State as *Sensitive/Critical* (Table 63).

Lamprey are increasingly also becoming regarded as indicator species of overall aquatic health and three species of lamprey are known (or suspected) to inhabit

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[88] Gillnet fishery records from the 1920's make no mention of sockeye salmon. Additionally, there are generally less than 5 adults captured by fisheries biologists every year and they are presumed to be Columbia River strays.

the Wilson River watershed (Table 63). The Pacific and river lampreys are anadromous fishes while the and Western brook lamprey are solely freshwater residents. All three species are federally listed as *Species of Concern* and listed by the State as Sensitive/Vulnerable, with the latest population assessments of At Risk for both the Pacific and Western brook lampreys (Table 63).

Additionally, two species of sturgeon, Green and White sturgeon, spend at least portions of their life cycles in the lowermost reaches of the Wilson River. Neither species are listed by the State but the North Coast ESU of the Green sturgeon is federally listed as a Species of Concern (Table 63). Several other species of non-game fish inhabit the Wilson River watershed but little is known about the health, abundance, distributions or status of their populations.

9.3 Native and Introduced Salmonids

All the salmonids currently found in the Wilson River are native to the watershed except summer steelhead trout, which are not indigenous to Tillamook Bay. They have been stocked throughout the Basin since 1965 but are not known to be naturally reproducing or self-sustaining in the Basin.[89]

9.4 Native/Introduced Species Interactions

Summer steelhead trout are currently the only introduced salmonid known to inhabit the watershed. They are, however, reportedly not naturally reproducing (see previous footnote). Given their presence in the system and the similarity of their habitat/food preferences to other native salmonids, it is likely that summer steelhead are negatively interacting with native salmonids (e.g., occupying habitat, consuming food resources, behavioral interactions) but the extent and severity is unknown. The Tillamook Estuaries Partnership, with funding from the US Environmental Protection Agency's National Estuary Program, has in place an aggressive exotic species detection program that covers Tillamook Bay (Cohen 2004) but no such systematic program exists for the detection of introduced species in the Wilson River and implementation of the plan has been stymied by lack of funding.

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[89] Summer steelhead trout are not known to be naturally reproducing or self-sustaining (Keith Braun [ODFW-Tillamook Fish Biologist], personal communication, July 12, 2007).

Table 63. Status of native fish species found (or likely to be found) in the Wilson River watershed (as of December 2007). Species populations or management units that have not been evaluated have no data in the cells.

Species [1]	ESU / DPS / SMU [2]	ESA Listing Status [3]	ESA Critical Habitat[4]	Oregon State Status[5]	Interim Assessment[6]
Steelhead trout (*Oncorhynchus mykiss*)	Coastal Winter	Species of Concern [7]	NA	Sensitive/ Vulnerable	Potentially at Risk
Chinook salmon (*O. tshawytscha*)	Coastal Fall	Not Warranted	NA	NA	Not at Risk
Chinook salmon (*O. tshawytscha*)	Coastal Spring	Not Warranted	NA	NA	At Risk
Chum salmon (*O. keta*)	Coastal	Not Warranted	NA	Sensitive/ Critical	At Risk
Pink salmon (*O. gorbuscha*)	Undefined in Oregon				
Coho salmon (*O. kisutch*)	Coastal	Not Warranted [7]	NA	Sensitive/ Critical	Not at Risk
Cutthroat trout (*O. clarki clarki*)	Oregon Coast	Not Warranted[7,8]	NA	Sensitive/ Vulnerable	Not at Risk
Pacific lamprey (*Lampetra tridentata*)	Coastal	Species of Concern [9]	NA	Sensitive/ Vulnerable	At Risk
River lamprey (*L. ayresi*)	Oregon Coast	Species of Concern [9]	NA	Sensitive/ Vulnerable	NA
Western brook lamprey (*L. richardsoni*)	Coastal	Species of Concern [9]	NA	Sensitive/ Vulnerable	At Risk
Green sturgeon (*Acipenser medirostris*)	North Coast [10]	Species of Concern [9]	NA	NA	Not At Risk
White sturgeon [11] (*Acipenser transmontana*)	Oregon	NA	NA	NA	Not At Risk
Threespine stickleback (*Gasterosteus aculeatus*)					
Coast Range sculpin (*Cottus aleuticus*)					
Prickly sculpin (*Cottus asper*)					

Sources for ESU/DPS/SMU: NOAA Fisheries Northwest Regional Office website (http://www.nwr.noaa.gov/ESA-Salmon-Listings/Index.cfm) and ODFW's Oregon Native Fish Status Report (2005).

[1] The ESA defines a "species" to include any distinct population segment (DPS) of any species of vertebrate fish or wildlife.

[2] For Pacific salmon, NOAA Fisheries considers an Evolutionarily Significant Unit, or "ESU," a "species" under the ESA. For Pacific steelhead, NOAA Fisheries has delineated Distinct Population Segments (DPSs) for consideration as "species" under the ESA.

[3] Updated final listing determinations for salmon species were issued on June 28, 2005 (70 FR 37160). Updated final listing determinations for West Coast steelhead species were issued on January 5, 2006 (71 FR 834).
[4] Final critical habitat designations for several West Coast salmon and steelhead species were issued on September 2, 2005 (70 FR 52488 and 52630).
[5] As of 2/13/2007. From the State Threatened and Endangered and State Sensitive lists.
[6] Assessment of Species Management Units (SMUs) From ODFW's Native Fish Report (2005).
[7] Updated from the 2001 Wilson River Watershed Assessment (E & S Environmental 2001). Likely to be re-listed by NOAA Fisheries as *Threatened* in early 2008.
[8] There is still some debate within NOAA Fisheries whether this ESU is likely to become endangered in the near future.
[9] Species petitioned with the US Fish and Wildlife Service for listing.
[10] Northern Coast species management unit (SMU), reflecting the DPS definitions set by NOAA Fisheries.
[11] Lower Columbia/Coastal population of Oregon species management unit (SMU).

9.5 Historic Salmonid Distribution

Salmon and trout were known to inhabit the Wilson River watershed and have been utilized by humans for at least the last 1,000 years (USACE 1975). Information pertaining to their distribution at the time of European settlement through the early 1900's, however, is virtually non-existent. Even distributions of other species native to the watershed (e.g., lampreys, minnows, suckers, sculpins, sturgeons, etc.) are not clearly defined.

There is a dearth of historical fish distribution information for fishes inhabiting the Wilson River watershed. Recognizing this, the Oregon Department of Fish and Wildlife (ODFW) conducted an analysis using a map of stream size and gradient developed by the Coastal Landscape Analysis and Modeling Study (CLAMS[90]) to identify areas above current fish distributions that could have potentially supported salmon/steelhead in the past (Kavanagh et al. 2005). The analysis assumed that fish distribution would have been limited by stream gradients if impediments such as physical barriers or poor habitat were not present and compared the current fish distribution maps with the CLAMS-generated maps. Although somewhat speculative in nature, the results indicate that historic salmon distributions may have been similar to their present distributions[91].

9.6 Current Salmonid Distributions

There are approximately 2,421.4 miles of perennial and intermittent streams in the Wilson River watershed (Table 64). Anadromous salmonid species, present in every subwatershed in the Wilson River basin, can be found along roughly 119.6 miles of Wilson River streams, or in approximately 20.2% of the perennial streams found in the watershed. Including resident cutthroat trout, salmonids can

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[90] Found online at http://www.fsl.orst.edu/clams/.
[91] See maps 17 and 18 in Kavanagh et al. 2005.

be found along roughly 312.7 miles of Wilson River streams, or in approximately 52.8% of the perennial streams found in the watershed (Table 64). Chum salmon have the most restricted distribution (~16 miles; Table 65 and Map 5) while winter steelhead trout have the broadest *mapped* distribution (~116 miles; Table 65 and Map 8). Although ubiquitous throughout the Wilson River watershed, no specific spatial data layers yet exist mapping the distribution of coastal cutthroat trout. Additionally, little is known about the spatial extent of the sea-run (anadromous) form of coastal cutthroat trout. Overall, however, coastal cutthroat trout frequently occur well upstream of winter steelhead trout and exhibit the broadest salmonid distribution in the Wilson River, generally corresponding to "Type F" (fish-bearing) streams (see Table 64 footnotes).

Table 64. Fish presence by stream type.

Stream Type	Fish Presence [1]	Stream length (miles)	% Stream Type	% of Total
Perennial	Fish[2]	312.66	52.8	12.9
	Non-fish[3]	167.30	28.3	6.9
	Unknown	111.73	18.9	4.6
Intermittent	Fish[2]	0.00	0.0	0.0
	Non-fish[3]	782.61	42.8	32.4
	Unknown	1,047.28	57.2	43.2

[1] Classified by the Oregon Department of Fish and Wildlife. Includes both verified and non-verified presence and/or absence. Stream classification rules under the FPA, however, have changed and all unknown streams are in the process of being reclassified as Fish or Non-fish using DEM-modeled criteria.

[2] Fish-bearing = Type F.

[3] Non fish-bearing = Type N.

The Oregon Department of Fish and Wildlife, based upon the species/race life history stages, has designated stream segments by the type of fish use (roughly corresponding to their respective life history stages). Fish use type 1 corresponds to spawning and rearing habitat, type 2 to rearing and migration habitat, and type 4 to previous or historic distribution (i.e., not detected/observed in the within the past five reproductive cycles).

Chum salmon, the anadromous salmonid species with the narrowest distribution range in the Wilson River watershed (refer to Table 65 and Map 5), can only be found in the lowermost reaches of the Wilson River in the Lower Wilson (lower two thirds) and Little North Fork Wilson (lower third) subwatersheds (Map 5).

Spring Chinook salmon, the anadromous salmonid with the second-most restricted distribution range in the Wilson River watershed (refer to Table 65 and

Map 6) and can generally be found in the mainstem of the Wilson River from tidewater up to the confluence of the Devils Lake Fork and South Fork of the Wilson subwatersheds (Map 6).

Table 65. Wilson River anadromous fish presence by species, miles, and percent of the perennial streams in the watershed inhabited by the species. [1]

Common Name	Miles Inhabited	% Inhabited [1]	Distribution Map [2]
Chum salmon	15.59	2.6	Map 5.
Chinook salmon – Spring run	32.77	5.5	Map 6.
Summer Steelhead [3]	73.51	12.4	Map 8.
Chinook salmon – Fall run	76.24	12.9	Map 6.
Coho salmon	105.85	17.9	Map 7.
Winter steelhead	116.20	19.6	Map 8.

[1] Percent of perennial streams in the Wilson River watershed occupied by the species.

[2] An Oregon Department of Fish and Wildlife (ODFW) analysis derived from juvenile anadromous salmonid productivity and habitat distributions concluded that historic distributions of anadromous salmonids in the Wilson River watershed were probably very similar to their current distributions (Kavanagh et al. 2005).

[3] Not a native race of fish. Summer steelhead were introduced into the Wilson in the early 1960's and are entirely supported by hatchery programs.

The species with the next broadest range of distribution are the summer steelhead trout and the fall Chinook salmon, each inhabiting nearly the same number of miles of streams in the Wilson River watershed (refer to Table 65 and Maps 6 and 8). Both species can be found in every subwatershed of the Wilson River but summer steelhead trout can generally be found further upstream than fall Chinook in the Devils Lake Fork and Jordan Creek subwatersheds while fall Chinook salmon can generally be found further upstream than summer steelhead in the Little North Fork, Upper Wilson/Cedar Creek, North Fork and South Fork subwatersheds (Maps 6 and 8).

Coho salmon have the second broadest distribution of anadromous salmonids found in the Wilson River (refer to Table 65 and Map 7), are widely distributed throughout the mainstem and larger tributaries of the Wilson, and are found in all the subwatersheds in the Wilson (Map 7).

Winter steelhead are the most broadly dispersed of all the anadromous salmonids found in the Wilson River (excludes the resident form of cutthroat trout), are widely distributed throughout the mainstem and moderate to larger tributaries of the Wilson, and are also found in every subwatershed in the Wilson (Table 65 and Map 8).

9.7 Historic Salmonid Abundance

Salmon runs in Oregon's rivers and streams have been reduced from predevelopment conditions but it is unclear by how much (Meengs and Lackey 2005) because reliable and consistent fish counts don't appear until several decades after settlement. Additionally, there is little data specific to the Wilson River watershed that characterizes the historic abundance of fish. There are, however, some basin-wide (Tillamook Basin) studies from which we can infer historical trends and actions that were likely to have affected fish populations in the Wilson River watershed in historical times.

Some of the earliest accounts of fish in the basin come from some of the first European explorers who, from their interactions with the Native Tillamook peoples, described how the Tillamook caught "many salmon in the small creeks" (Bancroft 1886). Early settlers to the region describe the rivers of the area as teeming with hordes of trout and salmon, especially as the freshets arrived in the fall (Maddux 1976). By the late 1800's, commercial salmon gillnet fisheries in the bay were operational. The first cannery in the bay opened in 1885 and stimulated a small commercial fishery, presumably targeting coho salmon (*Oncorhynchus kisutch*), one of the most abundant anadromous fishes present in pre-settlement Tillamook Bay (Coulton et al. 1996). Despite the San Francisco market for Tillamook Bay canned salmon (USACE 1975), canneries did not keep pack records until 1892. That same year, the first commercial fishing regulations (directed at coho) were instituted and involved seasonal and weekend closures (Mullen 1981). Even though coho were being intensively harvested beginning in the 1880's, catch records for these early commercial fisheries were often not kept. Spawning records, however, *were* kept beginning in the early 1900's and continue, with few interruptions, through to today (discussed in greater detail below).

Even though there is a paucity of data on historic salmon abundance in the Tillamook Basin from the mid-1800's until the early 1900's, we can use 1) estimated salmon harvest by Native Americans inhabiting the area, 2) fishery data and 3) cannery data to generate rough estimates of how large the runs were. For example, using Tillamook Native American population estimates and likely salmon consumption and harvest rates (for all species combined), Meengs and Lackey (2005) estimated that the Native Tillamook peoples harvested an average 1.97 million pounds of salmon from the Tillamook Basin every year. Using Craig and Hacker's (1940) estimate that Native Americans harvested anywhere from 28-57% of a run, depending on the size of the run, we estimate that average yearly biomass of all salmon returning the Tillamook Basin was between 3.46 – 7.04 million pounds. The Northwest Power Planning Council (1986) determined that the average weight for all species of salmon returning to the Columbia River was 6.62 – 9.27 pounds. Using this estimate to convert the total run size in pounds to the numbers of individuals returning to the Tillamook Basin, we estimate that the average annual run size was between 0.37 – 1.06 million salmon (Table 66). Using cannery pack data from the late 1800's, Meengs and Lackey (2005) estimated that the average annual run size in the Tillamook Basin in the late 1800's was approximately 285,000 salmon (234,000 coho and 51,000 Chinook; Table 66).

Table 66. Estimated historical smolt and adult anadromous salmonid counts from the Tillamook Basin and Wilson River in the late 1800's.

Basin/Subbasin [1]	# Coho Smolts	# Coho Adults	# Chinook Adults	Total Adults	Reference
Tillamook Bay	--	--	--	370,000-1,060,000 [2]	Meengs and Lackey 2005 Craig and Hacker 1940 NWPPC 1986
Tillamook Bay	--	234,000	51,000	285,000 [3]	Meengs and Lackey 2005
Tillamook Bay	3,288,000	329,000 [4]	--	--	Lawson et al. 2007
Tillamook Bay	--	292,500 [5]	--	--	Lawson et al. 2007
Wilson River	--	62,300-112,100 [4]	--	--	Lawson et al. 2007

[1] Tillamook Bay estimates include the Wilson River subbasin.
[2] Estimate derived from Native American consumption rates and amounts and average fish size.
[3] Estimate derived from historic cannery pack data.
[4] Estimate derived from juvenile salmonid productivity and stream habitat potential.
[5] Estimate derived from fisheries catch data.

In a study that focused specifically on coho salmon, Lawson and others (2007), using coho salmon smolt abundances and 1950's fisheries catch data from the Tillamook Basin and the *current* habitat potential, estimated that the annual historic number of returning adult coho salmon to the Tillamook Basin would have been between 292,500 (catch data) and 329,000 (from smolt abundance and stream habitat potential; Table 66). Lawson and others (2007) also estimated historic productivity of systems based on the number of hectares in a basin and provided an estimate of the number of adult coho salmon per hectare per year (see Figure 23 in Lawson et al. 2007). Using their productivity estimate for basins larger than ~12,355 acres (5,000 hectares), we calculated that the Wilson River may have produced between 62,300-112,100 adult coho per year (25th and 75th percentiles, respectively; Table 66). Lawson and others (2007) also estimated that the number of potential coho salmon *smolts* annually leaving the

Tillamook Basin in the late 1800's would have been about 3.29 million (Table 66). These estimates, however, should be regarded only as approximations of potential historic adult and juvenile abundances as there were a number of assumptions that were used in the calculations.

Because of their reliance on salmon as a primary protein source, salmon abundance has been shown to be a good predictor of Native American populations (Baunhoff 1963, Sneed 1972, Donald and Mitchell 1975, Hunn 1982). It is possible, however, that the precipitous population decline experienced by the Native Tillamook peoples (from first European contact through the middle to end of the 1800's) affected the size of salmon runs in Tillamook Bay, including the Wilson River. Therefore, salmon runs may have been larger from about the 1850's through the 1880's than just about any other time in post-glacial history because the Native Tillamook peoples were no longer harvesting large quantities of fish (Craig and Hacker 1940, Hewes 1973). Estimating run sizes or abundances prior to the 1900's with any degree of certainty, however, is difficult. Reliable and consistent fisheries data from the early 1900's to today, on the other hand, provides more reliable abundance estimates.

In a 1965 Oregon Fish Commission (later changed to "Oregon Department of Fish and Wildlife") report, Arthur Oakley reported the landings of Tillamook Bay salmonids (round weight) from 1923-1961 and the estimated numbers of fish caught in the fishery each November from 1957-1961. Oakley reported the numbers during three time periods (1923-47, 1948-56, and 1957-61) and assumed that the fish weights reported by fish buyers from 1957-61 was the actual total weight of the fish. During the reported time period, chum salmon were the most abundant salmonid captured in the fishery, with coho, Chinook, and steelhead following (Table 67). The poundage of each salmonid species captured in the fishery declined dramatically during each of the three successive time with declines of 91-97.5% from 1923 to 1961 (Table 67). Because there were limited fishing restrictions and closures during these time periods and the declines extended to stocks and localities outside of the Tillamook basin, Oakley attributed the decline to "some climatological or oceanic factor" and not necessarily to heavy fishing pressures (mortality rate of ~40%) or other "deleterious watershed activities."

9.8 Current Salmonid Abundance

The majority of abundance data (e.g., spawning counts, resting hole counts, juvenile outmigrants) collected by the Oregon Department of Fish and Wildlife (ODFW) is tabulated at a coarse scale (e.g., 5th Field or combination of 5th Field HUCs) and is similarly reported here, except where finer-scale resolution exists.

A three-year Rapid Biological Assessment (RBA), started in 2005, is ongoing in the Tillamook Basin (Bio-Surveys 2005, 2006). Information from the RBAs is presented on a subwatershed basis, where available.

Table 67. Average annual catch (in pounds) and average number of fish captured annually (in parentheses; 1957-61 only) of Tillamook Bay salmonid fisheries from 1923-1961 as reported by Oakley (1966).

	Species				
Time Period	**Steelhead**	**Chinook**	**Coho**	**Chum**	**Totals**
1923-47	36,987	277,406	384,656	844,016	1,543,065
1948-56	25,225	152,480	123,861	306,653	608,219
1957-61	2,957 (355)	19,247 (832)	9,620 (955)	69,386 (6,292)	101,210 (8,413)

Although variable, salmonid abundances have increased, some dramatically, since the 2001 OWEB watershed assessment. Most abundance estimates peaked between 2001 and 2003, except for peak counts of adult spring Chinook salmon in resting holes which peaked in 2004 (Table 68). It should be noted, however, that 1) these increasing abundance estimates correspond closely with the recent cycles of ocean productivity and 2) numbers are still a fraction of historic abundance estimates. Caution, therefore, should be used when considering the relative influence of freshwater habitats on recent abundance estimates.

Adult coho salmon abundance estimates for Tillamook Bay increased substantially in 2002 and 2003 but declined substantially between 2003 and 2004 (Table 68). Adult fall Chinook salmon counts in Tillamook Bay, however, have remained relatively stable since 2001 while spring Chinook salmon counts appear to be on the rise (Table 68). Adult Chum salmon counts in Tillamook Bay have decreased dramatically since 2001 and, at last count in 2004, the Tillamook population is 20% lower than the historic 30 year average but appears to be rebounding[92] (Table 68). There is no long-term Wilson River winter steelhead data available but recent counts indicate a decrease in the numbers of returning adults between 2003 and 2004 (Table 68). However, due to the small data sample, a reliable trend is not yet feasible. Few studies have targeted Tillamook Bay or Wilson River coastal cutthroat trout. The ODFW, however, has been running downstream migrant smolt traps in the Wilson River and expanded adult coastal cutthroat trout estimates increased from 1998 through 2001 but have been declining since (Table 68).

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[92] Keith Braun (ODFW-Tillamook Fish Biologist), personal communication, 7/12/07.

Table 68. Adult abundance estimates and trend data (for spring Chinook salmon) by population, species and return year. Source: Oregon Department of Fish and Wildlife's 2005 Oregon Native Fish Status Report.

