Chapter 1

Introduction: Forestry and Forest Management in Oregon

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Photo: Emily Jane Davis, © Oregon State University

There are 337 public water providers in Oregon that rely on surface water for some or all of their supply. They serve nearly 3.5 million Oregonians. These providers may own their source water watersheds, but many do not. As a result, they often have little control over activities occurring in their source watersheds, many of which are forested and managed by a diversity of owners.

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1.1. Purpose and overview

The Oregon Forest Resource Institute board of directors asked OFRI staff to summarize the current science knowledge regarding the effects of forest management on drinking water. *Trees to Tap* is the result of that effort. The last OFRI-commissioned report on this topic — *Municipal Water Supplies from Forest Watersheds in Oregon: Fact Book and Catalog* by Paul Adams and Mark Taratoot — was published in 2000. That report summarized the findings of a survey of 30 major municipal water systems in Oregon and the literature of the day on forested watersheds and the effects of forest management. This 2021 report is being prepared under contract by Oregon State University's Institute for Natural Resources using faculty from the OSU College of Forestry as subject matter experts (See pages iii and iv).

The purpose of this project is to:

- Update that 2001 report by synthesizing current science about the impacts of forest management on community drinking water supplies.
- Describe and analyze the management of forested municipal watershed systems.

Our report will focus on 156 community water systems (those with 15 or more hookups serving 25 or more people year-round) that rely on surface water.

The project has three major components:

- A science review focusing on four topics identified by the Steering Committee as priorities: sediment and turbidity; changes in water quantity; forest chemicals; and natural organic matter and disinfection byproducts. We will divide our forest management effects analysis of these four topics into three areas: harvesting, roads, and reforestation.

- A survey of the 156 water utilities, along with three detailed case studies to identify their needs and concerns.
- An atlas including information on each of the source watersheds for the 156 CWS utilities.

1.1.1. Importance of forests for clean water

Western forests are managed for many diverse purposes, including wood products, recreation and wildlife habitat. By filtering rain and snowfall and delivering it to streams or aquifers, forests also produce the highest quality and most sustainable sources of fresh water on earth, arguably their most important ecosystem service (NRC 2008; Neary et al. 2009; Creed et al. 2001).

Oregonians value water produced from Oregon forests and rank water quality and quantity as primary concerns with forest management. Oregon's extensive and diverse forests generally produce high-quality water and supply the majority of the state's community water systems. Forest practices designed to minimize impacts to water quality have improved significantly in recent decades. At the same time, demand for all forest ecosystem services continues to rise against a backdrop of a changing climate with uncertain implications for source water supplies from forested areas.. Together, these trends point to the importance of maintaining and expanding public awareness of current science knowledge regarding the complex relationships between forest hydrology and forest management.

1.1.2. Approach of the report

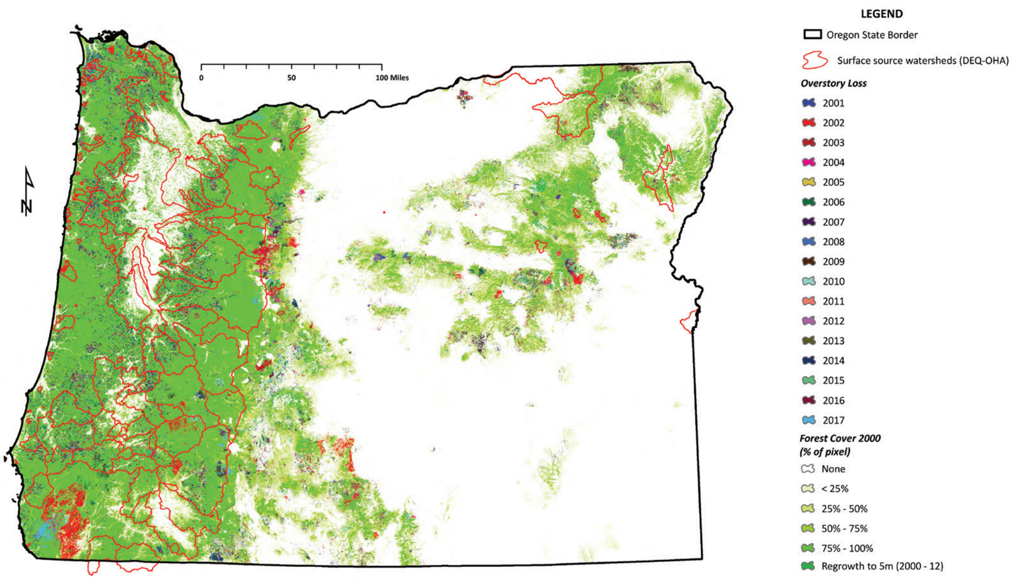
OFRI is a state agency established by the Oregon Legislature in 1991, funded by a dedicated forest products harvest tax and governed by a 13-member board. The institute was created to:

- Enhance collaboration among forest scientists, public agencies, community organizations, conservation groups and forest landowners
- Provide objective information about responsible forest management
- Encourage environmentally sound forest practices through training and other educational programs.