			Abundance by Return Year							30 Year Average
	Species	**Run**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	
Tillamook [a]	Coho [b]		--	--	1,734	1,416	13,733	14,042	4,584	
Tillamook [c]	Chinook	Fall [d]	--	--	3,876	14,820	16,872	13,908	15,048	14,364
Tillamook [e]	Chinook	Spring	--	--	2.7 [f]	2.7 [f]	4.5 [f]	3.6 [f]	9.2 [f]	8.1 [f]
Tillamook [g]	Chum [d]		--	--	5,508	40,176	36,126	23,733	20,169	24,462
Wilson [h]	Steelhead [i]	Winter	--	--	--	--	--	7,855 [j]	6,168 [j]	
Wilson [k]	Coastal Cutthroat Trout [l]		2,500	1,250	2,950	3,800	--	1,800	1,000	

[a] Includes Netarts Bay tributaries and Watseco Creek.
[b] Full seeding level = 5,700.
[c] Includes Netarts Bay tributaries.
[d] Expanded from peak counts of spawning fish per mile.
[e] Primarily from the Wilson, Kilchis, and Trask Rivers.
[f] Trend data only: number of adults counted per resting hole.
[g] All tributaries to Tillamook Bay.
[h] Wilson River and Kilchis River basins.
[i] Long-term data unavailable.
[j] Calculated from number of redds per mile, assuming 1.04 adults/redd (from Susac 2005).
[k] Little North Fork Wilson
[l] Approximate expanded number of downstream migrants captured in an ODFW Lifecycle Monitoring Program downstream migrant smolt trap. Years in which expansions could not be made are not presented.

Estimates of the number of juvenile salmonid species inhabiting the Wilson River during the summers of 2005 and 2006 were calculated in the Tillamook RBA studies. Information in the RBA was tabulated at the stream level (e.g., 7th Field HUCs and higher) and is presented at both the stream (Appendix K) and subwatershed (e.g., 6th Field HUCs; below) levels. Because the RBAs were carried out in the summer after nearly all of the Chinook and all of the chum salmon juveniles have left the system, their numbers were not reported. Additionally, RBA surveyors were unable to make distinctions between young-of-the-year (YOY) steelhead and cutthroat trout. Their counts, therefore, were combined into a "0+" category. Steelhead and cutthroat trout older than one year were differentiated into distinct categories.

Wilson River summer juvenile coho abundances in 2006 were much greater than 2005 (Table 69) and, being the most productive coho stream in the Tillamook Basin, accounted for approximately 43% of the entire Tillamook Basin juvenile coho population. The increase in numbers of juvenile coho in 2006 was in response to a surge in adult escapement for the 2005 winter brood, a direct result of good ocean productivity cycles. The top three producers of juvenile coho salmon in 2005 were, in order of magnitude, the Little North Fork of the Wilson, Devils Lake Fork, and the mainstem Wilson River (spanning several subwatersheds) and accounting for a combined 68.1% of the coho produced in the Wilson River (Table 69). The top three in 2006 were the same with the exception that the third biggest producer was the North Fork of the Wilson, replacing the mainstem Wilson, and accounting for a combined 63.2% of the coho produced in the Wilson River (Table 69).

Wilson River summer juvenile steelhead (age 1+) abundances were slightly lower in 2006 than 2005 (Table 69) but the Wilson River was still the most productive Tillamook Basin steelhead producing stream. The top three producers of juvenile steelhead in 2005 were, in order of magnitude, the mainstem Wilson River (spanning several subwatersheds), Little North Fork of the Wilson, and Devils Lake Fork, accounting for a combined 75.8% of the steelhead produced in the Wilson River (Table 69). The top three producers in 2006 were the same as in 2005, with the exception that the North Fork of the Wilson replaced the Devils Lake Fork, and accounted for a combined 76.4% of the steelhead produced in the Wilson River (Table 69). It should be noted, however, that steelhead are predominantly found in riffles/rapids and the RBA surveys only counted individuals in pools. Therefore, the actual number of steelhead juveniles produced is likely to be significantly underestimated by the RBAs.

Wilson River summer juvenile cutthroat trout (includes both resident and anadromous forms age 1+) also were slightly lower in 2006 than in 2005 (Table 69). The top three producers of cutthroat trout in 2005 were, in order of magnitude, the mainstem Wilson River (spanning several subwatersheds), the Little North Fork of the Wilson, and Jordan Creek, accounting for a combined 54.4% of the cutthroat trout produced in the Wilson River (Table 69). The top three producers in 2006 were the same, with the exception that the North Fork of the Wilson replaced Jordan Creek, and accounted for a combined 66.1% of the cutthroat trout produced in the Wilson River (Table 69).

The overall top three producers of juvenile salmonids in 2005 (and the most abundant salmonid) were, in order of magnitude, the mainstem Wilson River (0+ trout), the Little North Fork of the Wilson (coho salmon), and the Devils Lake Fork of the Wilson (coho salmon; Table 69). The top three producers in 2006 were the same except the Little North Fork of the Wilson (coho salmon) was the top producer, the mainstem Wilson River (coho salmon) was the second largest producer, and the Devils Lake Fork of the Wilson (coho salmon) was the third largest producer of juvenile salmonids (Table 69).

Table 69. Estimated abundance of Wilson River summer juvenile salmonids by species, subwatershed and year. Relative percent contribution (species by watershed) in parentheses. For a complete list of abundance estimates by sample locations, see Appendix O – Juvenile Salmonid Abundances. Source: 2005 and 2006 Tillamook Rapid Biological Assessments.

		Expanded Juvenile Salmonid Abundance and (subwatershed % contribution to the watershed, by species)			
6th Field HUC	**Year**	**Coho**	**0+ trout**	**Steelhead [1]**	**Cutthroat [2]**
Non-classified HUCs[3]	2005	17,875 (19.8)	35,545 (40.0)	12,030 (50.0)	2,120 (21.9)
	2006	23,725 (11.3)	12,990 (22.4)	10,025 (45.9)	3,245 (37.3)
Lower Wilson	2005	435 (<1)	315 (<1)	15 (<1)	125 (1.3)
	2006	575 (<1)	45 (<1)	55 (<1)	75 (<1)
Little North Fork Wilson	2005	25,430 (28.1)	19,970 (22.5)	3,960 (16.4)	1,590 (16.5)
	2006	63,960 (30.3)	15,650 (27.0)	4,070 (18.6)	1,590 (18.3)
Middle Wilson	2005	460 (<1)	970 (1.1)	210 (<1)	185 (1.9)
	2006	185 (<1)	680 (1.2)	175 (<1)	195 (2.2)
Jordan Creek	2005	3,165 (3.5)	5,060 (5.7)	1,635 (6.8)	1,545 (16.0)
	2006	15,585 (7.4)	5,375 (9.3)	930 (4.3)	715 (8.2)
Upper Wilson/ Cedar Creek	2005	5,460 (6.0)	4,780 (5.4)	470 (2.0)	1,175 (12.2)
	2006	21,525 (10.2)	6,145 (10.6)	1,460 (6.7)	785 (9.0)
North Fork Wilson	2005	9,365 (10.4)	9,450 (10.6)	1,980 (8.2)	1,345 (13.9)
	2006	26,545 (12.6)	8,740 (15.1)	2,605 (11.9)	910 (10.5)
Devils Lake Fork	2005	18,280 (20.2)	7,665 (8.6)	2,275 (9.4)	1,155 (12.0)
	2006	42,880 (20.3)	5,175 (8.9)	1,275 (5.8)	555 (6.4)
South Fork Wilson	2005	9,920 (11.0)	5,040 (5.7)	1,500 (6.2)	425 (4.4)
	2006	15,900 (7.6)	3,145 (5.4)	1,230 (5.6)	620 (7.1)
	2005	90,390	88,795	24,075	9,665
	2006	210,880	57,945	21,825	8,690

[1] Winter steelhead counts.

[2] Coastal cutthroat trout. No distinction made between resident and anadromous forms.

[3] The Rapid Biological Assessment (RBA) surveys did not categorize the mainstem Wilson River (or unnamed tributaries) into 6th Field HUCs.

The ODFW, for approximately the last 60 years, has conducted spawning surveys (abundance data) and adult resting hole counts (trend data) in several streams in and around the Tillamook Basin, including in the Wilson River. Spawning surveys targeted coho, chum and fall Chinook salmon while resting hole counts targeted summer steelhead, spring Chinook salmon and sea-run cutthroat trout.

Chum salmon spawning counts indicate substantial fluctuation in the last several decades with relatively steady but very small numbers of spawning individuals in the Wilson River during the last 10+ years while, overall, counts are well-depressed compared with historic numbers (Figure 50). Fall Chinook spawning counts in the Wilson River also indicate annual fluctuation but the counts over the last 30+ years have remained relatively constant and similar to, but slightly depressed from, historic numbers (Figure 51). Coho salmon spawning counts in the Wilson River indicate steady and dramatic declines from the 1970's through the 1990's when the population crashed, but recent years have seen a dramatic, but variable increase in counts (Figure 52).

Spring Chinook salmon resting hole counts in the Wilson River indicate a low, steady, cyclic pattern of several fish counted per resting hole for a year or two followed by few to no fish counted per resting hole for a year or two (Figure 53). Summer steelhead resting hole counts in the Wilson River also indicate a variable but relatively steady number of adult steelhead counted with an increasing trend in the number counted in each hole since the mid-1990's (Figure 54). Sea-run cutthroat trout resting hole counts in the Wilson River plummeted in the 1970's and have remained relatively low (~3 fish per resting hole) since, with the exception of 2004-2005 where counts were similar to pre-1970 levels (Figure 55).

Most of the native salmonids found in the Tillamook Basin and Wilson River have been supplemented by hatchery fish at some point in the past. Recent stocking of Tillamook Basin hatchery fish, however, has been limited (Table 70) and no stocking of either chum salmon or cutthroat trout has occurred in the Tillamook Basin in the last ten years[93].

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[93] There has never been a hatchery program for chum salmon in Tillamook Bay. The only releases ever done were "payback fish" for eggs taken for other purposes (personal communication, Keith Braun, ODFW-Tillamook Fish Biologist, 7/12/07).

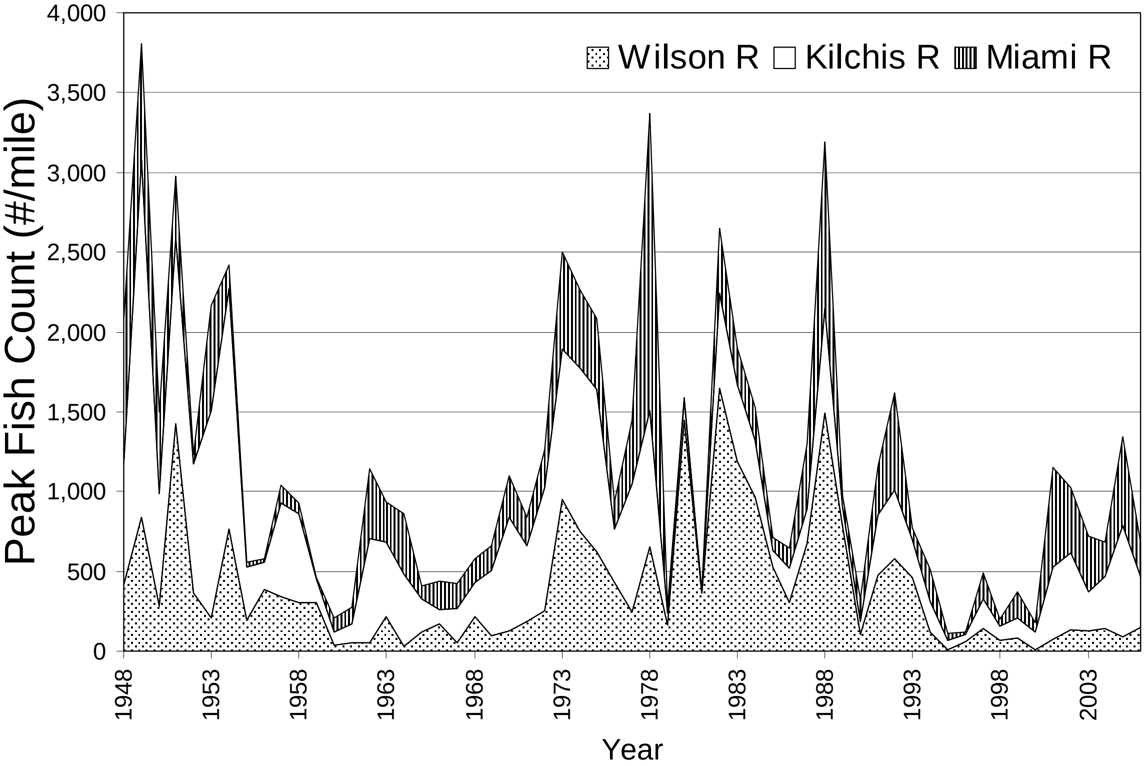

Figure 50. Chum salmon spawning counts, expressed as the peak number of fish per mile, from principle streams in the Tillamook Basin.

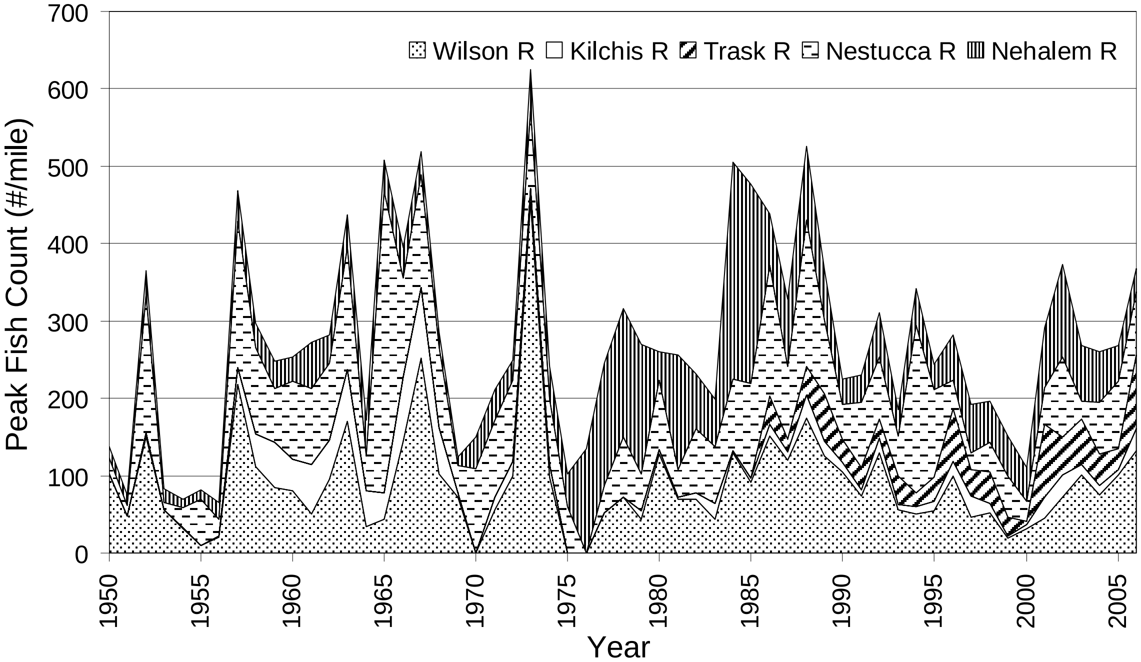

Figure 51. Fall Chinook salmon spawning counts, expressed as the peak number of fish per mile, from principle streams in and around the Tillamook Basin.

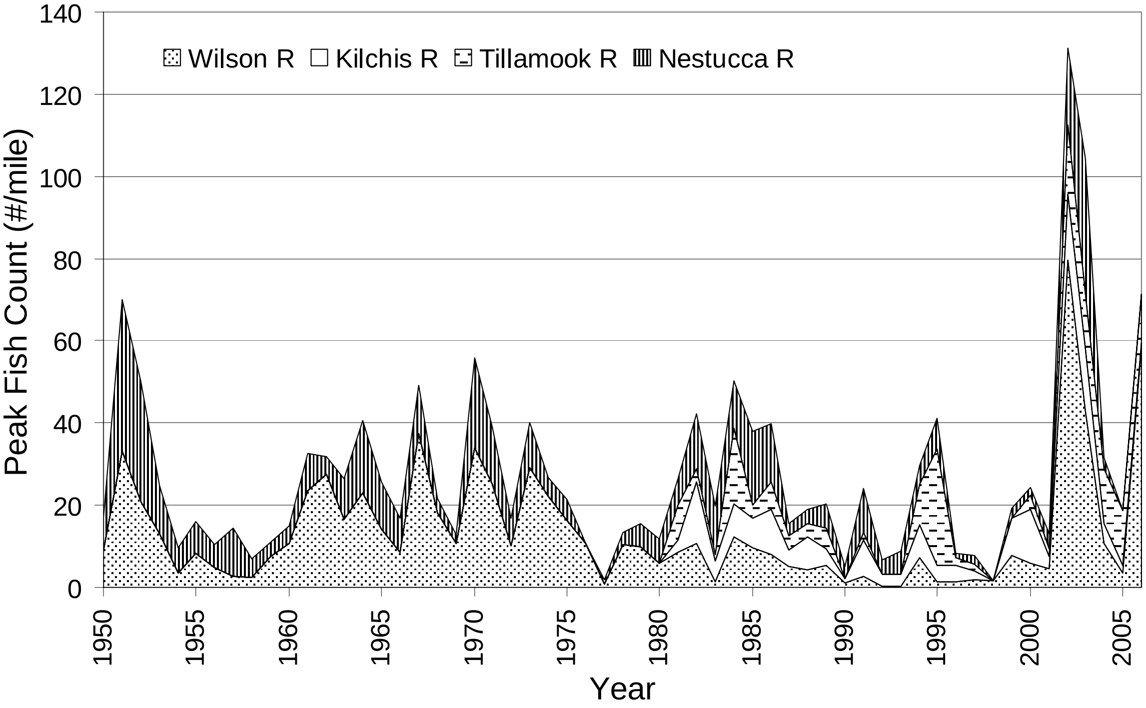

Figure 52. Coho salmon spawning counts, expressed as the peak number of fish per mile, for principle streams in and around the Tillamook Basin.

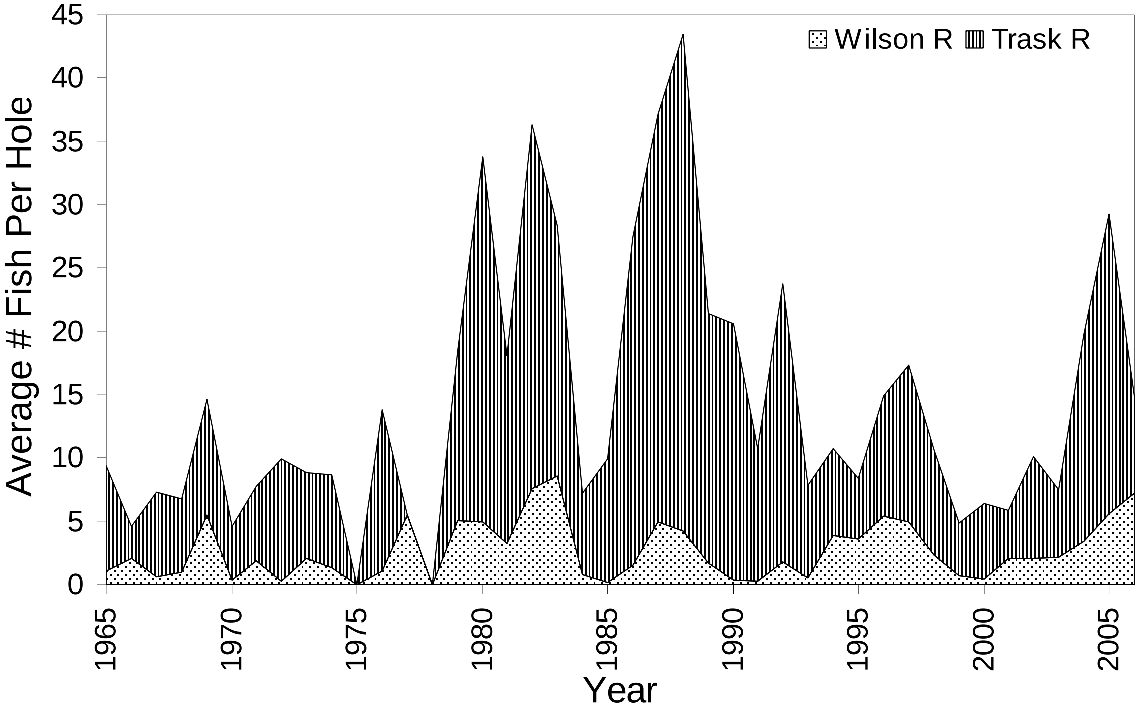

Figure 53. Spring Chinook salmon resting hole counts, expressed as the average number of fish per hole, for principle streams in the Tillamook Basin.

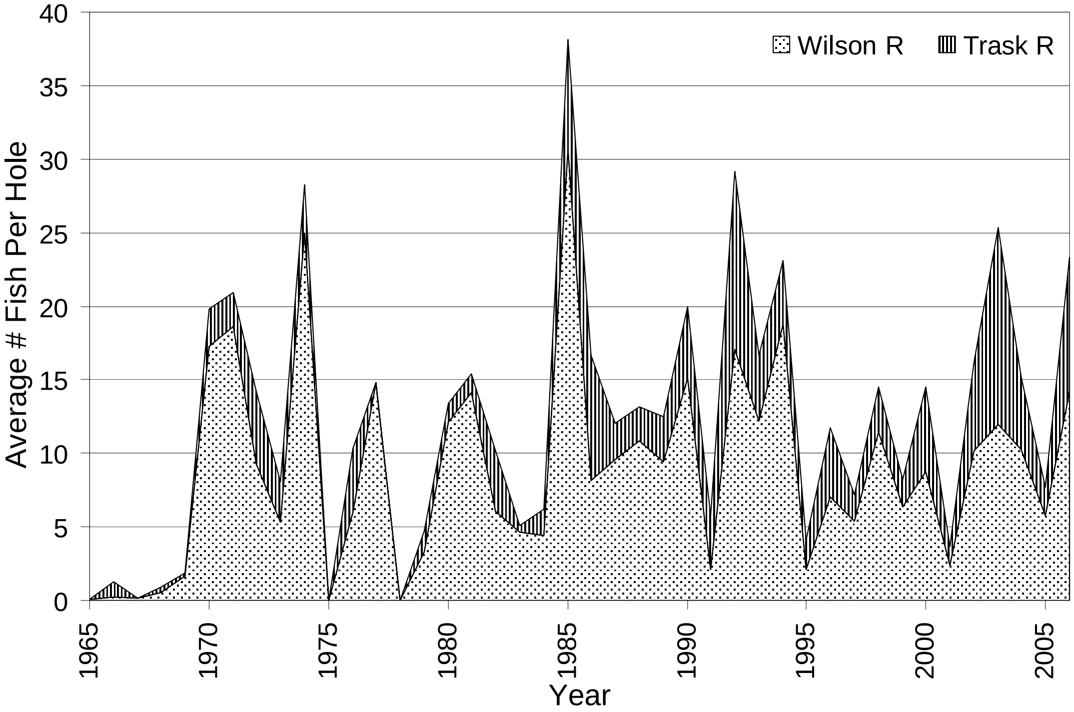

Figure 54. Summer steelhead resting hole counts, expressed as the average number of fish per hole, for principle streams of the Tillamook Basin.

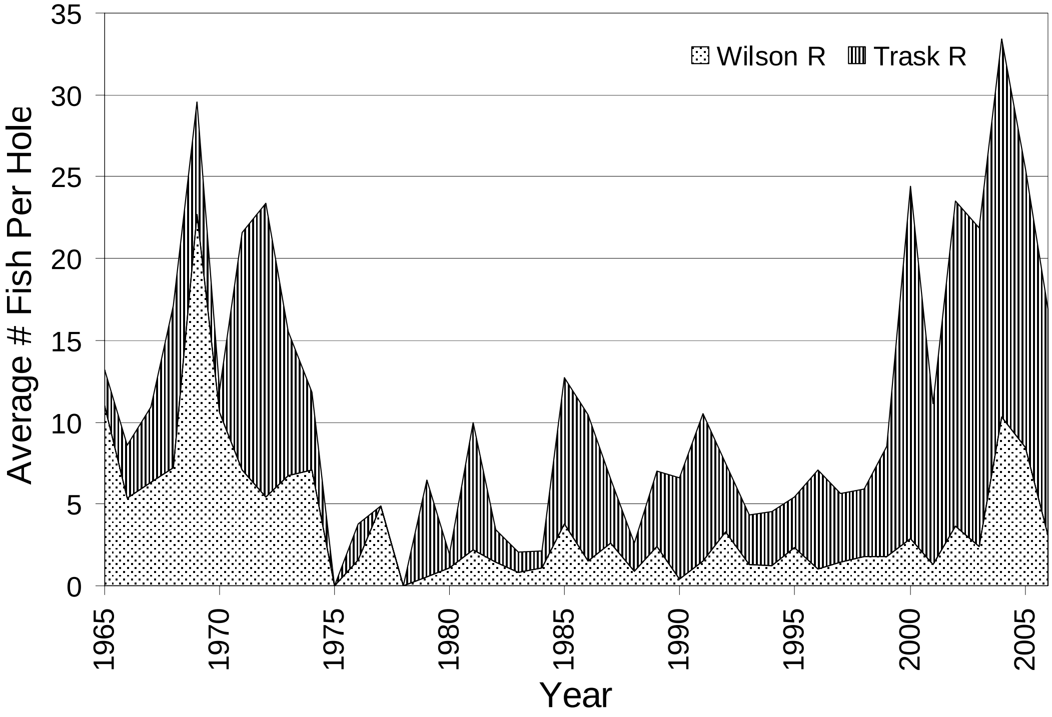

Figure 55. Sea-run cutthroat trout resting hole counts, expressed as the average number of fish per hole, for principle streams of the Tillamook Basin.

Table 70. Recent hatchery releases of native juvenile salmonids in the Tillamook Basin and Wilson River.

System	Species	Run	Type	Average # Per Year [1]
Wilson River	Steelhead	Winter	Smolts	110,000
		Summer	Smolts	50,000
	Chinook	Spring	Smolts	125,000
		Spring	Unfed Fry [3]	20,000
		Fall	Unfed Fry [3]	60,000
Tillamook Basin (excluding the Wilson River)	Coho		Smolts	Variable [2]
	Chinook	Fall	Smolts	113,000
		Fall	Unfed Fry [3]	290,000
		Spring	Smolts	220,000
	Chum			No Stocking
	Cutthroat Trout			No Stocking

[1] Averages from 1998-2002 or 1999-2003, depending on available data.

[2] Releases have gone from ~200K to ~100K. An Oregon Department of Fish and Wildlife study (2005) indicates that since 2002, less than 6% of spawning fish were of hatchery origin.

[3] Unfed fry are STEP (Salmon and Trout Enhancement Program) hatchbox fry and the actual number of fry released annually varies drastically.

9.9 Current Salmonid Population Status

The overall status of anadromous salmonids in the Wilson River has not changed from the 2001 OWEB Wilson River watershed analysis. With the exception of fall Chinook salmon, which are maintaining a relatively robust population, and winter steelhead, for which not enough information exists, populations of the rest of the native salmonids inhabiting the Wilson River are depressed compared with historic abundances[94]. Recent population trends (e.g., <10 years), however, derived from current ODFW and RBA data, have changed from the 2001 OWEB watershed analysis. While the recent increased coho salmon counts look promising, it should be noted that there has been tremendous temporal variability, indicating the tenuous nature of population recovery attempts (see Figure 52).

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[94] Historic salmonid abundances discussed in Section 9.2.

Table 71. Status and recent population trends of anadromous salmonids in the Wilson River.

Species/race	Status	Population Trends	
		Through 2001[a]	Present[b]
Chinook salmon			
Fall	Healthy	Stable or Increasing	Stable / Possibly increasing
Spring	Heavily supported by hatchery fish, depressed compared with historic abundance	Possibly declining	Stable / Possibly Increasing
Coho salmon	Heavily influenced by hatchery fish, severely depressed compared with historic abundance	Declining	Highly Variable
Chum salmon	Depressed compared to historic abundance	Declining	Stable
Steelhead trout			
Winter	Heavily influenced by hatchery fish, numbers appear low	Declining	Insufficient Data / Possibly Declining
Summer	Introduced, supported entirely by hatchery fish	Declining	Variable / Possibly Increasing
Cutthroat trout	Stable/Depressed	Possibly Declining	Variable / Possibly Increasing

[a] From Table 2.2 in the 2001 OWEB Wilson River watershed assessment (E & S Environmental Chemistry 2001).

[b] Sources: the Tillamook Bay Environmental Characterization (TBNEP 1998), the Oregon Department of Fish and Wildlife's Oregon Native Fish Status Report (ODFW 2005), recent Tillamook Basin Rapid Biological Assessments (Bio-Surveys 2005 and 2006) and long-term ODFW spawning and resting hole counts.

9.10 Fish Habitat Condition[95]

9.10.1 Methods

The Oregon Department of Fish and Wildlife (ODFW) has conducted extensive stream habitat surveys throughout the State beginning in the early 1990's and continuing through today. To 1) assess current aquatic habitat conditions and 2) develop reference/benchmark habitat conditions relevant to Oregon coastal streams, the ODFW conducted a supplemental Tillamook Basin analysis of aquatic habitat data collected from 1991 through 2003 (Kavanagh et al. 2005). The ODFW, based on summary data from the long-term Aquatic Inventories Project (AIP), originally developed reference/benchmark aquatic habitat values derived from streams in areas with low impact from human activities (e.g.,

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[95] Fish habitat condition is assessed relative to Properly Functioning Conditions (PFCs).

wilderness or roadless areas, late-successional or mature forest; Foster et al. 2001) and included both coastal and Cascadian streams. Data from the supplemental Tillamook Basin aquatic habitat surveys (Kavanagh et al. 2005) refined some of the reference/benchmark values to reflect conditions specific to Tillamook Basin systems.

A total of 124 reference sites, surveyed between 1992 and 2003, were selected within the Oregon Coastal coho ESU (from Sixes River to Necanicum, including the upper Umpqua in the Cascade ecoregion) to represent natural or historic conditions within the range of coho salmon. Data from these surveys were compiled and the 25th and 75th quartiles were used by ODFW as a range of conditions representing "UNDESIRABLE/LOW" quality (25th quartile) and "DESIRABLE/HIGH" quality (75th quartile) habitat breakpoints. In this watershed analysis, we use the terms LOW and HIGH to represent the 25th and 75th quartiles, respectively. Additionally, for the purposes of this assessment, we assume that data from ODFW's 75th quartile represents Properly Functioning Conditions but also recognize that the middle 50% of the data also represents some level of proper function. From these data, twelve key habitat attributes with particular relevance to Tillamook Basin streams (as identified by the ODFW; Foster et al. 2001) were selected to represent reference/benchmark conditions against which watersheds, subwatersheds, streams and reaches could be assessed. ODF requested the data be summarized by subwatershed (see Table 72 below). To provide managers with decision-making tools relative to specific locations within subwatersheds, however, the data are also presented at the stream- and reach- levels in Appendix P – Summary of Aquatic Habitat Conditions.

Individual streams were not compared to PFCs. Rather, all aquatic habitat variables from all reaches within each subwatershed were compared to ODFW-established reference conditions, pooled by subwatershed, and the *overall* conditions within each subwatershed were then "scored" by calculating the percent of stream reach aquatic habitat conditions falling into each ODFW-established quartile (i.e., what proportion of the key habitat attributes in all stream reaches in a subwatershed are meeting PFCs). Subwatersheds were then rated as Minimally Degraded, Degraded, or Severely Degraded (refer to Table 72 and Table 74 for a complete list of definitions and criteria). It is important to note, however, that some subwatersheds (e.g., Lower Wilson River and Middle Wilson River) contained relatively few surveyed stream reaches. Additionally, the use of LOW and HIGH habitat breakpoints as assessed using relatively recent habitat data (e.g., within the past 20 years) is problematic, but currently the only tool available. Caution, therefore, should be exercised when interpreting the degree to which a subwatershed is rated as properly functioning.

Table 72. Aquatic habitat benchmarks established by the Oregon Department of Fish and Wildlife. Bolded terms represent key habitat attributes.

Habitat Type	**Description**	**Range of Conditions** [1]	
		Low	**High**
POOLS	POOL AREA (% Total Stream Area)	**<19**	**>45**
	POOL FREQUENCY (Channel Widths Between Pools)	>20	5-8
	RESIDUAL POOL DEPTH (m)		
	SMALL STREAMS (<7m width)	<0.2	>0.5
	MEDIUM STREAMS (≥7m & <15m width)		
	Low Gradient (slope <3%)	<0.3	>0.6
	High Gradient (slope >3%)	<0.5	>1.0
	LARGE STREAMS (≥15m width)	<0.8	>1.5
	COMPLEX POOLS (Pools w/ LW [2] pieces ≥3)/km	<1.0	>2.5
	DEEP POOLS (>1m deep/km)	**=0**	**>3**
RIFFLES	WIDTH/DEPTH RATIO (Active Channel)		
	EAST SIDE	>30	<10
	WEST SIDE	>30	<15
	GRAVEL (% Area)	**<26**	**>54**
	SILT-SAND-ORGANICS (% Area) – FINES	**>22**	**<8**
	VOLCANIC PARENT MATERIAL	>15	<8
	SEDIMENTARY PARENT MATERIAL	>20	<10
	CHANNEL GRADIENT <1.5%	>25	<12
SIDE CHANNELS	% SECONDARY CHANNELS	**<0.8**	**>5.3**
POOLS & RIFFLES	BEDROCK (% Area)	**>11**	**<1**
SHADE	(Reach Average, %)	**<76%**	**>91%**
	STREAM WIDTH <12 meters		
	WEST SIDE	<60	>70
	NORTHEAST	<50	>60
	CENTRAL - SOUTHEAST	<40	>50
	STREAM WIDTH >12 meters		
	WEST SIDE	<50	>60
	NORTHEAST	<40	>50
	CENTRAL - SOUTHEAST	<30	>40
LARGE WOOD (LW) [3]	(15cm x 3m minimum piece size)		

Habitat Type	Description	Range of Conditions [1]	
		Low	High
	PIECES / 100 m stream length	**<8**	**>21**
	VOLUME / 100 m stream length	**<17**	**>58**
	"KEY" PIECES (>60cm dia. & ≥10m long) /100m	**<0.5**	**>3**
RIPARIAN CONIFERS	(30m from both sides of channel)		
Western Oregon	NUMBER >20in dbh/1000ft stream length	<150	>300
	NUMBER >35in dbh/1000ft stream length	<75	>200
	NUMBER >20in dbh/1000ft stream length	**<22**	**>153**
	NUMBER >35in dbh/1000ft stream length	**=0**	**>79**

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[1] Established by the Oregon Department of Fish and Wildlife Aquatic Inventories and Analysis Project (Foster et al. 2001) and the Fish Habitat Assessment in the ODF Tillamook Study Area (Kavanagh et al. 2005). High and low values represent stream survey data that fell above and below the 75th and 25th percentiles, respectively. Shaded values represent the 12 key aquatic habitat attribute criteria established using only Oregon Coast reference sites (e.g., they do not include, with the exception of the Umpqua River, Cascadian streams).

[2] Instream large wood

[3] Values for large wood in streams in forested basins

9.10.2 Results

Every subwatershed exhibited key habitat attributes that were skewed toward POOR conditions (Table 73). On the other hand, every subwatershed exhibited key habitat attributes that were skewed toward GOOD conditions (Table 73). In general, most of the reaches in the subwatersheds exhibited LOW pool conditions (e.g., % Pools and Deep Pools; Table 73). In fact, greater than 50% of the surveyed reaches in the Jordan Creek, Middle Wilson, Upper Wilson/Cedar Creek, and South Fork Wilson subwatersheds exhibited LOW levels of % Pools. Jordan Creek, however, *also* exhibited HIGH levels of Deep Pools (Table 73). With the exception of the Jordan Creek and Lower Wilson subwatersheds, most of the subwatersheds exhibited a relatively HIGH % Side Channels (Table 73). The majority of the surveyed reaches contained moderate amounts of % Bedrock but the Upper Wilson/Cedar Creek subwatershed exhibited relatively low % Bedrock (Table 73). Additionally, half of the subwatersheds exhibited a relatively high amount of % Fines (e.g., poor habitat quality; Lower Wilson, Devils Lake Fork, North Fork Wilson, and South Fork Wilson; Table 73).

Table 73. Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories Project habitat condition in the Wilson River watershed. Percent of reaches (and number) by subwatershed (6th Field HUC) of key aquatic habitat attributes falling into LOW and HIGH categories, as specified by ODFW Aquatic Inventories Project. Highlighted boxes represent data that are ≥50% different from benchmark/reference conditions. For aquatic habitat conditions displayed by subwatershed, stream and reach refer to Appendix P – Summary of Aquatic Habitat Conditions.

Habitat Parameter	**Devils Lake Fk . – 26 reaches**			**Jordan Creek – 15[b] reaches**		
	<25% (LOW)	**>25% but <75%**	**>75% (HIGH)**	**<25% (LOW)**	**>25% but <75%**	**>75% (HIGH)**
% Pools	38 (10)	50 (13)	12 (3)	50 (7)*	50 (7)*	0 (0)*
Deep Pools	27 (7)	46 (12)	27 (7)	14 (2)*	21 (3)*	64 (9)*
% Side Channels	8 (2)	50 (13)	42 (11)	13 (2)	67 (10)	20 (3)
% Bedrock	31 (8)	42 (11)	27 (7)	67 (10)	27 (4)	7 (1)
% Fines	31 (8)	54 (14)	15 (4)	7 (1)	87 (13)	7 (1)
% Gravel	31 (8)	65 (17)	4 (1)	80 (12)	20 (3)	0 (0)
# Pieces LW	31 (8)	23 (6)	46 (12)	50 (7)*	43 (6)*	7 (1)*
LW Volume	38 (10)	42 (11)	19 (5)	71 (10)*	21 (3)*	7 (1)*
Key Pieces LW	65 (17)	35 (9)	0 (0)	64 (9)*	29 (4)*	7 (1)*
% Shade [a]	38 (10)	42 (11)	19 (5)	0 (0)	40 (6)	60 (9)
# Conifers >50cm DBH	62 (16)	38 (10)	0 (0)	64 (9)*	36 (5)*	0 (0)*
# Conifers >90cm DBH	96 (25)	4 (1)	0 (0)	100 (14)*	0 (0)*	0 (0)*
Percentage of Reach-parameters by category	41.3% (129/312)	41.0% (128/312)	17.6% (55/312)	48.0% (83/173)	37.0% (64/173)	15.0% (26/173)

[a] Some variables were only assessed in 14 of the 15 stream reaches (denoted with an asterisk*).

[b] Not a quantitative measure.

Table 73 (continued). Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories Project habitat condition in the Wilson River watershed. Percent of reaches (and number) by subwatershed (6th Field HUC) of key aquatic habitat attributes falling into LOW and HIGH categories, as specified by ODFW Aquatic Inventories Project. Highlighted boxes represent data that are ≥50% different from benchmark/reference conditions. For aquatic habitat conditions displayed by subwatershed, stream and reach refer to Appendix P – Summary of Aquatic Habitat Conditions.

Habitat Parameter	Little N. Fk. Wilson – 9 reaches			Lower Wilson – 2 reaches		
	<25% (LOW)	>25% but <75%	>75% (HIGH)	<25% (LOW)	>25% but <75%	>75% (HIGH)
% Pools	22 (2)	67 (6)	11 (1)	0 (0)	100 (2)	0 (0)
Deep Pools	0 (0)	44 (4)	56 (5)	50 (1)	50 (1)	0 (0)
% Side Channels	0 (0)	44 (4)	56 (5)	0 (0)	100 (2)	0 (0)
% Bedrock	22 (2)	67 (6)	11 (1)	50 (1)	50 (1)	0 (0)
% Fines	0 (0)	100 (9)	0 (0)	100 (2)	0 (0)	0 (0)
% Gravel	33 (3)	56 (5)	11 (1)	0 (0)	50 (1)	50 (1)
# Pieces LW	11 (1)	67 (6)	22 (2)	50 (1)	50 (1)	0 (0)
LW Volume	11 (1)	67 (6)	22 (2)	50 (1)	50 (1)	0 (0)
Key Pieces LW	33 (3)	67 (6)	0 (0)	50 (1)	50 (1)	0 (0)
% Shade	33 (3)	0 (0)	67 (6)	0 (0)	0 (0)	100 (2)
# Conifers >50cm DBH	100 (9)	0 (0)	0 (0)	50 (1)	50 (1)	0 (0)
# Conifers >90cm DBH	78 (7)	22 (2)	0 (0)	50 (1)	50 (1)	0 (0)
Percentage of Reach-parameters by category	28.7% (31/108)	50.0% (54/108)	21.3% (23/108)	37.5% (9/24)	50.0% (12/24)	12.5% (3/24)

Table 73 (continued). Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories Project habitat condition in the Wilson River watershed. Percent of reaches (and number) by subwatershed (6th Field HUC) of key aquatic habitat attributes falling into LOW and HIGH categories, as specified by ODFW Aquatic Inventories Project. Highlighted boxes represent data that are ≥50% different from benchmark/reference conditions. For aquatic habitat conditions displayed by subwatershed, stream and reach refer to Appendix P – Summary of Aquatic Habitat Conditions.

Habitat Parameter	Middle Wilson – 7 reaches			N. Fk. Wilson – 9 reaches		
	<25% (LOW)	>25% but <75%	>75% (HIGH)	<25% (LOW)	>25% but <75%	>75% (HIGH)
% Pools	100 (7)	0 (0)	0 (0)	44 (4)	56 (5)	0 (0)
Deep Pools	71 (5)	29 (2)	0 (0)	11 (1)	44 (4)	44 (4)
% Side Channels	0 (0)	43 (3)	57 (4)	0 (0)	56 (5)	44 (4)
% Bedrock	29 (2)	57 (4)	14 (1)	11 (1)	89 (8)	0 (0)
% Fines	14 (1)	29 (2)	57 (4)	33 (3)	44 (4)	22 (2)
% Gravel	43 (3)	57 (4)	0 (0)	22 (2)	78 (7)	0 (0)
# Pieces LW	0 (0)	29 (2)	71 (5)	11 (1)	33 (3)	56 (5)
LW Volume	29 (2)	57 (4)	14 (1)	11 (1)	78 (7)	11 (1)
Key Pieces LW	43 (3)	57 (4)	0 (0)	78 (7)	22 (2)	0 (0)
% Shade	0 (0)	57 (4)	43 (3)	67 (6)	33 (3)	0 (0)
# Conifers >50cm DBH	86 (6)	14 (1)	0 (0)	100 (9)	0 (0)	0 (0)
# Conifers >90cm DBH	100 (7)	0 (0)	0 (0)	100 (9)	0 (0)	0 (0)
Percentage of Reach-parameters by category	42.9% (36/84)	35.7% (30/84)	21.4% (18/84)	40.7% (44/108)	44.4% (48/108)	14.8% (16/108)

Table 73 (continued). Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories Project habitat condition in the Wilson River watershed. Percent of reaches (and number) by subwatershed (6th Field HUC) of key aquatic habitat attributes falling into LOW and HIGH categories, as specified by ODFW Aquatic Inventories Project. Highlighted boxes represent data that are ≥50% different from benchmark/reference conditions. For aquatic habitat conditions displayed by subwatershed, stream and reach refer to Appendix P – Summary of Aquatic Habitat Conditions.