In fall of 2017, OFRI contracted with the OSU School of Forestry and the OSU Institute for Natural Resources to revise and expand the 2001 report to reflect more recent research and refinements in best management practices (BMPs). A 10-member steering committee helped identify priorities for the science review and review the draft project chapters. The steering committee met four times from January 2017 to June 2018 in the lead-up to the science review. Members reviewed all the draft products. Their comments were incorporated, and revisions were circulated back to the committee for a subsequent review. Steering committee members were not asked to approve the final products in this report.

1.2. The landscape of source watersheds in Oregon

Drinking water source watersheds are shown in Map 1-1 along with the amount of forest cover and overstory losses from 2001–2017. Source watersheds predominate in the Cascades, Coast Range and in smaller areas of the Oregon Coast. Only 12 source watersheds exist east of the Cascade ridgeline; communities in that part of the state largely rely on groundwater, which is much more dependable than surface water supplies. Also evident on Map 1-1 are areas of overstory loss, such as in the southwest part of the state where the Biscuit Fire in 2002 (red) and the Chetco Bar Fire in 2017 (blue) occurred.



Map 1-1. Forest cover change in Oregon, 2001–2017.

1.2.1. Water quality and land uses

Water quality at the raw water intake depends on land cover and land uses in the contributing drainage area. The Oregon Department of Environmental Quality (DEQ) developed the Oregon Water Quality Index (OWQI) to describe overall conditions by stream, region, statewide and land use. The OWQI is based on water temperature, pH, dissolved oxygen, biological oxygen demand, total solids, nitrogen, phosphorus and bacteria using 160 long-term monitoring sites throughout Oregon. Scores are determined from seasonal averages (summer and fall-winter-spring) where high-quality data was available for at least 10 years. A site is scored from 10 to 100, with scores 90 – 100 rated *excellent*; 85 – 89 *good*; 80 – 84 *fair*; 60 – 79 *poor*; and 10 – 59 *very poor*.

Figure 1-1 shows statewide Oregon Watershed Restoration Inventory (OWRI) results for five different dominant land uses in a 5-mile upstream buffer from the sample site. The "mixed" category is used when none of the other four land uses exceed 50% in the upstream area. Data is from over 8,500 samples collected by DEQ from water years 2009–2018, averaged by dominant land use for that water year. The cleanest water occurs where forest is the dominant upstream land use. Year-to-year variability in water quality is less (at least since water year 2011) for forests than for other land uses.

Aside from just land use, there are regional differences in average OWQI scores throughout the state. Table 1-1 provides information on these differences based on DEQ

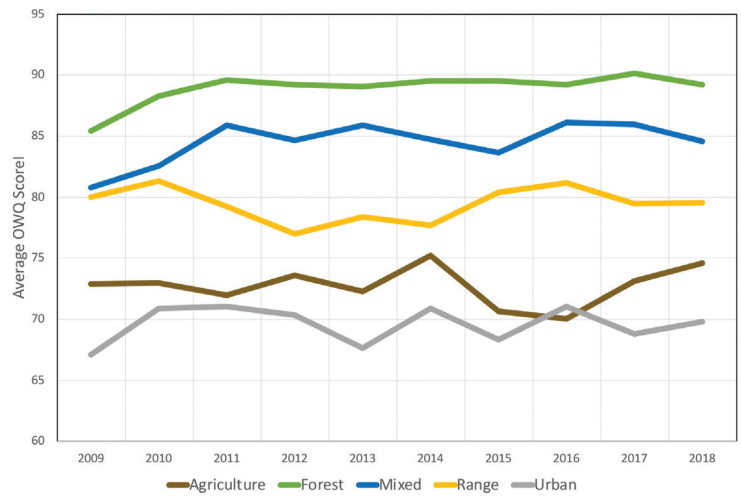


Figure 1-1. Average Oregon Water Quality Index scores by dominant land use from 2009—2018. Source: https://www.oregon.gov/deq/FilterDocs/OWQIdata.xlsx

Table 1-1. Average OWRI scores by basin (region), WY2009 – WY2019.

Basin	Agriculture	Forest	Mixed	Range	Urban	*Average*
Columbia			86		86	*86*
Deschutes	47	92	92	81		*86*
Grande Ronde	91	91	87			*90*
Hood	81	85	90	84		*83*
John Day	88			87		*87*
Klamath	31	82	67	90		*62*
Malheur	28			54		*40*
Mid Coast		89				*89*
North Coast		86	78			*85*
Closed Lakes	79			83		*82*
Owyhee	52			84		*73*
Powder				73		*73*
Rogue	79	90	80			*86*
Sandy			91			*91*
South Coast		89				*89*
Umatilla	74		82			*75*
Umpqua		89	85			*87*
Lower Willamette	60	95	89		68	*70*
Middle Willamette	82	95	90		91	*85*
Upper Willamette	85	94	93			*88*
Statewide Averages	*73*	*89*	*84*	*79*	*70*	*81*

Source: https://www.oregon.gov/deq/FilterDocs/OWQIdata.xlsx watershed basin. In any given basin (with the exception of Hood River), the water quality from dominantly forest land use matches or exceeds the scores for other uses. Removing "mixed" from the analysis, the water coming from forest land uses is often substantially better than from agriculture and urban uses, and is better on average than range (the other nonintensive land use).

1.2.2. Forests in Oregon

How you define "forest" determines their extent. According to the U.S. Geological Survey's National Land Cover Database, which uses 30-meter resolution Landsat satellite data, forests cover about 35% of Oregon (including open water) (Oregon Explorer Land Cover 2011: https://oregonexplorer.info/tools/oe-atlas). This definition is based on having 25% or greater tree canopy cover within the 30-m pixel. Using the U.S. Forest Service definition of "forest," 47% of the state of Oregon is forested, with about 38% of the state considered "commercial" quality timberland. The Forest Service definition is based on having 10% or greater tree canopy cover, but requires a minimum 1 acre size and at least 120 feet of width. We'll use the Forest Service definition in our discussion.

These forests are held and managed by a diversity of owners (Figure 1-2). The Forest Service manages 47%, the U.S. Department of Interior's Bureau of Land Management another 12%, and other federal owners 1%. The state owns 3%, and counties and local government another 1%. Thus, almost two-thirds of forests in Oregon are in public ownership. Tribal forests comprise 2%, with large private owners (more than 5,000 acres) owning 22% and smaller private owners 12%.

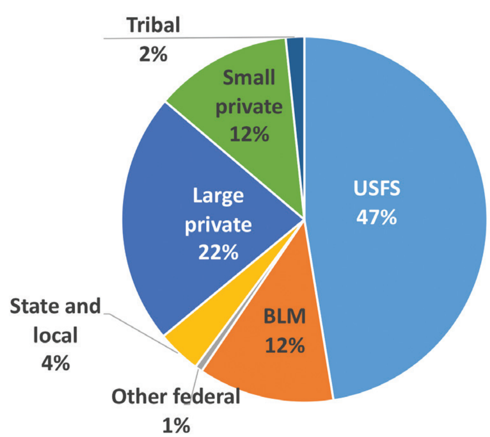


Figure 1-2. Ownership of forest lands in Oregon. Source: OFRI 2019

1.2.3. Land uses and ownership in community water supply watersheds

Community water supply source watersheds overlay larger land cover and land use patterns in Oregon. These source watersheds cover almost 19,000 square miles, or about 19% of the state, and are outlined in Map 1-1. Figure 1-3 shows the average percentages by different owners and land uses in the source watersheds for the 156 community water systems. These percentages are not area-weighted but rather the average of the percentages for each community water system. The greatest proportion — approximately one-third — of source watershed areas are owned by industrial (more than or equal to 5,000 acres) timberland owners; although in aggregate just under 40% of source watersheds are in public ownership (federal, state, local). Small woodland owners and rural residential properties own 14%, with private agricultural lands almost 9% and urban just over 3%.

However, the watershed ownership pattern differs regionally. Table 1-2 shows this same land cover and land use pattern divided into three broad regions of the state: the Oregon Coast; valleys, principally the Willamette, Umpqua, and Rogue; and the dryside, which is everything east of the Cascade divide. In evaluating Table 1-2, it's important to recognize that the dryside contains only 12 community water systems, compared to 90 in the valleys and 54 in the coast regions.

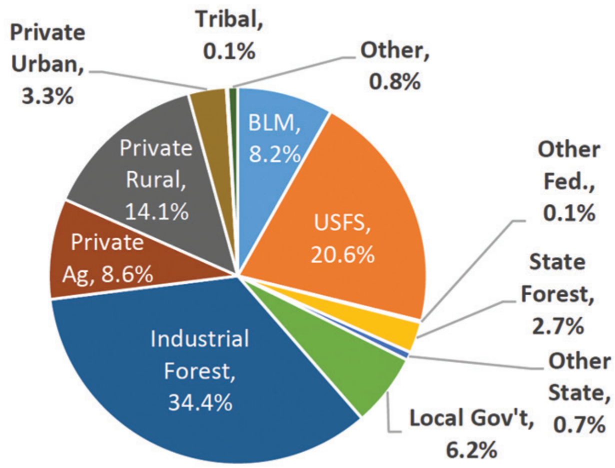


Figure 1-3. Statewide ownership and land uses of source watersheds. Source: DEQ dwpLandUseSumtable.xlsx.