	Upper Wilson/Cedar Creek – 17 reaches			**S. Fk. Wilson – 12 reaches**		
Habitat Parameter	**<25% (LOW)**	**>25% but <75%**	**>75% (HIGH)**	**<25% (LOW)**	**>25% but <75%**	**>75% (HIGH)**
% Pools	65 (11)	35 (6)	0 (0)	83 (10)	17 (2)	0 (0)
Deep Pools	47 (8)	41 (7)	12 (2)	50 (6)	25 (3)	25 (3)
% Side Channels	0 (0)	12 (2)	88 (15)	0 (0)	33 (4)	67 (8)
% Bedrock	6 (1)	41 (7)	53 (9)	8 (1)	67 (8)	25 (3)
% Fines	18 (3)	47 (8)	35 (6)	33 (4)	58 (7)	8 (1)
% Gravel	12 (2)	76 (13)	12 (2)	25 (3)	50 (6)	25 (3)
# Pieces LW	0 (0)	24 (4)	76 (13)	8 (1)	42 (5)	50 (6)
LW Volume	18 (3)	59 (10)	24 (4)	25 (3)	17 (2)	58 (7)
Key Pieces LW	24 (4)	76 (13)	0 (0)	8 (1)	33 (4)	58 (7)
% Shade	29 (5)	18 (3)	53 (9)	0 (0)	58 (7)	42 (5)
# Conifers >50cm DBH	94 (16)	6 (1)	0 (0)	58 (7)	42 (5)	0 (0)
# Conifers >90cm DBH	100 (17)	0 (0)	0 (0)	100 (12)	0 (0)	0 (0)
Percentage of Reach-parameters by category	34.3% (70/204)	36.3% (74/204)	29.4% (60/204)	33.3% (48/144)	36.8% (53/144)	29.9% (43/144)

While stream survey data is compared to these aforementioned benchmark/reference conditions, the ODFW does not rate the overall ecological function of streams or subwatersheds and there are no agency- or literature-established criteria for doing so[96]. To rate the overall aquatic functionality of aquatic habitats (i.e., Proper Functioning Condition [PFC]) in each subwatershed, we established criteria that incorporate ODFW Aquatic Inventories Project-established reference conditions for key aquatic habitat attributes (Table 74). Using ODFW's Aquatic Inventories Project stream survey data, the twelve key aquatic habitat attributes in each reach were compared to benchmark/reference conditions and summed by stream and subwatershed. The Proper Functioning Condition of each subwatershed was rated according to an intuitive set of criteria based upon how the key habitat attribute survey data compared to ODFW-established "benchmark/reference" conditions (i.e., how the observed data compared to ODFW "benchmark/reference" data). Criteria, and the resulting Proper Functioning Condition ratings, are presented in Table 74. In subwatersheds where less than 5 stream reaches were surveyed, Proper Functioning Condition was not rated.

While we have defined different functioning conditions based on how the data fall into discrete quartiles, it is important to note that on-the-ground data represent a *range* of conditions. Therefore, we have attempted to account for this range of conditions by indicating more than one (condition) classification for the subwatershed of interest (see Table 75 for some examples). Additionally, in this ranking scheme, each of the 12 key habitat attributes is weighted equally. If, however, land use managers have reason to believe one or more of the key attributes deserves more weight than another, the overall subwatershed condition rating would change. Finally, because the data are a snapshot(s) in time, long-term habitat monitoring is critically important for accurately capturing and assessing trends in the aquatic conditions in the Wilson River watershed. Nevertheless, the current subwatershed condition ratings provide a baseline against which future ratings can be gauged for determining trends and assessing the effectiveness of protection and/or restoration actions.

Proper Functioning Condition was rated in seven of the eight subwatersheds found in the Wilson River (Table 75). There was not enough stream survey information in the Lower Wilson River subwatershed (e.g., less than 5 surveyed stream reaches) to assess/rate the Proper Functioning Condition. Of the seven subwatersheds rated, none had key habitat attribute data that met the criteria for the "Very Good Condition" (i.e., none were in as good of condition as the ODFW AIP reference streams). Data from one subwatershed (Little North Fork

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[96] Some previous watershed assessments have presented a weighted rating criteria after discussions with managers identified clear rankings of variables.

Wilson), however, was similar enough that it received a GOOD condition rating. Two subwatersheds were rated as being in MODERATE condition (Upper Wilson/Cedar Creek and South Fork Wilson), three were rated at as being POOR condition (Devils Lake Fork, Middle Wilson and North Fork Wilson) and one was rated as being in VERY POOR condition (Jordan Creek; Table 75).

While the PFC ratings are derived from established benchmark/reference conditions, there is no established criteria for rating streams, subwatersheds, or watersheds based on the benchmark/reference conditions. Additionally, while there is certainly broad-scale utility in rating subwatersheds (e.g., to identify long-term condition trends or subwatersheds where restoration activities could be focused), it may be more useful to identify small-scale areas where restoration efforts may be focused (e.g., streams or stream reaches). We have, therefore, provided a detailed list of stream and reach conditions in Appendix P – Summary of Aquatic Habitat Conditions.

Table 74. Definitions and criteria for scoring subwatershed Proper Functioning Conditions (PFCs) based on established "benchmark/reference" aquatic habitat conditions (e.g., ODFW AIP data).

Subwatershed Condition[1]	**Definition**	**Quartile Criteria**[2]			**Data Distribution Curve Description** [1]
		Lower 25%	**Middle 50%**	**Upper 25%**	
VERY GOOD	Aquatic habitat conditions in the subwatershed are functioning in an ecologically appropriate manner	<25	>55	>25	Skewed slightly / heavily right of a normal distribution
GOOD	Aquatic habitat conditions in the subwatershed are *generally* functioning in an ecologically appropriate manner	>20	>45	20-25	Approximately normally distributed (e.g., normally distributed data relative to the ODFW "benchmark/reference" reaches)
MODERATE	Some of the aquatic habitat conditions in the subwatershed are functioning in an ecologically appropriate manner but some are not and/or are threatened by degradation	≤35	≤50	<25	Skewed slightly left of normal
		>25	<50	>25	Elevated lower and upper quartiles, depressed middle quartile
		<25	>50	<25	Depressed lower and upper quartiles, elevated middle quartile
POOR	Many of the aquatic habitat conditions in the subwatershed have been degraded and are not functioning in an ecologically appropriate manner	>35	≤50	<25	Skewed comparatively left of normal
VERY POOR	Most of the aquatic habitat conditions in the subwatershed have been degraded and are not functioning in an ecologically appropriate manner	>45	≤50	<20	Skewed heavily left of normal

[1] As compared to the reference watershed data compiled in the ODFW Coastal stream survey data.

[2] "Benchmark/reference" conditions established by the Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories and Analysis Project (Foster et al. 2001) and the Fish Habitat Assessment in the ODF Tillamook Study Area report (Kavanagh et al. 2005).

Table 75. Proper Functioning Condition ratings for Wilson River subwatersheds based on the percent (and total number) of key habitat attributes in all stream reaches falling into each of three Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories Project habitat rating quartile categories.

Subwatershed	**# Stream Reaches**	**<25% (LOW)**	**>25% but <75%**	**>75% (HIGH)**	**Proper Functioning Condition Rating [a]**
Devils Lake Fk.	26	41.3% (129/312)	41.0% (128/312)	17.6% (55/312)	POOR
Jordan Cr.	15 [b]	48.0% (83/173)	37.0% (64/173)	15.0% (26/173)	VERY POOR
Little N. Fk. Wilson	9	28.7% (31/108)	50.0% (54/108)	21.3% (23/108)	GOOD
Lower Wilson	2	37.5% (9/24)	50.0% (12/24)	12.5% (3/24)	Na
Middle Wilson	7	42.9% (36/84)	35.7% (30/84)	21.4% (18/84)	POOR
N. Fk. Wilson	9	40.7% (44/108)	44.4% (48/108)	14.8% (16/108)	POOR
Upper Wilson/Cedar Cr.	17	34.3% (70/204)	36.3% (74/204)	29.4% (60/204)	MODERATE
S. Fk. Wilson	12	33.3% (48/144)	36.8% (53/144)	29.9% (43/144)	MODERATE

[a] Proper Functioning Condition was not rated for subwatersheds with fewer than 5 surveyed stream reaches.

[b] Some of the key habitat attributes were only recorded by ODFW Aquatic Inventories Project surveyors in 14 of the 15 surveyed stream reaches.

9.11 Instream Large Wood

The purpose of this section is to summarize the amount of instream large wood (LW) observed during ODFW Aquatic Inventory Project (AIP) surveys. Discussions pertaining to both modeled riparian and landslide LW contributions can be found in sections

9.11.1 Methods

The Oregon Department of Fish and Wildlife (ODFW) conducted extensive stream habitat surveys throughout the State beginning in the early 1990's and they continue through to today. To 1) assess current aquatic habitat conditions and 2) develop reference/benchmark habitat conditions relevant to Oregon coastal streams, the ODFW conducted a Tillamook Basin analysis of aquatic habitat data collected from 1991 through 2003 (Kavanagh et al. 2005). Additional aquatic habitat data were collected by ODFW in 2004 and 2006. Both sets of data are presented below.

The ODFW defines key pieces of large instream wood as having a diameter greater than 2 feet (60 centimeters) and greater than or equal to 33 feet (10 meters) in length and breaks the number of key pieces of large instream wood per 330 feet (100 meters) of stream length into three categories (Foster et al. 2001). According to these reference criteria, stream reaches that contain more than 3 pieces of large instream wood per 330 feet (100 meters) constitutes a HIGH level, reaches containing less than 0.5 pieces per 330 feet (100 meters) constitutes a LOW level, and reaches containing from 0.5 to 3.0 pieces per 330 feet (100 meters) constitutes a moderate level. It is important to note that relatively few streams within each subwatershed were surveyed and results should be interpreted accordingly.

9.11.2 Results

Data from ODFW aquatic habitat surveys conducted in 2004 and 2006 indicate that 53% of stream reaches surveyed in the Wilson River watershed (51 of 96) contained moderate to HIGH levels of key pieces of wood while 47% (45 of 96) contained LOW levels of key pieces of wood (Table 76). Of the stream reaches rated moderate to HIGH, however, only 8 of 96 (8.3%) were rated as having a HIGH number of key pieces of large wood (Table 76). At the subwatershed scale, the South Fork of the Wilson River, the Upper Wilson/Cedar Creek, the Little North Fork of the Wilson River, the Middle Wilson River and the Lower Wilson River all had 50% or better of the stream reaches rated moderate or HIGH for key pieces of large wood (91.7%, 76.5%, 66.7%, 57.1% and 50%, respectively), while the only subwatershed with 25% or less of the stream reaches rated moderate or HIGH was the North Fork of the Wilson River (Table 76), making it a good candidate for activities that will lead to increased instream large wood recruitment. At the reach scale, one reach in Jordan Creek (1 of 11 reaches; Jordan Creek subwatershed), four reaches in the mainstem of the South Fork Wilson (4 of 6 reaches; South Fork Wilson subwatershed) and three reaches in tributaries to the South Fork Wilson (3 of 6 reaches; South Fork Wilson subwatershed) contained high levels of key pieces of wood (Table 76).

Table 76. Number of stream reaches, by stream and subwatershed, with low, medium, and high levels of key pieces of wood (# key pieces/100m). Data summarized from Oregon Department of Fish and Wildlife's (ODFW) Aquatic Inventories Project surveys (see Appendix P – Summary of Aquatic Habitat **Conditions** for details).

		Number of reaches per category		
Subwatershed	Stream (# reaches) ^{1}	LOW (<0.5 pieces)	medium (≥0.5≤3.0)	HIGH (>3.0 pieces)
Devils Lake Fk.	Devils Lake Fk. (8)	8	0	0
	Deyoe Cr. (4)	0	4	0
	Drift Cr. (1)	1	0	0
	Elk Cr. (4)	3	1	0
	Elliot Cr. (5)	3	2	0
	Idiot Cr. (2)	2	0	0
	W. Fk. Elk Cr. (2)	0	2	0
Jordan Creek	Jordan Cr. (11)	6	4	1
	S. Fk. Jordan Cr. (3)	3	0	0
Little N.Fk. Wilson	Berry Cr. (2)	0	2	0
	Little N. Fk. Wilson (6)	3	3	0
	White Cr. (1)	0	1	0
Lower Wilson	Kansas Cr. (2)	1	1	0
Middle Wilson	Fall Creek (7)	3	4	0
N. Fk. Wilson	Rodgers Cr. (2)	2	0	0
	Rodgers Cr. Tribs (4)	4	0	0
	W.Fk.N.Fk. Wilson (3)	1	2	0
Upper Wilson/ Cedar Creek	Ben Smith Cr. (4)	1	3	0
	Cedar Cr. (7)	3	4	0
	Jones Cr. (3)	0	3	0
	N. Fk. Cedar (3)	0	3	0
S. Fk. Wilson	S. Fk. Wilson (6)	1	1	4
	S. Fk. Wilson Tribs (6)	0	3	3
TOTALS	**# streams (# reaches)**			
Devils Lake Fk.	7 (26)	17	9	0

		Number of reaches per category		
Subwatershed	Stream (# reaches) [1]	LOW (<0.5 pieces)	medium (≥0.5≤3.0)	HIGH (>3.0 pieces)
Jordan Cr.	2 (14)	9	4	1
Little N. Fk. Wilson	3 (9)	3	6	0
Lower Wilson	1 (2)	1	1	0
Middle Wilson	1 (7)	3	4	0
N. Fk. Wilson	3 (9)	7	2	0
Up. Wilson/Cedar	4 (17)	4	13	0
S. Fk. Wilson	2 (12)	1	4	7

[1] Summarized from ODFW Aquatic Inventories Project aquatic habitat stream surveys conducted in the Wilson since 2001.

9.12 Splash-Damming and Effects

While splash-damming was commonplace in the Tillamook River, it was a technique apparently not utilized in the Wilson River (Sedell and Duval 1985). Instead, large log drives that occurred during high water events were the norm (Farnell 1980) and occurred as far upstream as the Lee’s Camp area (~30 miles upstream of tidewater; Sedell and Duval 1985). Even though Farnell (1980) mentions that log drives occurred in the Wilson River basin as far upstream as 22.5 miles, there is no factual evidence of log drives upstream of head of tide. There is, however, stream channel evidence of log drives (refer to Map 20) on the Wilson River which were apparently utilized between 1893 and 1908 (Farnell 1980). There is insufficient information, however, pertaining to the effects these log drives may have had on the Wilson River. Potential effects from log drives may have included increased bank erosion (from log scouring), increased sedimentation rates from bank erosion, decreased riparian vegetation (from log scouring), removal of naturally-occurring large wood accumulations (from “flushing” as wood rafts built up behind them or purposely by humans in preparation for log drives), and displacement of streambed gravels/substrates (Sedell and Duval 1985).

9.13 Fish Passage Barriers

Access to quality habitats is one of the keys to salmonid survival in the Wilson River watershed. Salmon need an unrestricted network of connected streams to ensure genetic diversity and long-term survival (Roni et al. 2002). Connected fish-habitat depends, in part, on successful fish passage through culverts. Culverts at road stream crossings can become impassable for several reasons. Fish moving upstream may be unable to enter a culvert because the culvert outlet is suspended at a height too high for a fish to jump. Culverts can become clogged with debris that prevents fish passage. Steep gradient culverts may increase water velocity making fish passage impossible or very restricted, and water depth in a culvert may become too shallow for fish to swim.

Culverts are relatively easy to inventory and evaluate; they are located along roads that are accessed by vehicle or on foot. Managers can determine which culverts are obstacles to fish passage and decide whether to replace or repair a culvert. This simple determination is a necessary component to a successful salmon-river restoration plan. First, however, culverts need to be inventoried and classified as to their overall functionality.

In 2006, workers from Duck Creek Associates, Inc. surveyed all the open and blocked roads in the Wilson River watershed. Every stream crossing was rated in terms of the likelihood that the stream supported fish. Surveyors' classified streams while at a stream crossing as either fish bearing, likely fish bearing, unlikely fish bearing, or no fish presence. This was based solely on professional judgment that included estimating stream gradient (> 20% = no fish) and visually inspecting downstream of a culvert for an obvious natural barrier to upstream migration such as a waterfall. Additionally, surveyors judged whether or not adult and juvenile fish could pass through a particular culvert based on the gradient of the culvert, debris blocking the culvert, and the general condition of the culvert.

Surveyors identified 926 stream crossings, of which 144, or 16%, were considered (known, likely or observed) barriers to fish-passage (Table 77, Maps 58-59). Blockage types described by surveyors range from collapsed and sediment filled culverts to blocked inlets and outlets and well as perched culverts.

Table 77. Results from the 2006 field assessment of culverts. Barriers to fish passage were classified as an observed barrier, a likely barrier, a possible barrier, or no barrier at all to adult and juvenile fish.

Barrier Type	Observed Barrier	Likely Barriers	Possible Barriers	No Barriers
Adult and Juvenile	1	15	105	100
Juvenile Only	2	10	11	NA
No Fish	NA	NA	NA	682
Total	3	25	116	782

For the purposes of this assessment, we estimated the number of miles of potential fish habitat blocked to upstream migrations. Miles of potentially blocked habitat was measured in a GIS by overlaying the stream crossing point layer on the ODFW stream layer. First the intersection of the stream crossing, stream, and road layers were located, then we used the measuring tool to determine the length of "verified" or "assumed" fish habitat that had been blocked by the barrier. As described in the GIS metadata associated with the stream layer, "verified" and "assumed" are designations of fish presence. Table 78 lists the number of miles of potential fish habitat blocked by culvert barriers. Adult barriers block a slightly higher percentage of potential habitat than do juvenile only barriers. There were 313 stream miles designated as fish habitat. Nearly 25 miles or 7.8% of potential habitat are blocked by impassable culverts (a detailed list of the road location of these barriers is given in Appendix Q – Fish Barriers).

Table 78. Miles of potential fish habitat blocked by culvert barriers along roads in the Wilson River watershed. Potential fish habitat refers to the ODFW designation of verified and assumed fish presence.

Age Class Barrier	Miles of potential habitat blocked	Percent of total fish bearing streams
Adult Barrier	14.3	4.6
Juvenile barrier	10.3	3.3
Total	**24.6**	**7.8**

Beaver. Each stream crossing was evaluated for the effects of beaver activity. Beaver activity was noted at 10 of the 926 stream crossings.

9.14 Priority Streams

The ability to identify particular streams or stream segments where protective measures would likely produce the greatest overall benefit to aquatic health is of particular importance to natural resource managers. To date, however, no comprehensive criteria existed whereby natural resource managers could select geographic areas in which to concentrate protective/restorative measures based upon a clearly-defined prioritization scheme. Duck Creek Associates, in conjunction with ODF staff, identified several factors critical to the protection of aquatic resources and developed a process for prioritizing where those activities would be likely to produce the greatest overall beneficial impacts to aquatic resources.

9.14.1 Methods

In order to develop a scheme for prioritizing stream reaches where, if protected and/or restored, would provide the greatest overall beneficial impacts to aquatic resources, we identified several factors known to be of particular importance. They included:

- the presence of ODF Salmon Anchor Habitat/s (SAH),
- areas of high fish use (e.g., high juvenile density[97]), as measured during the 2005 Tillamook Basin Rapid Biological Assessment (RBA; Bio-Surveys)[98],
- areas of high fish habitat intrinsic potential[99] (IP; see discussions in Chapter 4 Stream Channels and Channel Modification and Appendix E – Detailed Methodologies),
- areas of anadromous fish spawning and rearing, as identified by ODFW fish use GIS layers (e.g., Type 1),
- areas of anadromous fish rearing and migration, as identified by ODFW fish use GIS layers (e.g., Type 2), and
- the presence of fish-bearing streams (Type F), as identified by ODF GIS layers.

After identifying their relative importance to ODF, we combined them into a logical prioritization scheme. Consequently, the list can be used as a screening tool – when overlayed in a GIS – to identify streams and stream reaches that are of particular importance to aquatic resources. We did not include the presence of listed (state and/or federal) or candidate fish species because of the tenuous and changing nature of species listings. They could be included in future stream/stream reach identification scenarios, however, if managers deemed it appropriate. Additionally, to the best of our knowledge, no chum salmon juvenile density data for the Wilson River watershed exists[100] nor are there literature-established values for defining their habitat IPs.

The resulting prioritization scheme took the following form (in order of importance from greatest to least):

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[97] Density data (# fish/square foot) from the 2005 RBA were divided into quartiles and the 75th quartile was used as the breakpoint for defining "high density". Coho >0.587; steelhead >0.127, cutthroat >0.122.

[98] GIS layers were not yet available for the 2006 RBA survey but will eventually be available from the Tillamook Estuaries Partnership offices located in Garibaldi, OR and online at www.tbnep.org.

[99] Species-specific habitat intrinsic potentials are discussed in great length in Burnett et al. 2007 where values ≥0.75 are considered "high" (unless otherwise specified, we assumed the same).

[100] There are, however, outmigrant smolt trap data for chum salmon from the Little North Fork Wilson subwatershed.

1. SAH overlayed with areas of high fish density (or where density information is lacking, high IP),
2. SAH,
3. Areas outside of SAH with high fish density (or where density information is lacking, high IP),
4. Areas where multiple anadromous fish species spawn and rear,
5. Areas where multiple anadromous fish species rear and migrate,
6. Areas where a single anadromous fish species spawns and rears,
7. Areas where a single anadromous fish species rears and migrates,
8. Fish-bearing streams, and
9. Areas of high IP but where no fish are present.

9.14.2 Results

Salmon Anchor Habitats (SAHs) occur in the Little North Fork Wilson, Upper Wilson/Cedar Creek (including Ben Smith Creek), and Devils Lake Fork subwatersheds. When overlayed with areas of high fish density and – where density information is lacking – high IP, two stream sections (both in the Little North Fork Wilson subwatershed) were identified (Table 79).

Chum salmon are likely not well represented by the fish stream/reach prioritization scheme. They do not occur[101], however, on ODF lands and because 1) they are generally only present during cooler months (e.g., fall/winter) and 2) their young enter the ocean before the warmer summer water temperatures, chum salmon are not likely to be negatively influenced by current ODF management practices.

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[101] Official ODFW species presence/absence layers do not depict chum salmon in waters on ODF lands. However, ODFW Fish Biologists on the Tillamook district (Keith Braun and Dave Plawman) note that chum salmon have been observed on ODF/BLM matrix lands.

Table 79. Priority stream reach categories (ranked from low to high) for protection and/or restoration.

Prioritization Attributes	Subwatershed Name	Miles in Wilson River[1]	Length (mi) and Percent on ODF lands
Non-fish-bearing streams but with high IP	Devils Lk Fk	0.23	0.15 (64)
	Jordan Cr	0.07	0.07 (100)
	Little N Fk Wilson	0.11	0.11 (100)
	Middle Wilson	0.05	0.05 (100)
	Upper Wilson/Cedar Cr	0.10	0.10 (100)
Fish-bearing streams	Devils Lk Fk	60.09	51.66 (86)
	Jordan Cr	33.96	28.36 (84)
	Little N Fk Wilson	38.30	29.91 (78)
	Lower Wilson	52.55	15.16 (29)
	Middle Wilson	26.62	23.67 (89)
	N Fk Wilson	41.05	28.68 (70)
	S Fk Wilson	32.94	32.94 (100)
	Upper Wilson/Cedar Cr	41.69	34.78 (83)
Rearing and migration corridors used by a single anadromous species	No streams match this query	NA	
Spawning and rearing corridors used by a single anadromous species	No streams match this query	NA	
Rearing and migration corridors used by multiple anadromous species	Lower Wilson	1.49	0.0 (0)
Spawning and rearing corridors used by multiple anadromous species	Devils Lk Fk	5.95	5.67 (95)
	Jordan Cr	3.40	3.38 (99)
	Little N Fk Wilson	2.49	1.62 (65)
	Lower Wilson	5.70	0.79 (14)
	Middle Wilson	4.08	3.41 (84)
	N Fk Wilson	4.03	3.30 (82)
	S Fk Wilson	2.56	2.56 (100)
	Upper Wilson/Cedar Cr	4.82	3.59 (74)
Areas outside of SAH but with high density and high IP	Devils Lk Fk	2.99	
	Jordan Cr	4.07	
	Lower Wilson	14.57	
	Middle Wilson	9.31	
	N Fk Wilson	5.99	
	S Fk Wilson	3.38	
Areas inside of SAH and with high density and high IP	Little N Fk Wilson	0.19	
	Devils Lk Fk	2.65	2.65 (100)

[1] Includes all stream in the Wilson River watershed, not just streams occurring on ODF lands.

9.15 Key Findings and Recommendations

None of the anadromous salmonid species inhabiting the Wilson River watershed are currently listed as *Threatened* or *Endangered* under the federal Endangered Species Act (ESA; refer to Table 63 in section 9.3 Native and Introduced Salmonids). Numerous species/stocks, however, including several non-salmonids, are listed by the state as *Sensitive/Vulnerable* or *Sensitive/Vulnerable* (Table 63). While no introduced salmonids, except the summer steelhead stock/race, are known to occur in the Wilson River, information pertaining to the introduction and establishment of non-salmonid species is severely lacking. Additionally, information pertaining to native non-salmonid abundance and distribution is non-existent.

Although the Tillamook Bay estuary is likely to be the conduit for potential introduced species invasions, we recognize that such introductions may occur off ODF lands. However, because some invasions can have far-reaching and catastrophic effects on local, native populations, we recommend that ODF maintain a close working relationship with the ODFW and Tillamook Estuaries Partnership to identify, in the early stages, potential invasions by non-native species.

Historic salmonid distributions are likely very similar to their current distributions (Kavanagh et al. 2005) and current abundances, with the exception of fall Chinook salmon, are likely severely depressed compared to their pre-European abundances. Indeed, abundance counts from the past 50+ years, with few exceptions, generally indicate decreasing abundances coupled with high variability, underscoring the tenuous nature of many of these stocks/runs (refer to sections 9.7 – Historic Salmonid Abundance and 9.8 – Current Salmonid Abundance for more detailed information). Accordingly, extra precaution should be employed when considering whether a species will be impacted by management actions. Additional caution is urged when considering the effects of multiple actions within relatively discrete geographic areas (e.g., individual streams).

Because of the high variability in peak abundance counts, we recommend extreme caution when interpreting the effectiveness of restoration activities, especially over the short-term. Additionally, the effectiveness of restoration projects should be repeatedly assessed over the course of several years and even decades. Furthermore, long-term monitoring activity costs should be included when calculating future projects' costs.

Fish habitats in the Wilson River watershed have been significantly influenced by both natural and human-caused disturbances. The Tillamook Burn fires and subsequent timber harvest and road-building activities significantly altered the types and availability of high-quality aquatic habitats present in the Wilson. Perhaps the most significant effect was the removal of large wood from the system, both from the streams ("stream-cleaning") and from the riparian (fires and subsequent harvest). The lack of instream large wood pieces (see section 9.10 – Fish Habitat Condition) is likely having a detrimental effect on the overwintering abilities of juvenile salmonids and on the accumulation of gravels, especially in the Jordan Creek subwatershed where 80% of the surveyed stream reaches exhibited LOW percent gravel, HIGH percent bedrock and LOW percent pools, relative to ODFW "reference/benchmark" reach data (Table 73; although this may partially be a relic of historic log drives).

Data for several key habitat attributes from reaches throughout the various Wilson River subwatershed often are not apportioned according to ODFW's Aquatic Inventories Project (AIP) reference reach data. When considered collectively, however, the data may suggest that aquatic habitat conditions in the Wilson River are still exhibiting some level of functionality. For example, data for conditions within the Little North Fork of the Wilson subwatershed are fairly evenly distributed among the LOW, moderate and HIGH categories (28.7%, 50%, and 21.3%, respectively), indicating that its aquatic habitat conditions are likely functioning in a manner similar to other coastal watersheds that have experienced relatively little human disturbance (refer to section 9.10 – Fish Habitat Condition). Key habitat attribute data from the Jordan Creek subwatershed, on the other hand, are skewed relatively heavily toward LOW categories (48% LOW, 37% moderate, 15% HIGH), indicating that its aquatic habitat conditions may be compromised. Indeed, two other subwatersheds exhibit similar patterns (Devils Lake Fork and North Fork Wilson). In contrast, key habitat attribute data for the Upper Wilson/Cedar Creek, Middle Wilson and South Fork Wilson subwatersheds indicate only a moderate distributional skew away from reference conditions (refer to section 9.10 Fish Habitat Condition).

In order to develop a scheme for prioritizing stream reaches, we identified several factors known to be of particular importance (see section 9.14 Priority Streams for details). After identifying their relative importance to ODF, we combined them into a logical prioritization scheme. The resulting list (also detailed in section 9.14 – Priority Streams), organized by decreasing importance and (generally) increasing land area, can be used as a screening tool – when overlayed in a GIS – to identify streams and stream reaches that are of particular importance. These streams/reaches, if protected and/or restored, would provide the greatest overall beneficial impacts to aquatic resources. Priority streams/reaches occur in every subwatershed (see Table 79 in section 9.14 – Priority Streams) and ranged in length from less than 0.1 miles to more than 60 miles with most of the reaches occurring in large, contiguous chunks (as opposed to fragmented). Because of the presence of Salmon Anchor Habitats, the subwatersheds with the highest priority streams all occur in the Little North Fork Wilson, Upper Wilson/Cedar Creek (including Ben Smith Creek), and Devils Lake Fork subwatersheds. Not surprisingly, this result also *generally* corresponds with subwatersheds where aquatic habitat conditions were in MODERATE to GOOD shape (compared to ODFW "reference/benchmark" streams). The identification and placement of future conservation and restoration measures could largely be informed using this list to identify areas of concern.

Additionally, when evaluating fish abundance estimates, aquatic habitat conditions, habitat intrinsic potentials (IP), and core coho and steelhead habitats in conjunction with each other, subwatersheds can be compared to assess where *initial* restoration efforts could be focused. For example, aquatic habitat conditions in the Upper Wilson/Cedar Creek and the Little North Fork Wilson were rated as being in MODERATE and GOOD condition (respectively), the subwatersheds contains high IP for coho and steelhead, areas of high core habitat for coho and steelhead, and contributes relatively large numbers of coho, steelhead and cutthroat trout. Restoration efforts in these subwatersheds, therefore, would be a low priority, relative to other subwatersheds. Conversely, aquatic habitat conditions in the Devils Lake Fork and the South Fork Wilson were rated as being in POOR and MODERATE condition (respectively), yet the subwatershed contains areas of high IP and core habitats for coho and steelhead, contribute relatively large numbers of coho salmon and cutthroat trout but produces relatively few steelhead. Therefore, restoration efforts in these subwatersheds could be focused on improving aquatic habitat conditions (e.g., increasing the number of pools and pieces of large wood), primarily for steelhead (low abundances), but also for coho, which are likely to re-listed. Likewise, aquatic habitat conditions in Jordan Creek and the Middle Wilson were rated as being in VERY POOR and POOR condition (respectively), the subwatersheds contain areas of high IP and core habitat for steelhead (but none for coho), yet they produce relatively few of both[102]. Restoration efforts here could be focused on increasing the number of pools, number of deep pools (primarily in the Middle Wilson), percent gravel and large wood.

Two actions would arguably have the largest beneficial impact on aquatic wildlife and their associated habitats:

1. encouragement of instream large wood recruitment in landslide- and debris-flow prone areas in and upstream of high priority aquatic areas,

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[102] The exception being that portions of non-HUC-classified streams in the Wilson that produced coho and steelhead may be part of the Middle and Lower Wilson subwatersheds. Refer to Table 69 and the Tillamook Estuaries Partnership's 2005 and 2006 Rapid Biological Assessments.

2. placement of instream large wood in and upstream of high priority aquatic areas.

As key pieces of large wood begin to recruit to (or are placed in) the streams, we would expect to see an increase in pool frequency, decreases in the number of habitats where bedrock dominates, increases in gravels, and increases in aquatic cover associated with wood accumulations. It is important to note, however, that the effectiveness of instream large wood depends on size of the receiving channel, size of the piece(s) of wood and the probability that large wood additions will accumulate (related to channel roughness, meander, riparian vegetation, wood size/length, etc.). Our modeling results indicate that riparian stands will be unable to provide adequate functional wood throughout the next century for streams of about 30 feet in width and greater. Streams of this width are at the upper end (and beyond) the size range generally recommended for large wood placement (e.g., ODF & ODFW 1995). Nevertheless, these are the streams with highest value for fish and the lowest potential for large wood recruitment (see Maps 31, 32, 33, and 37). It will be worthwhile, therefore, to look for opportunities for stable wood placement within these general areas. The models used an estimate of average channel width, and do not capture details of spatial variability in channel configuration: some reaches within the channels identified as high priority for fish, and low potential for riparian recruitment of functional wood, will fall within the range of channel widths and slopes recommended for wood placement (page 5 in ODF & ODFW 1995). These are the sites to look for.

In summary, there has been a decreasing abundance in most species in the last 50+ years, aquatic habitat conditions are moderately impaired, and the Little North Fork Wilson is in the best overall aquatic shape (and the high fish numbers generally reflect this). On the other hand, aquatic conditions in the Jordan Creek, Devils Lake Fork, Middle Wilson and North Fork Wilson subwatersheds are in the poorest shape and, with the exception of the North Fork Wilson where numbers are high and the Devils Lake Fork where coho numbers are high, fish numbers generally reflect this. Additionally, there are low amounts of instream large wood and numbers of pools (including deep pools) throughout the watershed. Adhering to the management recommendations mentioned above will help to 1) ensure adequate funding for long-term monitoring activities, 2) reduce the likelihood that an exotic species invasion will go unnoticed for some time, 3) reduce sedimentation and erosion and increase riparian shade (in some areas), 4) restore fish passage to useable habitat, 5) enhance the recruitment of large wood to streams thereby improving aquatic habitat complexity, and 6) maintain (or enhance) aquatic habitat conditions throughout the Wilson.

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10 Synthesis

10.1 Watershed Condition

Overall, the Wilson River watershed appears to be in relatively reasonable functioning condition (i.e., functioning in an ecologically appropriate manner); the current conditions largely the result of the human-induced disturbances that have occurred over the last 100+ years. However, the watershed is largely recovering from these disturbances and is in an intermediate recovery phase. Although a few notable exceptions exist, current management activities are generally promoting this recovery. The ensuing discussion explores these ideas further.

Successful management of any watershed includes identifying factors (current and projected future) that limit riparian and aquatic resources and implementing management strategies that work to remove them. In the Wilson River watershed, the following features are not currently limiting factors:

- stream temperature and discharge,
- water use and withdrawal,
- sedimentation from landsliding, and
- hydrologic connectivity of roads.

The following watershed features are currently limiting (some aspect[s] of) riparian and/or aquatic resources:

- large pieces of instream wood (current),
- conifer large wood recruitment to streams,
- instream channel complexity (e.g., few pools, low percent gravel, low off-channel habitats, etc.). Additionally,
- highway fill is limiting channel migration and flood flows in some lower sections of the Wilson; see Map 20 and Table 7), and
- numerous stream crossings are currently acting as barriers (or potential barriers) to fish migration (adults and/or juveniles; see Table 38).

The following watershed features are considered potential (current) and/or future limiting factors:

- stream crossings rated as having a high washout potential (see Table 35),
- some dispersed camping and OHV recreation areas are acutely impacting riparian vegetation and sedimentation in some areas (projected to increase with increased OHV use; see sections 6.7 and 7.5), and
- stream temperatures and/or shade conditions are projected to become limiting in several principal streams in the Wilson (based on modeled results; see Table 62).

Since European settlement, the Wilson River watershed has experienced widespread natural and human-influenced disturbance. Although current timber harvest and riparian management practices adhere to widely-accepted standards (e.g., Forest Management Practices), much of the watershed has been heavily impacted by past management practices (e.g., timber harvesting, wildland fire activities, road building, conversion of lowlands to agricultural production, stream cleaning, etc.). While the Wilson is currently in a state of recovery, the combined effects of legacy and current practices are largely evident in:

- the young, even-aged riparian forest stands,
- the low potential for near- and long-term large wood recruitment to streams
- the low amounts of instream large wood,
- the low number of pools (including deep pools),
- the lack of instream diversity,
- the relatively high number of stream crossings that
    - exhibit a high washout potential and
    - are potentially blocking fish passage,
- and the quantity of road segments, trails, and dispersed recreation sites that are actively eroding to streams.

Although recovering, these legacy effects – particularly from the Tillamook Burns and subsequent road-building and logging activities – are still having a moderate to high impact on the Wilson. Furthermore, riparian and large wood recruitment modeling exercises indicate the legacy effects will continue to impact the Wilson into the foreseeable future (e.g., >100 years). Because there are no examples on which to base the recovery of a watershed after these kinds of large-scale disturbance events, it is difficult to determine how far along in the recovery process the Wilson River watershed is.

Conversely, the negative effects of current management practices on overall watershed condition are considered relatively low. Effects on hydrology, for example, are currently considered negligible. There are, however, exceptions. For instance, we found that some recreational activities (e.g., dispersed camping near streams/wetlands, unrestricted OHV use of non-designated trails) are negatively influencing sedimentation, riparian vegetation, and washout risk in some areas.

Despite the relatively low impact of current management practices, there are distinct opportunities to adjust management activities to promote watershed recovery. Limiting recreational use and focusing restoration efforts on streamside areas will likely have a beneficial impact on the recovery of riparian areas. Fixing stream crossing with high washout potential and removing fish blockages will reduce sedimentation and open up additional areas for fish spawning, migration and rearing (although the degree to which this will aid in the recovery of a species is unclear). Additionally, tailoring riparian and upland silvicultural treatments for the enhancement/recruitment of large wood may help the aquatic habitat conditions recover at a faster rate.

In summary, while many basic biological and ecological requirements are largely being met by the current conditions in the Wilson, the lack of large wood (riparian and aquatic; especially conifers) is arguably having the largest impact on aquatic habitat complexity (e.g., lack of pools, deep pools, large wood accumulations, cover, low gravels, etc.) and large wood recruitment is projected to remain below target levels well into the next century.

10.2 Summary of Answers to Questions

Below is a list of Oregon Watershed Enhancement Board (OWEB) Critical and Oregon Department of Forestry (ODF) Key Supplemental historic and current condition questions. Questions are organized into resource categories (loosely corresponding to the primary chapters in this document) by their origin (i.e., OWEB or ODF) and abbreviated answers are provided below. Readers looking for more detailed discussions should refer back to the previous chapters/sections where individual topics are addressed.

10.2.1 Historical Condition Questions

OWEB Critical Question: What were the characteristics of the watershed’s resources at the time of the European exploration/settlement?

The historical characteristics of Tillamook Bay (and the Wilson River watershed) prior to the mid-1800's are not well documented (refer to section 3.2.1 Early European Settlement) and our current understanding of the natural resources during exploration and settlement is limited to a handful of written accounts from early explorers and pioneers and to research into and accounts from Native American culture. What can be gleaned, however, is that the Tillamook Basin was rich in natural resources (e.g., fish, shellfish, crab, berries, roots big game, large timber, etc.), was subject to periodic natural and anthropogenic disturbances (e.g., fire, landsliding, etc.; refer to sections 3.4.1, 3.4.2, 3.4.3, and 3.5.2), and that the vegetative communities resembled what they are today (section 3.2.2).

OWEB Critical Question: What are the historical trends and locations of land use and other management impacts?

Historical land use and management impacts included periodic burning by Native Americans. European settlers cleared large sections of the lowlands and tidal areas, drained wetlands, and diked the rivers for agricultural use. Much of the uplands were heavily logged and/or burned over (both naturally- and human-influenced) and, with some exceptions, replanted primarily with one species of tree, the Douglas fir. Additionally, copious roads were installed in much of the watershed after the Tillamook Burns (refer to sections 3.3.1, 3.3.2, 3.4, and 3.5).

OWEB Critical Question: What are the historical accounts of fish populations and distributions?

Fish population accounts are relatively sparse. Early historic fish population data come primarily from gill-net fisheries but more detailed records, including spawning and redd counts were collected by ODFW starting around the middle of the last century (mid-1950's). Recent research into pre-European fish abundance, coupled with historic government agency abundances data, indicate many fish species/stocks had considerably larger populations compared to recent counts/estimates. Prior to the middle of the last century, almost no information exists pertaining to fish distributions. Furthermore, no known information exists pertaining to historic non-salmonid abundances and distributions. See sections 9.3, 9.5, and 9.7.

ODF Key Supplemental Question: What natural disturbances (floods, windstorms, fires) occurred in historic times? Discuss their impact on the aquatic ecosystem. Compare how these impacts have changed over time. In particular, note changes due to European settlement or changes in land management practices.

Periodic natural disturbances in the Wilson included fire, windstorms, and flooding. Fires frequency and severity have decline over the last 50+ years while relatively recent (e.g., <15 years) flooding and windstorm events have registered as some of the largest on record (with frequency in the last 20+ years) and peak flow discharge has increased in the last 40 years. Modeled landslide and debris-flow disturbances are also a natural part of the Wilson. See sections 3.4, 4.8, 5.3, 7.1.1, 7.2, and 7.3.

ODF Key Supplemental Question: What is the management history of the forestland in the watershed (e.g., salvage logging, replanting of burned areas)?

Early European settlers cleared large areas of timber in the lowlands near waterways, and, as technologies progressed, further up into the watershed. Early harvest operations were cut and burn and replanting after harvest didn't become commonplace until the mid-1900's. After the Tillamook Burns, huge tracts of land were salvage logged and replanted, usually with a single species (Douglas fir). See sections 3.3.1, 3.5.1, 3.5.2, and 3.5.3.

10.2.2 Current Condition Questions

10.2.2.1 Stream Channels

OWEB Critical Question: What is the distribution of channel habitat types throughout the watershed?

Because the channel habitat type classifications were not of primary interest, results from the analysis are presented in Appendix F – Classification of Stream Channel Habitat Types.

OWEB Critical Question: What is the location of channel habitat types that are likely to provide specific aquatic habitat features?

We developed a classification of stream channel habitat types and modeled the Habitat Intrinsic Potential (IP), habitat core areas, biological hotspots and channel disturbance areas. High coho IP areas occurs primarily in the lower South Fork Wilson and upper Devils Lake Fork subwatersheds, with a smaller amount in the Upper Wilson/Cedar Creek subwatershed. High steelhead IP areas occur throughout the Wilson but are generally relegated to the upper portions of the principal tributaries (e.g., 6th-field HUCs). Core steelhead areas occur throughout the Wilson in every subwatershed. Biological hotspot areas (>0.8) occur on approximately 14% of the fish-bearing network. See Maps 13-18 and sections 4.3, 4.4, and 4.5.

OWEB Critical Question: What is the location of areas that may be the most sensitive to changes in the watershed condition?

Sensitive channels in the Wilson occur primarily in headwater streams and are found throughout the subwatersheds with the highest concentration of channels found in the Little North Fork Wilson and the Cedar Creek portion of the Upper Wilson subwatersheds (see Map 19 and section 4.6).

ODF Key Supplemental Question: Where are channel modifications located?

Channel modifications have occurred throughout the Wilson but have been primarily restricted to the mainstem Wilson River corridor (along the highway; see Map 20 and section 4.7).

ODF Key Supplemental Question: Where are historic channel disturbances located (e.g., splash dams, stream cleaning)?

Historic channel disturbance (largely from previous reports) from log drives occurred as far upstream as the Lee’s Camp area (~31 miles upstream). Log drives in the Wilson ended in 1908 and no splash-dams are known to have occurred in the Wilson. Historic records indicate that stream cleaning (e.g., removing log jams) occurred extensively in the Wilson at least until the early 1970’s (end of records; see section 4.8).

ODF Key Supplemental Question: What channel habitat types have been impacted by channel modification?

The majority of channel habitat types in the Wilson impacted by channel modification occur off of ODF lands. Where they do occur on ODF lands, they occur primarily in less-responsive, steep and/or confined segments and are found in the North Fork Wilson and Jordan Creek subwatersheds (Table 8; see section 4.9).

ODF Key Supplemental Question: What are the types and relative magnitude of the past and current channel modification?

Answers to this question are found within the various sections that discuss channel modifications (see sections 4.7, 4.8, and 4.9).

10.2.2.2 Hydrology and Water Use

OWEB Critical Question: What land uses are present in your watershed?

Land uses were previously discussed in sections 3.3.1, 3.3.2, and 3.5.

OWEB Critical Question: What is the flood history in your watershed?

Periodic flooding is relatively commonplace in the Tillamook Basin. The largest recorded peak flow event occurred on November 6th, 2006. Since stream gage records were first kept in the Wilson, seven of the nine annual events that had recurrence intervals of 10 years or greater have occurred since 1970 (see sections 3.4.2 and 5.2).

OWEB Critical Question: Is there a probability that land uses in the basin have a significant effect on peak flows?

Results from the Distributed Hydrology Soil Vegetation Model (DHSVM) indicate that land use has affected peak flows in some streams in the Wilson River watershed, especially after the Tillamook Burns (e.g., 6.4% increases in total discharge). Neither changes in vegetation or roads, however, appear to have a significant effect on modeled changes in peak flows (see section 5.3).

OWEB Critical Question: Is there a probability that land uses in the basin have a significant effect on low flows?

Results from the DHSVM modeling exercise indicate that current vegetation conditions and roads have had little effect on mean low flows in the Wilson River watershed. While many of the smaller drainages show large percent increases (e.g., the Little North Fork), the magnitude of change is very small (hundredths of a cfs; see section 5.3).

OWEB Critical Question: For what beneficial use is water primarily used in your watershed?

Only four new water rights have been applied since publication of the 2001 Wilson River Watershed Assessment. Three are for manufacturing-related use of water, and the fourth (from a well) is for irrigation. Collectively these new application are for less than 0.01% of the total instantaneous withdrawal rate already allocated. Consequently, the values reported in the 2001 Wilson River Watershed Assessment are not modified from what was originally reported. The majority (~70%) of water is appropriated in the Lower Wilson River watershed, is used for irrigation, and is removed from the Wilson below the confluence with the Little North Fork (i.e., very low in the system). The second largest use for appropriated water (~30%) is for municipal and domestic water supplies, which is also withdrawn primarily in the Lower Wilson River subwatershed (see section 5.2.2).

OWEB Critical Question: Is water derived from a groundwater or surface water source?

The majority (> 90%) of appropriated waters are from surface, rather than groundwater, sources (see section 5.2.2).

OWEB Critical Question: What type of storage has been constructed in the basin?

No significant water storage has been constructed in the watershed (see section 5.5.2.2).

OWEB Critical Question: Are there any withdrawals of water for use in another basin (inter-basin transfer) or is water being imported for use in the basin?

No inter-basin transfer occurs, beyond the application of water withdrawn from the Wilson River to irrigated lands in the adjacent Trask River watershed and no water is being imported for use in the basin (see section 5.5.2.2).

OWEB Critical Question: Are there any un-permitted uses of water occurring in the basin?

It is not known to what extent (if at all) un-permitted uses of water are occurring in the basin (see section 5.5.2.2).

OWEB Critical Question: Do water uses in the basin have an effect on peak or low flows?

Consumptive water use does not exceed the estimated volume of natural stream flow in any month, either in average (50% exceedance flows) or dry (80% exceedance flows) years. Consumptive use of water is far below the amount available in all months. When the instream water right is added to consumptive uses, however, there is insufficient flow to meet all uses during the months of August – October in average years, and in May, July – October in dry years. Instream flow rights, although they have a late priority date, should be adequate in maintaining ample flows needed by salmonids and other aquatic species (see section 5.5.2.3).

ODF Key Supplemental Question(s): The OWEB Critical Questions sufficiently address ODF's concerns. Therefore, there are no ODF Key Supplemental Questions relating to hydrology and water use.

10.2.2.3 Riparian and Wetlands

OWEB Critical Question: What are the current conditions of the riparian areas in the watershed?

In terms of species composition, approximately two-thirds of the watershed riparian zones are dominated by mixed conifer-hardwood species. This “Mixed” forest type is characterized as a stand having ≤80% of the observed basal area in a single species, and is typified by the Douglas-fir and red alder community type in shifting proportions of co-dominance. Hardwood-dominated sites occur throughout the watershed, representing ~22% of all riparian acres, and 24% of ODF riparian zones. Conifer-dominated stands were less prevalent, representing only 13% of the riparian land area in the watershed (see section 6.1.5 – Riparian Vegetation Current Conditions).

OWEB Critical Question: How do the current conditions compare to those potentially present or typically present for this Ecoregion?

The majority of the riparian vegetation of the Wilson River watershed is in an early-mid successional state, with a mixed hardwood-conifer forest composition in varying degrees of co-dominance. The series of stand-replacement fires followed by multiple salvage logging events ending in the 1950s defined the current vegetation to a near complete stand-replacement in the uplands and riparian zones for the watershed as a whole.

The potential vegetation types of the Wilson River will likely include a mosaic of even-aged stands for many years, as the current stand structure matures, and mortality due to self-thinning (stem exclusion phase) carries through to the next growth cycle (10-30 years). These stand types differ from others that are characteristic of this Ecoregion for the primary reason that the large-scale disturbances were so complete in removal of older, established trees. The diversity of vertical structures is dramatically reduced in the current condition from the potentially multi-layered stand structure that existed prior to Euro-American settlement. See sections 3.2.2 – Vegetation and 6.1.5 – Riparian Vegetation Current Conditions.

OWEB Critical Question: How can the current riparian areas be grouped within the watershed to increase our understanding of what areas need protection and what the appropriate restoration/enhancement opportunities might be?

The current mapping efforts for the riparian zones followed a similar classification scheme for mapping upland vegetation, using a series of vegetation codes to estimate species mix, size class and stem density. These units were typically 1,500 feet long and 100 foot wide, and contained a range of patch diversity over a shifting longitudinal stream profile. The results indicated that this form of classification did not provide enough resolution for determining adequate placement for field sample sites to determine statistically sound and accurate stand composition and structure inventory data. As such, the classification scheme was beneficial for a watershed-level assessment to evaluate stand compositional dynamics, shade, and LW recruitment at the broad scale. Additionally, the vegetation classifications – when overlayed with landslide/debris flow hazards – identified coarse-scale areas where large wood development/recruitment may benefit from stand treatments and where it may not.

In 2008, ODF will acquire high-resolution LiDAR data of the Wilson River watershed (and others), which contains a minimum of the bare earth and canopy height elevations for the watershed. These data can be used to further identify manageable units, suitable for site-specific treatments to enhance (at a minimum) conifer growth and establishment and increasing the potentials for LW recruitment in the time period beginning in ~2050 – 2100. These manageable units will likely be small in size (~1-2 acres) and should contain elements of topography (terraces, benches, usable slopes, etc), canopy characteristics, and vegetative composition in the mapping effort. This form of riparian mapping and management is different from traditional forestry mapping and operations at large scales, but allows for traditional on-the-ground patch-level treatment prescriptions and operations. See section 6.3.2 – Pathways for Management Action.

OWEB Critical Question: Where are the wetlands, ponds, and lakes in this watershed?

The highest concentration of wetlands is located in the Lower Wilson River subwatershed (~570 acres) located off of ODF Lands (see section 6.4 and Map 40).

OWEB Critical Question: What are the general characteristics of wetlands, ponds, and lakes in the watershed?

The major wetland types on ODF lands included freshwater forested and emergent wetland types. The overall condition of the wetlands and ponds within ODF lands is generally good; road influence may cause increased siltation in some areas, though there appears to be relatively intact riparian buffers available to slow sediment delivery. In areas where management has occurred near wetland areas, standing tree buffer areas appear to be present on ODF lands (see section 6.4).

OWEB Critical Question: What opportunities exist to restore wetlands in the watershed?

As part of a Best Management Practice, it is important to evaluate areas of potential emergent wetland environments and provide mechanisms of buffer enhancement to increase the success of wetland establishment. This is especially true for lower gradient systems where beaver activity is observed. Accommodation of natural disturbance processes, such as beaver activity, provides the mechanisms necessary to create patch diversity of wetland communities. Minimizing recreational and other land-use impacts in these areas would increase the potential for wetland diversity in the watershed (see section 6.4).

ODF Key Supplemental Question: What are the current riparian vegetation characteristics on state forests lands within the watershed?

At the subwatershed scale (Figure 9 and Table 19), the distribution of ODF-managed riparian zones is highly biased toward mixed conifer/ hardwood types; mixed types ranged between ~48% and 73% of each subwatershed riparian areas. Hardwood dominated types were abundant (~20 – 49%) in all subwatersheds except Devils Lake Fork (7%) and the SF Wilson (16%) subwatersheds, where conifers were more prevalent (28 and 22% conifers, respectively). See section 6.1 – Riparian Composition and Structure.

ODF Key Supplemental Question: Which riparian areas currently have high, moderate, and low large wood input potential for key conifer pieces (>24-inch conifer)?

Because the riparian structure and composition is currently following an early-mid successional trend toward a stem-exclusion phase, a pulse of instream large wood (LW) is expected to be generated in the next 50 years from self-thinning mortality. This material is mostly hardwood, with few large pieces (>24 inches). In addition, the data suggest there are progressively fewer conifer trees that will be recruited to the canopy through time, and with a notable decline in conifer tree mortality (and recruitment to the stream channel) through time. Overall, the Wilson River riparian zones are not projected to provide key conifer wood that meets >24 inch standards under a non-managed scenario. The Devils Lake Fork and South Fork Wilson River subwatersheds are expected to attain the highest large conifer densities per 1,000 feet of stream channel, though these numbers are expected to remain under current ODFW benchmarks. See section 6.2 Potential Future Conditions.

ODF Key Supplemental Question: Which riparian areas will provide high large wood input potential for key conifer pieces under 50- and 100-year scenarios? Map these areas. Additionally, map areas of low and moderate wood input for each scenario.

The models run as part of this analysis and field observation suggest the canopy dynamics are currently in a ‘stem exclusion’ phase, where the overstory canopy is represented by small diameter trees in a period of growth stagnation from competing canopy pressures. The long-term outlooks suggest a decline in the number of trees entering the canopy strata through time, and more importantly, the rate by which trees will enter the canopy strata. The latter is of particular importance as it indicates a long-term trend of current trees getting larger in diameter (an ODF priority), but less replacement of those larger trees from the younger size classes of today. Hence, as the fewer, larger trees die, there does not appear to be a replacement cohort for those large-diameter trees in the future. These combined observations strongly suggest the trajectory of the riparian zones in all subwatersheds will not meet the definitions of "mature forest conditions" (see section 6.2 Potential Future Conditions).

ODF Key Supplemental Question: Are there known concentrations of noxious weeds in the riparian areas? Where do these problem areas exist?

The presence of Scotch broom (*Cytisus scoparius*), garlic mustard (*Alliaria petiolata*) and Japanese knotweed (*Polygonium cuspidatum*), are of growing concern to the health of the watershed. Invasion vectors for these species include recreation, equipment use, roads, and imported material from infested areas (e.g., road fill). See section 6.5 – Noxious and Non-native Weed Species.

ODF Key Supplemental Question: To what extent do recreational activities impact riparian vegetation?

Results based on ODF's dispersed campsite database indicate that OHV impacts and unrestricted use of riparian areas have significant impacts on riparian vegetation. The two most frequently reported impacts were tree damage and soil compaction – both of which have direct and indirect impacts on riparian vegetation health (see section 6.7 – Recreational Impacts on Riparian Vegetation – Direct and Indirect Effects).

10.2.2.4 Sediment Sources

Sediment sources questions and answers have been broken down into four distinct categories: general questions, non-road-related questions, road-related questions, and recreation-related questions.

10.2.2.1.1 General Questions

OWEB Critical Question: What are the current sediment sources in the watershed and their relative significance?

The primary sources of sediment in the watershed are shallow-rapid landslides, debris flows triggered by shallow-rapid landslides, roads, and off-highway-vehicle trails. The effects and significance of these sources differ with process. Landslides and debris flows are natural events important to ecological processes in the watershed, but management-related increases in landslide rate and reductions in large wood available for recruitment to channels by landslides and debris flows have severe and cumulative detrimental effects to the watershed ecosystem. The watershed is recovering from increased rates of landsliding and reduced rates of landslide-carried wood delivery following extensive fires, salvages logging, and timber harvest in landslide-prone areas over the past century. The slow rate of tree growth will cause landslide and debris-flow delivery of large wood to channels to be persistently reduced from natural rates well beyond the next century. Roads and off-highway-vehicle trails are not natural features: both contribute fine sediment and roads are a source of landslides. Although site-specific inputs have significant local effects, overall these are not significant sources of sediment in the watershed.

OWEB Critical Question: Are any new sources of sediment anticipated in the watershed?

No.

OWEB Critical Question: Where are erosion problems most severe and qualify as high priority for remedying conditions in the watershed?

The lack of large wood in debris flow source areas and runout corridors poses the most severe problem associated with erosional processes in this basin.

10.2.2.1.2 Non-Road-Related Questions

ODF Key Supplemental Question: What is the distribution of slopes prone to shallow, rapidly moving landslides on state forest lands within the watershed?

All slopes in this basin exceeding 60% are subject to shallow, rapidly moving landslides. They are ubiquitous, but less common in the eastern portion of the basin, in the eastern Lower Devils Lake Fork and the South Fork of the Wilson. These are discussed in Chapter 7 and shown in Map 33.

ODF Key Supplemental Question: What is the distribution of debris flow-prone channels on state forest lands within the watershed?

All Type N channels with upslope debris flow source areas are debris-flow prone. They are ubiquitous throughout the watershed, although found in lesser quantities in the eastern portion of Lower Devils Lake Fork and the South Fork Wilson. Debris-flow-prone Type N channels are identified and ranked in Map 29 (section 7.2.2.1) and the Type F channels that receive these debris flows are identified in Map 26 (section 7.2.2.2). Debris flows may also contribute to formation of destructive debris-laden floods through Type F channels; channels most likely to experience debris-laden floods are identified in Map 28 (section 7.2.2.3).

ODF Key Supplemental Question: Are there locations with gullies or other active surface erosion areas in the watershed?

Gullies and extensive surface erosion do not form under typical conditions in the watershed. Activities that compact soil or processes that reduce soil permeability, such as wild fire, can trigger development of gullies and active surface erosion.

ODF Key Supplemental Question: Are there deep-seated, actively or recently actively moving landslides?

Small to moderate deep-seated landslides do occur in the watershed (on steep and planar slopes) and do contribute to road damage and production of sediment to stream channels. There have been an insufficient number of these landslides to characterize their sensitivity to management activities, but their deeper depth suggests that loss of root strength from forest cover is not a contributing factor. At times, these landslides can be major sources of sediment to channels and valley floors.. At present they are unpredictable and should be considered part of the natural (background) disturbance regime (see section 7.3 – Deep-seated Landslides).

ODF Key Supplemental Question: Are there any unusually erosion prone soils on steep slopes in the watershed?

Surface erosion in undisturbed (i.e., non compacted) forested soils is negligible because soil infiltration capacity typically exceeds precipitation intensity (Harr 1977) and soil compaction is minimal outside of roads and landings.

10.2.2.1.3 Road-Related Questions

ODF Key Supplemental Question: What portion of the road network is located in critical locations?

Approximately 20% of the road network is found in locations classified as “critical” (see section 7.4 – Road-Related Issues).

ODF Key Supplemental Question: What is the washout risk of roads within the watershed? Are road washouts present?

Along open roads ~46% of stream crossings are considered Low Washout potential; ~44% Moderate; and ~10% High. Along blocked roads ~42% of stream crossings are considered Low Washout Potential; ~16% Moderate: 15% High; and ~27% were washed out (see section 7.4.6.2 – Washout Risks).

ODF Key Supplemental Question: What proportion of the road system is hydrologically connected to streams?

Approximately 16% of the open road system is hydrologically connected while ~10% of the blocked roads are hydrologically connected (see sections 7.4.3 – Hydrologic Connectivity and 7.4.7 – Reducing Hydrologic Connectivity at Stream Crossings). However, the December 2007 storm event likely changed the hydrologic connectivity of some roads. A census of some of the areas we identified as suspect could help determine what proportion the hydrologic connectivity status of the road system has changed, if any.

ODF Key Supplemental Question: What are the surface drainage conditions of the roads?

Surface drainage is best reported in conjunction with hydrologic connectivity and prism stability to determine short term risk to the watershed. We found that 30 miles, or ~5% of the total roads in the Wilson River watershed, are actively delivering sediment to streams. Of those 30 miles, 16 miles, or 53% of the delivering total originates from blocked roads, while 14 miles, or 47% originates from open roads (see sections 7.4.3 through 7.4.11).

ODF Key Supplemental Question: What is the condition of the road prism?

Prism ratings categorize the extent to which a landslide or erosion is affecting a road prism. Approximately 10.5% of the open roads have significant blocking by landslides or erosion (Prism Stability Codes 1-3). Blocked roads have nearly 23% of the total rated as Stability Code 1-3 (see section 7.4.5 – Prism Stability).

10.2.2.1.4 Recreation-Related Questions

ODF Key Supplemental Question: To what extent do OHV trails and other recreational activities impact stream sedimentation?

Sedimentation is most acute where eroding trails intersect adjacent streams or road drainage systems linked to streams. Results from a field survey indicate that approximately 2.0 acres per mile are disturbed and 1,157 cubic yards of soil loss per mile of OHV trail. Where ODF has placed and maintained drainage features on designated trails, the sediment is successfully being diverted to the forest, but on unmaintained hydrologically connected trails, sediments can/are flowing directly into road drainage systems and streams (see section 7.5 – Recreation-Related Issues).

ODF Key Supplemental Question: What portion of the recreational trail network is located next to streams?

Of the OHV trails surveyed (42.7 total miles or about 28% of the total trail system), 2.1% ran parallel to streams. Data were unavailable for determining the percentage of other unsurveyed user-created trails that were parallel to streams. More accurate figures, therefore, were not available (see sections 7.5.1 – Off-Highway Vehicle Trails and 7.5.4 – Hydrologically Connected Trails). Because the exact number of OHV trails in the basin are unknown, this may not be a representative sample of the whole designated and undesignated trail network.

ODF Key Supplemental Question: What is the washout risk of recreational trails within the watershed? Are trail washouts present?

Of the trail-stream intersections that have no mitigating trail drainage engineering, bridging, and/or that exhibit trail grade/slope alignment in excess of trail standard maximums, almost half (of the surveyed trail-stream crossings) were found to have “high” or “moderate” washout potential. Additionally, 3.11 miles of sampled trails were found to have Prism Stability Priority Codes of 1-3 (Map 56; see section 7.5.7 – Recreational Trail Washout Risk).

ODF Key Supplemental Question: What proportion of the trail system is hydrologically connected to streams?

Of the OHV trails surveyed (42.7 miles; ~28% of the total trail system), 2.1% are hydrologically connected, indicating that about 7.3% of the total trail system (an estimated 150 total trail miles) is hydrologically connected (Map 55). Data were unavailable for determining the percentage of other unsurveyed user-created trails that were connected to streams. More accurate figures, therefore, are not available (see sections 7.5.1 – Off-Highway Vehicle Trails and 7.5.4 – Hydrologically Connected Trails). Because the exact number of OHV trails in the basin are unknown, this may not be a representative sample of the whole designated and undesignated trail network.

ODF Key Supplemental Question: What is the erosion condition of the trails?

Sedimentation is most acute where eroding trails intersect adjacent streams or road drainage systems linked to streams. Results from a field survey indicate that approximately 2.0 acres per mile are disturbed and 1,157 cubic yards of soil loss per mile of OHV trail. Where ODF has placed and maintained drainage features on designated trails, the sediment is successfully being diverted to the forest, but on unmaintained hydrologically connected trails, sediments can/are flowing into drainages (see sections 7.5.5 and 7.5.7). Additionally, the field assessment of trails found more highly eroding and hydrologically connected trails than were identified by the Duck Creek Associates survey, suggesting a greater degree of erosion than what was indicated in the road condition survey (see section 7.5.5 – Trail Erosion Condition).

10.2.2.5 Water Quality

OWEB Critical Question: What are the water quality criteria that apply to the stream reaches?

Dissolved Oxygen limited from river mile 3.5 to 10.1 (Highway 101 to the confluence with Little North Fork) from September 15 - May 31 and from river mile 5.8 to 27.2 (approximately 4 miles downstream of the confluence with Little North Fork up to Lee’s Camp) from September 1 - June 15 (Table 55; see section 8.2 – Water Quality Criteria, Limited Sections, and Status).

OWEB Critical Question: Are the stream reaches identified as water quality limited segments on the 303(d) list by the state?

Yes. From river mile 3.5 to 10.1 was listed in 2002 and from river mile 5.8 to 27.2 was listed in 2006 (Table 55; see section 8.2 – Water Quality Criteria, Limited Sections, and Status).

OWEB Critical Question: Do water quality studies or evaluations indicate that water quality has been degraded or is limiting the beneficial uses?

Since 2001, water quality in the Wilson has improved for the temperature, nitrogen, and bacteria criteria while the dissolved oxygen criteria was extended further upstream between the 2002 and 2006 water quality assessments. Temperature and bacterial contamination issues were addressed as part of the Tillamook Bay Watershed Total Maximum Daily Load (TMDL), completed by the Oregon Department of Environmental Quality (ODEQ 2001; see section 8.2 – Water Quality Criteria, Limited Sections, and Status).

ODF Key Supplemental Question: What stream temperatures are reasonably achievable under natural conditions, given climatic and geologic constraints?

The final model for predicting reasonably achievable stream temperatures included the following variables: effective shade, solar radiation, streamflow index, and air temperature. Modeled stream temperatures are presented in section 8.4 – Stream Temperatures, Reasonable Achievable and Compared to Potential Levels and Appendix V – Longitudinal T_{max} Profiles for all Principal Streams.

ODF Key Supplemental Question: How do the current shade levels along streams compare to historic levels by sub-watershed and stream size?

Current shade levels are predicted to increase for approximately the next 50 years, followed by a decrease that mirrors the projected decrease in riparian canopy cover (see sections 8.3 – Stream Shading and 6.2 – Potential Future Conditions).

ODF Key Supplemental Question: How do the current stream temperature levels compare to historic levels by sub-watershed and stream size?

The riparian shade and water temperature analysis conducted as part of this project focused on current and projected future conditions. However, given that past (pre-fire) riparian conditions likely included mature conifer stands (see discussion above), it is likely that current stream temperatures are elevated above historic levels (see section 8.4 – Stream Temperatures, Reasonable Achievable and Compared to Potential Levels).

ODF Key Supplemental Question: How do water temperatures compare to other nearby basins with similar flows and geology?

The only other nearby river basin with similar flow and geology is the Trask River watershed. Results from a one-tailed t-test comparing temperatures in the Trask and Wilson rivers indicate that temperatures in the Trask River are approximately 2 degrees Fahrenheit cooler than in the Wilson ($p < 0.001$; see section 8.5 – Stream Temperature Comparison with Adjacent Basins).

ODF Key Supplemental Question: Which specific dispersed recreation sites adversely affect water quality?

Results from 1) an analysis of ODF's dispersed campsite inventory and 2) an additional field sample of sites indicate that 33 dispersed recreation sites are located within 25 feet of a stream and 19 sites were rated as producing streamside damage (Table 25 in section 6.7.2.1 – Dispersed Campsite Inventory Data). Of the 18 sites visited during a field assessment, 13 were located within 10 feet of the high water mark of a stream, 3 were within 20-50 feet of a stream and observations of human impacts included direct erosion to the stream channel or wetlands, site-level tree mortality, severe compaction, and multiple user-defined trails to the stream channel (see Table 26 in section 6.7.2.2 – Field Sample of Dispersed Campsites; also see Appendix B – Photographic Plates, plate numbers 9-13, and sections 7.5.10 – High Priority Dispersed Camping Sites and 7.5.12.4 – Dispersed campsite upgrades).

10.2.2.6 Fish and Fish Habitat

OWEB Critical Question: What fish species are documented in the watershed? Are any of these currently state- or federally listed as endangered, threatened or candidate species? Are there any fish species that historically occurred in the watershed that no longer occur there?

Six salmonids (steelhead trout, cutthroat trout, Chinook, chum, pink[103] and coho salmon), three species of lamprey (Pacific, river, Western brook lamprey), two species of sturgeon (Green and White sturgeon), and several species of non-game fish have either been documented in, or – where records are lacking – are presumed to inhabit[104] the Wilson River watershed. No species are currently Federally- or State- listed as *Threatened* or *Endangered* (several are, however, Federally-listed as *Species of Concern* or State-listed as *Sensitive* and *Critical* or *Vulnerable*; see Table 63 in section 9.2 – Species, Listings, and Extinctions). There are no species that historically occurred in the Wilson River watershed but are no longer found there

OWEB Critical Question: What is the distribution, relative abundance and population status of salmonid species in the watershed?

Salmonids are distributed throughout each of the Wilson River subwatersheds. In general, cutthroat trout have the largest distribution while chum salmon have the narrowest. Additionally, there is substantial intra-annual variation in their distributions, based largely upon respective life history differences. Adult abundance (spawner) estimates have fluctuated considerably in the years since records were first kept and, with the exception of fall Chinook salmon, have exhibited declines. The salmonid population status' have not changed since the 2001 assessment (E&S Environmental Chemistry) but the recent population trends (e.g., <15 years) has. Refer to sections 9.5 through 9.9.

OWEB Critical Question: Which salmonid species are native to the watershed, and which have been introduced to the watershed?

With the exception of summer steelhead, all salmonids found in the Wilson River watershed are native to it (see section 9.3 – Native and Introduced Salmonids).

OWEB Critical Question: Are there potential interactions between native and introduced species?

Summer steelhead trout are currently the only introduced salmonid known to inhabit the watershed. They are, however, reportedly not naturally reproducing (see footnote #89). Given their presence in the system and the similarity of their habitat/food preferences to other native salmonids, it is likely that summer steelhead are negatively interacting with native salmonids (e.g., occupying habitat, consuming food resources, behavioral interactions) but the extent and severity is unknown (see section 9.4 – Native/Introduced Species Interactions).

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[103] Juvenile pink salmon were documented in a smolt trap on the Little North Fork Wilson in 2003. Dave Plawman (ODFW-Tillamook Fish Biologist), personal communication, July 12, 2007.

[104] Based upon geographic species distributions and/or documented presence in nearby river systems.

OWEB Critical Question: What is the condition of the fish habitat in the watershed (by subwatershed) in relation to Proper Functioning Condition targets or baselines?

Subwatersheds were rated relative to the condition in ODFW-established "reference/benchmark" reaches. Of the eight subwatersheds in the Wilson River, one was rated as being in GOOD condition (Little North Fork Wilson), three were rated as being in MODERATE condition (Middle Wilson, Upper Wilson/Cedar Creek, South Fork Wilson), two were rated as being in POOR condition (Devils Lake Fork and North Fork Wilson), one was rated as being in VERY POOR condition (Jordan Creek) and one was not rated (Lower Wilson) due to sample size issues with the data (see section 9.10 – Fish Habitat Condition).

ODF Key Supplemental Question: What are the levels of in-channel key pieces of large wood (>24-inch conifer) in the watershed?

Levels of instream key pieces of large wood in Wilson River subwatersheds are generally very LOW (<0.5 pieces/mile); 47% of the total stream reaches surveyed had a LOW number of key pieces of instream large wood. Only the Jordan Creek and South Fork Wilson subwatersheds had any reaches that had a HIGH (>3.0 pieces/mile; 1 and 7 reaches, respectively) number of key pieces of instream large wood (8% of the total stream reaches surveyed; see section 9.11 – Instream Large Wood).

ODF Key Supplemental Question: If splash-damming occurred in this watershed, are the effects still apparent?

Splash-damming is not known to have occurred in the Wilson River watershed. Log drives, however, were known to occur. The effects, however, have not been well mapped and, to a large degree, are likely to have recovered or in the process of recovery (see section 4.8 – Historic Channel Disturbances and 9.12 – Splash-Damming and Effects).

ODF Key Supplemental Question: What is the distribution of fish species, by life stage, in the watershed?

Existing data layers for the Wilson River do not specify the distribution of salmonids by life stage. Rather, they specify whether a particular species use is for 1) spawning and migration or 2) rearing and migration. The vast majority of each species distributions within the Wilson fall into the spawning and rearing use category (see Maps 5-8 and section 9.6 – Current Salmonid Distributions).

ODF Key Supplemental Question: What is the estimated historical fish presence?

Information pertaining to their distribution at the time of European settlement through the early 1900’s, however, is virtually non-existent. Recognizing this, the Oregon Department of Fish and Wildlife (ODFW) conducted an analysis to identify areas above current fish distributions that could have potentially supported salmon/steelhead in the past (Kavanagh et al. 2005). Although somewhat speculative in nature, the results indicate that historic salmon distributions may have been similar to their present distributions[105] (see section 9.5 – Historic Salmonid Distribution).

ODF Key Supplemental Question: How many miles of fish-bearing or potentially fish-bearing streams are blocked by culverts, and where are these blockages?

There are an estimated 24.6 miles (or 7.8% of the total miles [313] of designated fish habitat in the Wilson) of *potential* fish habitat that are blocked by impassable culverts (see Table 78 in section 9.13 – Fish Passage Barriers). Of the total percent blocked by culverts(7.8%), 4.6% are effective adult salmonid barriers and 3.3% are only barriers to juvenile salmonid movement. For a detailed list of the road location of these barriers, refer to Appendix Q – Fish Barriers).

10.3 Management Considerations

10.3.1 General

The Wilson River watershed is prone to periodic, large-scale disturbances. Large storm events lead to flooding and landsliding, resulting in debris-flows and torrents. Historic catastrophic fires with long fire-return intervals, combined with periodic storm events, historically recruited large wood and sediments to the system creating a rich, diverse freshwater habitat. Since European settlement, the watershed has been exposed to a variety of human-influenced events including frequent forest fires, creation of a dense network of forest roads, increasing forest recreation use and intense timber harvest.

It is important to consider that the riparian ecosystem has essentially been reset to an early-successional, even-aged, hardwood-dominated forest which modeling exercises predict, in the absence of management, is likely to persist for 100+ years. Furthermore, the Wilson has abundant steep, landslide-prone slopes and steep, mainstem channels that often confined and highly sensitive to management activities. For example, road building on steep slopes may lead to road failure

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[105] See maps 17 and 18 in Kavanagh et al. 2005.

and increased sedimentation to fish-bearing streams. Additionally, dispersed recreational trails on erosion-prone steep slopes that are hydrologically connected can dramatically increase sediment loading. While landsliding and debris-flows deliver sediments and large wood that is beneficial as aquatic habitat, increased fine sediments can inhibit survival of salmonid eggs and decrease the amount of available spawning gravel. Given that salmonid populations are depressed compared to historic levels and recent return rates are highly variable, management actions influencing these areas should be carefully considered.

While the road system in the Wilson is dense and some human-influenced barriers to fish movement exist, improvements to the existing infrastructure and well-designed new roads have largely eliminated sedimentation and fish passage issues. ODF-managed lands in the Wilson are currently being (or are attempting to be) managed to effectively address key issues influencing water quality and aquatic life. Additionally, continuation of current projects that address sedimentation and fish passage issues will help the watershed (e.g., speed up) continue its process of recovery.

Hydrologically, the Wilson has recovered from the Tillamook Burns evidenced by modeled low and peak flows that are ≤3% of baseline flows. Water quality issues (e.g., low dissolved oxygen, high stream temperatures, localized sedimentation), however, are still present during some portions of the year and streamside roads, chronic recreation-related impacts, and projected decreases in shade (under a “no management” scenario) are likely to continue to degrade water quality.

Sedimentation in the Wilson has been of considerable concern, especially after the Tillamook Burns and subsequent logging and road-building activities. However, current sediment sources from landsliding and debris flows should be considered at or near (e.g., slightly elevated) background levels as aerial and field surveys indicate that these types of disturbances were occurring in the Wilson prior to European settlement. This watershed analysis, however, has identified road segments that are actively eroding to streams that might increase sedimentation above background levels.

Riparian areas in the Wilson were essentially “reset” during the Tillamook Burns and are in an early seral stage (early recovery). This is evidenced by a general lack of large diameter trees and a relatively uniform age structure. Additionally, modeling results indicate that in the absence of active management, current riparian conditions are likely to persist into the foreseeable future (e.g., >100 years). Furthermore, few trees are projected to recruit to the larger diameter size classes, resulting in a lack of large wood recruiting to streams. Silvicultural prescriptions designed to encourage the production and recruitment of large conifers may help speed the recovery of both riparian and aquatic habitat condition.

Recreational activities in the Wilson have been occurring since settlement but large-scale activities (e.g., OHV riding and camping) are relatively recent and increasing at a rapid rate. Sedimentation and streamside shading impacts are of the greatest concern and are severe in some areas. The extent to which these activities are occurring throughout the watershed is not fully known but year-round use levels are considered chronic (as opposed to episodic) and will likely remain high.

From an aquatic habitat standpoint, the Wilson is still largely experiencing the legacy effects of past management practices evidenced by the lack of instream large wood, pools (including deep pools) and relatively low channel habitat complexity. While aquatic habitat conditions in the Wilson are recovering, three of the eight subwatersheds received a MODERATE to GOOD proper functioning condition rating but four of the subwatersheds are in POOR or VERY POOR condition. Even though modeling exercises predict large wood will recruitment to the streams at very low levels over the next 100+ years, accumulations of wood (and gravels) from natural landsliding and debris flows may help the system recover aquatic habitat complexity faster than predicted.

For specific management recommendations, refer to sections 10.3 – 10.8, below.

10.3.2 Data

The current riparian dataset for the watershed provides a broad and detailed view of the composition and structural attributes organized at the subwatershed scale. However, it does not provide the level of detail required to design or organize *site-specific* silvicultural prescriptions. This is primarily due to the inherently patchy nature of the riparian zones and extreme heterogeneity within riparian stands. Despite this, the combined field-collected and photo-interpreted stand data provide a basis for identifying candidate stands for silvicultural treatments that produce large wood. The best resource for assessing any given stand for both large-wood potential and the best silvicultural approach is the field forester. We have identified areas that appear to have a high potential (at the coarse scale) for developing large wood (Map 63). These areas can be considered a “list” of potential sites that require evaluation by a professional forester.

The current road dataset provides a comprehensive and detailed snapshot of current conditions in the Wilson (winter 2006). Additionally, it is a robust dataset that may be analyzed to identify the number and location of stream crossings that have a high potential for washing out and blocking fish passage. The dataset also provides information on the location of roads that actively erode sediment to streams. Storm events can change conditions on the ground, so managers should inspect stream crossings and areas of high erosion potential after such events.

Although ODF has some current recreation data which was used for general site condition summaries, it is insufficient to draw strong conclusions about the overall condition or priority status of recreational sites in the Wilson. We recommend that future surveys include current and established recreational assessment methodologies, such as the US Forest Service campsite and trail condition assessment protocols (as outlined in section 7.5.12.1 General Recommendations) based on current standards (e.g., Glidden 2005, Marion 2004, Cole 1989). Additionally, we recommend that ODF conduct a comprehensive survey of all recreational trails (including undesignated trails) in the Wilson as it would allow managers to better identify problem areas.

NetMap, utilized extensively in this watershed analysis, is a computer software program consisting of a set of analysis tools used to address the type, abundance, and spatial distribution of riverine habitats, degree of habitat diversity and disturbance potential, sources of erosion and sedimentation and sensitivity to land uses. Although this analysis was comprehensive, one of the drawbacks was the use of coarse 10-m DEMs to conduct all of the topographical and slope-stability analyses. A NetMap-based analysis using LiDAR data would allow for finer-scale analyses thereby increasing the confidence and conclusions of the overall assessment. Additionally, the DHSVM hydrology model used for this analysis is robust and well-established, the use of LiDAR data would also allow for finer-scale analyses at the watershed level.

Using recent fish abundance data coupled with modeled habitat predictions (using NetMap) allowed us to prioritize stream segments for protection and restoration. However, only one year of fish abundance data was available at the time of this analysis. Using data from multiple years would allow for more reliable ranking of key stream reaches. Additionally, given the lack of historic abundance data (e.g., pre-1930), estimates are somewhat speculative in nature. While salmonids are often the species of interest, non-salmonids also play a key role in the proper functioning of aquatic ecosystems. However, no data pertaining to non-salmonid species distributions and abundance exists.

10.3.3 Stream Channel and Channel Modification

Few human-caused channel modifications exist on ODF lands within the Wilson River watershed, and those that are present are due to legacy practices. Management recommendations for ODF lands should include inspecting the few existing areas of canyon and channel fill that have been identified from the road surveys to determine if vacating these road segments is feasible. Additionally, ODF should continue the current trend of locating roads away from channels and channel migration zones.

10.3.4 Hydrology and Water Use

Post-fire restoration of upland and riparian stands within the Wilson River watershed, combined with the inherent resiliency of rain-dominated forests to vegetation-related hydrologic change, results in few concerns over management-related impacts to either peak or base flows within the area. Road drainage networks are for the most part disconnected from the stream network, further reducing the likelihood of management-related flow impacts. Hydrology-related management recommendations for ODF lands include continuing to add cross-drain filters to further limit hydrologic connectivity to streams. The DHSVM (or similar model) could be run at the sixth-field subwatershed scale to evaluate the effects of proposed management actions if necessary.

The relatively low levels of water withdrawals within the Wilson River watershed have resulted in little concern that present consumptive uses significantly impact aquatic species on ODF lands. Potential future increases in population and urban development could, through restrictions on water uses, alter ODF's management practices.

10.3.5 Riparian and Wetlands

10.3.5.1 Riparian Enhancement Opportunities

10.3.5.1.1 Changes to Successional Dynamics: Large Wood and Shade Enhancement

Given the majority of the riparian zones exhibit high proportions of hardwood species, and that the successional changes predicted in the 100-year time frame do not indicate any substantial shifts in species composition through time, the riparian zones are likely to remain predominantly hardwood dominated for the foreseeable future. At the subwatershed scale, the current trajectories indicate a pulse of tree mortality, followed by a lag where mortality declines and mid-sized trees are not recruited to the canopy. This lag period trajectory appears to extend beyond the 100-year timeframe, assuming a no-management scenario. This has direct implications that limit the potential for instream LW recruitment and stream shading.

While the data were insufficient for writing site-specific prescriptions, the vegetation classification – when overlayed with landslide/debris flow hazards in a GIS – allowed coarse-scale areas to be identified where treatments encourage the development of large wood and conifers. Additionally, the incoming LiDAR information will make it possible to create a finer-scale map of 'manageable units', or areas where patch-level treatments can be made to maximize benefit to the stream system (shade and LW). The current trajectory benchmarks presented in the Riparian Vegetation Dynamics: "No Management" Scenario section (6.2.1) can be used as a basis for comparison to design site-level treatments and evaluate the effects to LW recruitment and shade (using additional modeling tools) as well as provide the site-level metrics for monitoring the effectiveness of the treatments. Future *Action Plan* treatments should focus on improving regeneration and recruitment to the canopy (≥14 inches DBH), favoring conifers where appropriate at the site-level, focusing on areas of the riparian zone that have high potentials for interaction with the stream channel, and where silvicultural operations will have the lowest impact, identifying terraces as primary locations, and using LiDAR data and ground-truthing. Future *Action Plans* should also include selecting treatment sizes that take advantage of the patch sizes inherent in the riparian zones. Treatments should be distributed along reaches to monitor the *reach-level* responses to LW and stream shading and incorporate enough land area to observe responses and provide the desired number of trees to engage the stream channel through time. We also recommend that ODF pair treatment reaches with similar reference reaches in the watershed (e.g., similar hydrology and morphologies, stand successional projections (no-management), and fisheries potentials) and monitor and evaluate treatment trajectories with reference trajectories using growth modeling tools, mortality estimates, projected LW recruitment, and stream shading potentials (as presented in this analysis). Finally, ODF should compare and contrast trajectories of each reach to evaluate if benchmarks are being met, and if the successional dynamics are improving toward the desired future condition.

10.3.5.1.2 Abatement of Invasive Weed Species

Perhaps the most critical and immediate action item for riparian areas in the Wilson River watershed is the immediate treatment and isolation of the Japanese knotweed at the Idiot Creek bridge. The positioning of this patch at the upper reaches of the watershed is of major concern, as knotweed propagates downstream following scouring and hydrologic disturbance patterns (pulses and floods). Treatment options to consider include pruning and chemical applications that target the rhizome system. Often multiple applications/ treatments over multiple years are required for success. Ground disturbances should be minimized to avoid spreading rhizomes to other reaches.

It is highly recommended that monitoring for weed species be incorporated into road surveys, stream surveys, and as stand-alone exercises to identify, map and eradicate non-native plant species from the system. Monitoring and treatment of the garlic mustard infestation in Gales Creek (outside the watershed) will minimize the chances that garlic mustard spread to the watershed.

To be effective, eradication of knotweed and other non-native species requires collaboration with other agencies and landowners. Development of BMPs with recreation groups and users can be effective in limiting the spread of weed species. Installation of wash stations at trailheads and outreach with the user groups to ensure their equipment does not act as vectors for spread, as well as limiting the ground disturbance by OHVs in and around infected areas are methods that can minimize the spread of these weed species.

10.3.5.1.3 Wetland Enhancement

Recreational impacts on the wetland environment, including OHV use and dispersed campsites, are potential avenues for decline in wetland abundance, water quality, size, and health. Development of BMPs that restrict uses in the near-wetland environment (within ~100 ft) will likely result in improved wetland buffer health. A 100 foot buffer area is recommended, as this corresponds to an approximate tree height; compaction and soil disturbance from OHVs and camping outside of this area will likely not contribute to buffer decline.

Though beaver activity can cause problems for certain forms of infrastructure, their presence is vital in the creation of new wetland areas, especially in the low-gradient systems found in Devils Lake Fork subwatershed. Allowing beaver to persist will likely result in increased wetland areas in many areas of the watershed, providing water storage capacity and improved fisheries habitats.

10.3.5.2 Recreation-related Effects

OHVs and dispersed campsite users present a high risk of introducing and spreading invasive species (e.g., plants, fungi, pathogens), especially where use is concentrated in the flood zone (e.g., where garlic mustard and knotweed are at the highest risk of spreading).

Tree removal, damage and loss of reproductive capacity in inner riparian zones from recreational impacts on shade, tree canopy and large wood (LW) recruitment are localized and occur at relatively small scales. Long-term implications, however, need to be assessed as they have the potential to become even more of a problem for ODF if user behavior and expectations of tolerance of current impacts keep shaping attitudes to resources.

Although relatively localized, human waste, garbage and other camp related impacts on water quality need to be addressed while the costs of camp closure, restoration, cleanup and upgrading need to be recovered from the users, probably through an overnight fee/permit program.

OHV and recreational impacts to wetlands areas are growing concern and the 25 foot buffer rule (e.g., exclusion) has not been consistently applied. Therefore, we recommend that recreational sites be set back from wetlands between 100-200 feet, consistent with the distances established in the literature. Additionally, at sites where instream large wood recruitment is limited (or limiting), ODF may want to consider relocating/moving campsites in these areas to beyond 100 feet from the stream.

A user education/involvement program will need to be applied in conjunction with an array of alternative solutions to eliminate or curtail the negative impacts identified in this study. ODF has begun this effort along a tributary of the Wilson at Browns Camp by posting signs. Such information needs to be included in all communications with users (camp hosts, event registration, websites and trail head sign boards, etc). However, heavy duty barriers, trail and camp relocation and revegetation actions need signs to improve user understanding. Unfortunately, a significant number of users disregard signs or circumnavigate barriers unless they are both robust and well maintained.

10.3.6 Instream Large Wood Recruitment, Debris Flows and Landsliding

The topography and climate of the Wilson Basin drive an erosion regime characterized by punctuated, storm-driven episodes of sediment production and transport. Shallow, rapid landslides are the primary mechanism for movement of sediment from hillslopes to stream channels. Landslides into small, headwater channels form deposits that restrict fluvial (water carried) transport, so that these small channels serve as storage reservoirs for sediment and wood, until scoured by a long-runout debris flow that can carry material to fish-bearing channels downstream.

Several factors link these processes of sediment production and transport to forest cover in the basin: landslide susceptibility is increased for a period of a decade or more after loss of forest cover, the volume of sediment stored in headwater channels is affected by the size and abundance of woody material in these channels, and incorporation of large wood into debris flows may limit runout length. Hence, management actions that alter the spatial distribution of stand types and the subsequent recruitment of large wood to headwater channels can alter the rate and location of sediment production and delivery within the basin. Strategic use of upslope leave areas in landslide source zones and riparian buffers on Type N channels may work to minimize management influences on rates of sediment production by landsliding. We have used empirical models of landslide initiation and debris-flow runout to identify and rank likely source areas for landslides and debris flows that will affect fish-bearing streams. These maps and GIS data files can be used to distinguish sites where leave areas and buffers are and are not likely to aid in reducing management impacts to the fish-bearing channel network.

Because they are subject to increased rates of blowdown, which may also contribute to shallow landsliding, the effectiveness of leave areas and buffers in mitigating management-related increases in landslide rate is not fully determined. It is important to recognize, however, that both serve other important functions: in particular, they can ensure a source of large wood to small headwater channels that act both to restrict fluvial transport of sediment and to provide a source of debris-flow-transported wood to downstream fish-bearing channels. Debris-flow deposits in fish-bearing channels are an important component of the Wilson River channel and riparian environment, and the ecological benefits provided by these deposits are heavily dependent on inclusion of large wood. Upslope leave areas and riparian buffers on debris-flow-prone Type N channels can be placed to ensure that debris flows delivering to reaches with high habitat value carry large woody material. We have ranked Type F channels in terms of current and potential future habitat value and identified the landslide source areas and debris-flow-prone Type N channels that serve as debris flow corridors to these channels.

Disturbance history in the basin has left the majority of riparian stands along Type F channels in predominantly early and mid seral vegetation types. Hence, these channels, for the most part, lack riparian sources of large wood, with key pieces (> 24 in diameter) in particularly short supply. Debris flows may serve as a primary source of large wood to many Type F channels well into the next century, assuming large wood sources exist in debris-flow source areas. Efforts to protect and enhance the growth of large conifer trees in these upslope and Type N source areas will increase availability of large wood to these reaches. Conversely, debris-flow delivered sediment and wood also poses a serious risk to downstream resources, particularly for channels large enough for flood flows to transport these materials. Topography and climate render channels throughout this basin sensitive to landsliding triggered by storm events. This is a natural process, and it is essential that management planning identify sites subject to destructive debris flows and debris-laden floods. At the same time, these processes are integral to creation of habitat features to which the ecosystem of this basin is adapted; to protect the fisheries and other resources provided by this ecosystem it is equally essential that management planning seek to minimize alterations of natural sediment and wood delivery rates. The analyses presented here provide guidelines to direct the location and type of conservation and restoration actions that should be effective, but it is also important to recognize that predictions of future occurrences (e.g., where landslides will occur) are hypotheses waiting to be tested.

10.3.7 Sediment Sources

10.3.7.1 Non-Road Related

The Wilson River is, overall, a system sensitive to disturbance. It has abundant steep, landslide-prone slopes and steep, often confined mainstem channels. The uniform stand structure across the basin, with a very low abundance of large trees, exacerbates this condition: sources of large wood that would aid recovery from disturbance don't exist. Streams subject to debris-laden floods generally also have low riparian wood recruitment and high value for fish. A big storm could hit these hard (as happened in 1996 and December 2007) no matter what management actions occur. Efforts to reduce upstream debris flow occurrence to these reaches could be beneficial, but pretty much involve the entire watershed. Most beneficial may be efforts to ensure opportunities for recovery; i.e., maintain and enhance riparian and upslope sources of wood through the sensitive reaches.

10.3.7.2 Road Related

Roads in the watershed are performing well in terms of limiting hydrologic connectivity, prism stability, and limiting the length of roads on critical locations like steep slopes and those with cut and fill slope slides. Even though hydrologic connection is low compared to other watersheds, problems exist in terms of active sediment loading to creeks. This is most pronounced on blocked roads that are not routinely maintained.

Many stream crossings pose a short-term risk to the watershed’s aquatic resources and have been identified as having a high washout potential. When stream crossings fail and are washed-out, fine sediments may be loaded into creeks imperiling critical salmon habitat. In light of the storms that swept through the Oregon coastal regions in 2006 and 2007, and the number of wash-outs that occurred as a result of those storms, the stream crossings that have a high washout potential are now considered extremely vulnerable and have been prioritized for inspection and repair. Similarly, many stream crossings were also identified as being potential blocks to fish passages. Although the number of stream miles cut-off by these potential blocks is relatively small compared to the overall amount of fish habitat, it remains extremely important to inspect and repair these potential blocks.

As stated previously, hydrologic connectivity is relatively low in the watershed. This fact is primarily a result of proper road engineering. The State has done an excellent job of installing cross drains that divert sediments to the forest floor where they filter out before entering streams. However, there are significant segments of hydrologically connected roads that are currently eroding directly to streams. These segments pose a longer-term risk to the watershed and should be inspected and repaired simultaneously with potentially failing stream crossings if they are in close proximity to one another. Otherwise, these longer-term hydrologically connected and eroding roads should be inspected after the high washout potential crossings and fish blocks have been inspected and repaired.

The issue of opening blocked roads to repair eroding segments remains problematic because of their isolation and access constraints. Many of these blocked roads may have been closed for some time and are alder- choked making access nearly impossible. Other may have eroded prisms that are now far too narrow to access with vehicles even if they were opened. In spite of these obstacles, this analysis has identified roads that are actively eroding to streams and are on blocked segments. It will be up to district engineers to determine which of these roads are feasible to repair and which are not.

The longest-term risk to aquatic resources are those roads located on steep slopes and adjacent to streams. These roads have been identified and as managers "catch-up" on inspecting and repairing the highest priority roads identified in this analysis, they could potentially turn their attention to these critically located long-term risk roads.

Short term risks at stream crossings are the most important and highest priority for manager to consider. Table 35 and Table 36 list roads crossings that are rated as having a high potential for washout. Table 38 lists stream crossings that may act as fish blocks. Appendix X – List of Priority Inspection Roads lists road with segments that are actively eroding.

10.3.7.3 Recreation-related effects

Steep terrain, heavy rainfall and soil types not well-suited for OHV use present challenges to recreational use in the Wilson River watershed. Some of the hydrologically connected trail segments are on legacy roads and skid trails adopted by OHV users. Furthermore, existing recreational use pressures are likely too high to be sustained but the lack of a complete trail census does not allow for a complete picture to be drawn. Additionally, poor trail design, location and lack of adequate maintenance has produced serious, although localized, levels of vegetation loss and sedimentation (e.g., 2 acres/1,157 cubic yards of aggregate soil loss per mile; considerably high compared to values presented in the literature that typically report measures in the low hundreds of cubic yards; see Marion and Cole 1996 and Glidden 2005 for some examples).

Current OHV trail data for the Wilson does not allow for a thorough identification of all trail segments at risk of a washout. Additionally, the lack of a complete trail inventory (which includes undesignated, user-created/braided trails) does not allow an estimation of how many stream crossings and hydrologically connected trail segments may be impacting aquatic habitats. Field samples of both designated and undesignated trails, however, clearly indicate problems do exist and that some impacts are serious (e.g., sediment delivery directly to streams).

Incorporation of key washout risk indicators in future field inventories will help inform ODF of trail conditions and identify high priority trails for corrective action(s). This action need not wait for a full scale forest-wide trail inventory, rather it can commence when any trail work repair priorities are being assessed. We recommend that ODF continue to develop and refine sustainable trail designs and Best Management Practices (BMP) based on updated recreational standards (e.g., Marion 2007, IMBA 2004, Steinholtz & Vachowski 2001, Wernex 1994). In addition, ODF should increase measures to reduce user pressure (events, season of use, trail closures) and designate 100 foot buffer zones designed to minimize watershed impacts. Finally, more rigorous enforcement and a monitoring system needs to be added to ODF's OHV and dispersed campsite management programs.

10.3.8 Water Quality

Current water quality limitations identified by the Oregon Department of Environmental Quality are due to dissolved oxygen for the period September 1 - June 15 in the Wilson River mainstem. Dissolved oxygen limitations are related to high water temperatures, which are in turn influenced by riparian shade.

Restoration opportunities are limited along the mainstem Wilson River for political as well as physical reasons. The dynamic nature of much of the Wilson River mainstem is a physical constraint to restoration activities. Fragmented ownership and small lot size in many areas, along with the desire of some homeowners for "river views" and to have structures in close proximity to the river, limit restoration opportunities. Opportunities for restoration on these small private parcels (either through acquisition, easements, or cooperation) may best be handled through the Tillamook Bay Watershed Council or other organizations (e.g., Nature Conservancy). Newly acquired State Park land along the highway 6 corridor are an example or additional public lands that may be available for restoration.

Modeled shade levels are generally predicted to increase along the principal streams over the 0-50 year time horizon, but decrease over the 0-100 year time horizon as stands mature and canopy conditions begin to break up. Channel widening, associated with debris flows also contribute to loss of effective shade. Recreation-related impacts to shade, temperature and other water-quality concerns (primarily sediment inputs) appear to be causing significant localized impacts, but probably represent a minor impact at the subwatershed scale.

Road-parallel streams (discussed above) also represent significant long-term limitations to stream shading. Stream parallel roads were identified as part of the recent ODF road assessment in the Wilson River (see Appendix M – ODF Roads Protocol for protocol). This information can be used in conjunction with the temperature limiting factors results (section 5.6 – Limiting Factors) to prioritize road segments for restoration. High-priority candidates include segments along the south bank of the West Fork North Fork Wilson, segments along Ben Smith Creek, Cedar Creek, Idiot Creek, Jordan Creek, Little NF Wilson, and South Fork Wilson River.

10.3.9 Fish and Fish Habitat

As of December 2007, none of the anadromous salmonid species inhabiting the Wilson River watershed are currently listed as *Threatened* or *Endangered* under the federal Endangered Species Act (ESA). Oregon coastal coho, however, are likely to be re-listed by NOAA Fisheries in early 2008 as *Threatened*. Additionally, numerous species/stocks are listed by the State as *Threatened* or *Sensitive* and/or *Vulnerable*. Since fish abundance survey data indicate general declines and high variability in peak abundance over the last 50+ years, we recommend using extreme caution when interpreting the effectiveness of restoration activities, especially over the short-term. Additionally, the effectiveness of restoration projects should be repeatedly assessed over the course of several years and even decades. Furthermore, long-term monitoring activities should be included when calculating future projects' associated costs.

Although the Tillamook Bay estuary may well be the conduit for potential introduced species invasions, introductions may also occur on ODF lands. Because some invasions can have far-reaching and catastrophic effects on local, native populations, we recommend that ODF maintain a close working relationship with the ODFW and Tillamook Estuaries Partnership to identify (early) potential outbreaks of invasive species.

Human-caused disturbances have drastically altered the condition of aquatic habitats within the Wilson River watershed. The Tillamook Burn fires, subsequent road-building and associated timber harvest activities (e.g., legacy effects) have significantly altered the types and availability of high-quality aquatic habitats present in the Wilson. From a hydrologic standpoint, the Wilson has largely recovered from these past activities. However, perhaps the most significant legacy effect was the removal of large wood from the system, both from the streams ("stream-cleaning") and from the riparian zone (fires and subsequent harvest). The lack of large instream wood pieces (and the lack of large wood recruitment in the riparian; see section 6.2 Potential Future Conditions) is having a substantial and persistent detrimental effect on the overwintering abilities of juvenile salmonids and on the accumulation of gravels, increases in pool frequency and presence of deep pools. This is especially evident in the Jordan Creek subwatershed where 80% of the surveyed stream reaches exhibited low percent gravel, high percent bedrock and low percent pools (although this may also be a relic of historic log drives). Therefore, silvicultural treatments that encourage the production and recruitment of large instream wood may well have a substantially positive impact on long-term aquatic habitat conditions (see section 6.3 Riparian Enhancement Opportunities and Map 63).

Current aquatic habitat data in the Wilson are often negatively skewed compared to ODFW's Aquatic Inventories Project (AIP) reference reach data. When considered collectively, however, (e.g., at the subwatershed scale) the data suggest that aquatic habitat conditions in the Wilson River are still exhibiting a reasonable level of functionality. For example, aquatic habitat conditions in the Little North Fork Wilson subwatershed are fairly evenly distributed among the LOW, MODERATE and HIGH categories (28.7%, 54%, and 21.3%, respectively), indicating that aquatic habitat conditions within this subwatershed are likely functioning in a manner similar to other coastal watersheds that have experienced relatively little human disturbance. Indeed, fish numbers in this subwatershed generally reflect this. Therefore, we recommend that ODF take actions that maintain the current conditions in this subwatershed.

Key habitat attribute data from the Jordan Creek subwatershed, on the other hand, are skewed relatively heavily toward LOW categories (48% LOW, 37% MODERATE, 15% HIGH), indicating that aquatic habitat conditions in this subwatershed are compromised compared to reference conditions. Indeed, steelhead and coho numbers generally reflect this. Because this subwatershed contains high habitat intrinsic potential but low fish numbers, ODF should consider restoration actions in this subwatershed that are geared toward steelhead and coho recovery and improvement of overall aquatic habitat complexity (e.g., increase the number of pools, percent gravel, and instream large wood).

Aquatic habitat conditions in the Upper Wilson/Cedar Creek and the Little North Fork Wilson, on the other hand were rated as being in MODERATE and GOOD condition (respectively), the subwatersheds contain high IP for coho and steelhead, areas of high core habitat for coho and steelhead, and contribute large numbers of coho, steelhead and cutthroat trout. Few restoration efforts, therefore, may be needed here and ODF should take actions that maintain the current conditions. Conversely, aquatic habitat conditions in the Devils Lake Fork and the South Fork Wilson were rated as being in POOR and MODERATE condition (respectively), yet the subwatersheds contain areas of high IP and core habitats for coho and steelhead, contribute large numbers of coho salmon and cutthroat trout but do not produce many steelhead. Therefore, restoration efforts in these subwatersheds could be focused on improving aquatic habitat conditions (e.g., increasing the number of pools, percent gravel, and large wood) for 1) steelhead (low numbers) and 2) coho (likely to be re-listed as *Threatened*).

Additionally, while apparently not a large issue in the Wilson, historic road-building activities have reduced the connectivity of stream reaches to each other, blocking the movements of fish. Although some fish blockages still exist (e.g., improperly sized culverts, steep gradients, too high steps at the mouth, etc.), current road-building and road-restoration practices have largely eliminated fish passage issues. Yet, the stream crossing washout potential and sedimentation issues identified in this assessment still have the ability to negatively impact aquatic habitats and, given the recent frequency of large storm events, should be immediately repaired or replaced. Furthermore, this assessment identified numerous recreational trails and dispersed recreation sites that were 1) hydrologically connected, 2) actively eroding, and 3) damaging riparian vegetation. To reduce sedimentation and increase riparian shade at these sites, ODF should 1) restrict their recreational use or close them altogether, 2) repair damaged areas, and 3) work to educate recreational users about the negative ecological, biological, and socio-economic effects from improper use.

In general, the Wilson River watershed is recovering and appears to be in relatively moderate shape given the high degree of disturbance it has experienced in the last 100+ years. While many basic biological and ecological requirements are largely being met by the current conditions in the Wilson, the lack of large wood (upslope, riparian and aquatic) is arguably having the largest impact on aquatic habitat complexity (e.g., lack of pools, deep pools, large wood accumulations, cover, low gravels, etc.) and large wood recruitment is projected to remain below target levels well into the next century. Tailoring riparian and upland silvicultural treatments for the enhancement/recruitment of large wood may help the aquatic habitat conditions recover at a faster rate. Indeed, as key pieces of large wood begin to recruit to the waterways, we would expect to see an increase in pool frequency, decreases in the number of habitats where bedrock dominates, increases in gravels, and increases in aquatic cover associated with wood accumulations.

10.3.10 Recreation

Historical conditions, physical characteristics and social pressures combine to present considerable challenge to preventing and repairing impacts on the watershed from recreational use. However, ODF has established an internal capacity to tackle these challenges and an array of partnerships, relationships and programs to pull in users to assist in their efforts. The focus of the recreation impact analysis was to try to gauge the extent and intensity of recreation impacts in the context of a larger watershed analysis. The tools, data and experience in doing this are not well developed and have few precedents in the region or nation.

Within those limitations, the results of this analysis do provide a picture of watershed impacts associated with recreation and direction for tackling those impacts and the data needs for managing and monitoring recreational use. Findings show that OHV and dispersed camping impacts occur throughout the watershed, across all seasons and produce some locally intense erosion and sedimentation. High rainfall, steep terrain and storm events exacerbate the effects of high levels of OHV use in a trail system that is not yet under full management control. Given the quantity of soil loss measured along a sample of trails, high priority needs to be given to assessing the extent to which this occurs in the rest of the trail system. The field work also assessed sample trail segments for washout risk indicators such as fall line alignment, steep grades and hydrologic connectivity and found significant occurrence of these indicators on all trail types, but particularly on undesignated and user-created trails. ODF has made considerable progress in rerouting, repairing and maintaining designated trails, and now all of these trails feature bridges or culverts at stream crossings.

Impacts on riparian areas are of particular concern and recreation (OHVs and dispersed camping) represents a potential vector for the spread of invasive species. Garlic mustard and Japanese knotweed are two new highly invasive species that were assessed by this study and both have a habit of invading flood plains in association with human disturbance, floods and recreation activity. In addition, the study revealed long term impacts of recreational use of inner riparian areas, including soil loss, site hardening, tree mortality and loss of vigor, vegetation loss and sedimentation. Where recreation sites a clustered and impacts are high, impacts can be expected on riparian vegetation, canopy tree health and long term large wood recruitment into streams.

With only 88 acres of wetlands in the watershed it will also be important to prevent further encroachment and impact from recreation along hydrologically connected trails and campsites. While ODF has successfully buffered streams from campsites within the formally designated campgrounds in the watershed, a majority of dispersed campsites are still within the stream bank and inner riparian zones (<100 ft from water). Highest priority should be given to high impact sites within 25 feet of streams identified in this report from ODF inventory data. This same inventory recorded but did not enter data that would identify sites within the inner riparian zone (25-100ft). Field assessment results show that sites in this category should also receive management attention.

However, dispersed camps are attractive because they are close to water, free, isolated and rustic which many locals prefer over designated and developed fee campgrounds closer to high activity areas. ODF must weigh the resource impacts and social implications of continuing to allow users to occupy sensitive riparian sites. Statewide trends indicate more people will be recreating closer to home as travel costs increase, and as fees increase for developed sites, more people will be seeking alternatives. Restricting access to inner riparian areas, or upgrading sites to contain impacts will be necessary actions to reduce impacts on riparian function and water quality.

ODF staff reports and field assessment work reinforce the need for placing a combination of very robust physical barriers, revegetation and explanatory signage to combat OHV and dispersed camp impacts. In addition, a more effective enforcement program is needed to set expectations of compliance and the consequences of non-compliance. Demand for recreation across the forest is projected to increase, particularly among motorized recreation uses. ODF has developed a skilled and talented staff that has applied considerable resources to establishing high quality recreation facilities and opportunities within the watershed. However, demand and the constraints of terrain, rainfall and historic patterns of use make it difficult to bring all trails and sites up to standard and maintain the ones already there.

The new round of recreation planning anticipated for the Tillamook State Forest will benefit from a thorough inventory of all trails like the one done by ODF for dispersed campsites. However, it will be important to design survey tools to gather information on impacts that reflect state of the art recreation monitoring protocols and that provide indicators that feed directly into long term monitoring programs. At this point we know impacts are occurring and a good indication of where to look or what to look for in prioritizing management actions. What is needed next is monitoring with effective tools and more quantifiable measures to gauge the rate of site deterioration and the relative impacts of management actions design to reverse those problems.

Recent advances in trail related research has produced much more specific guidelines and a greater understanding of trail design principles. This has in turn fostered the development of better resources, design standards and best management practice guidelines for improving user experiences, minimizing resource impacts and reducing management inputs. The time is right to incorporate these into the next round of recreation planning for Tillamook State Forest.

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