The statewide averages from Figure 1-3 are shown in the right-most column for comparison with the three regions. Industrial timberland predominates on the coast, is rare on the dryside, and is about a quarter of the ownership in the valleys region. Community water systems in the valleys have greater relative public ownership compared to industrial timber but also higher percentages of rural private owners and agriculture. Dryside source watersheds are predominantly publicly owned and mostly managed by the Forest Service.

Table 1-2. Average percent source watershed ownership by region.

Ownership Class	Coast	Valleys	Dryside	State
BLM	2.9%	13.5%	2.3%	8.2%
USFS	21.6%	19.7%	54.1%	20.6%
Other Federal	0.0%	0.3%	0.0%	0.1%
State Forest	4.0%	1.3%	0.0%	2.7%
Other State	1.1%	0.3%	0.2%	0.7%
Local Government	8.6%	3.9%	0.0%	6.2%
TOTAL PUBLIC	37.5%	38.6%	56.6%	38.1%
Industrial Forest	42.7%	26.1%	2.2%	34.4%
Private Ag Land	2.1%	15.2%	19.5%	8.6%
Private Rural Land	12.5%	15.8%	12.0%	14.1%
Private Urban Land	2.9%	3.6%	7.8%	3.3%
Tribal Land	0.1%	0.2%	1.8%	0.1%
Other Land & Water	1.6%	0.1%	0.1%	0.8%

Source: DEQ dwpLandUseSumtable.xlsx. Averages are not area-weighted, but by individual CWS percentages.

Each community water system typically has a unique pattern of ownerships and land uses. Information specific to each CWS will be provided in the atlas accompanying this report. Some community water suppliers have a single owner or manager, and can be either private or public. Others will have a diverse mix of land uses and owners. Even within a broad category, individual owners and managers will likely have different objectives and land management perspectives. Each situation will bring its own management opportunities and challenges, as well see in Chapter 2 with the CWS survey discussion, and Chapter 9 with the case studies of three community water suppliers.

1.2.4. Forest cover change

Oregon's forests are constantly changing at scales ranging from individual trees to stands to larger forest units. As we'll demonstrate in this report, these changes affect water quality differently depending on location, scale, and duration. Recent advances in interpretation of satellite images allow for refined analyses of forest cover change. For this project, we have partnered with the eMapr group in OSU's College of Earth, Oceans, and Atmospheric Sciences (CEOAS) to use their LandTrendr tools (Cohen et al. 2018; Masek et al. 2013) and Landsat data hosted by Google Earth Engine to identify forest cover changes statewide, as well as specifically for each of the 156 community source watersheds. Using Landsat satellite 30-meter pixel data, we have constructed a time-series of forest cover change from 1986 through 2018; and applying image interpretation and ancillary data, have been able to ascribe to each pixel a cover condition and likely source of disturbance if cover has changed. Essentially, we have been able to identify abrupt changes in forest cover (one year to the next); slow changes to forest cover that occur over a number of years, and recovery from disturbed conditions until "forest" is again achieved (i.e. trees about 16 feet in height).

Three basic causal factors drive forest cover change: timber harvest, fire, and disease and insect mortality. Harvest and fire tend to be abrupt forest cover changes, while disease and insect infestations are typically gradual. Ancillary annual data on wildfires (www.mtbs.gov) is used to separate this disturbance factor from other abrupt changes, with the residual most likely the result of timber harvest. We are evaluating the ability of the Oregon Department of Forestry Forest Activity Electronic Reporting and Notification System (FERNS) harvest notification spatial data to refine this identification. Identifying insect and disease effects on forest cover is more difficult because the changes occur over a longer time period; a procedure was developed to track individual pixels over time to identify downward trends in forest condition. Similarly, the slow process of recovery of forest cover can be tracked over time using essentially the same procedure. Figure 1-4 shows the results of our forest cover change analyses on a statewide basis over the years from 1986–2019. Change in this context is the percent of the state disturbed (recovered) by that causal factor in any given year. Categories displayed in the figure are: 1 – undisturbed; 40 – fire; 100 – unknown slow disturbance; 110 – unknown abrupt disturbance; 111 – unknown abrupt disturbance continuing a second year; and 160 – Recovery.

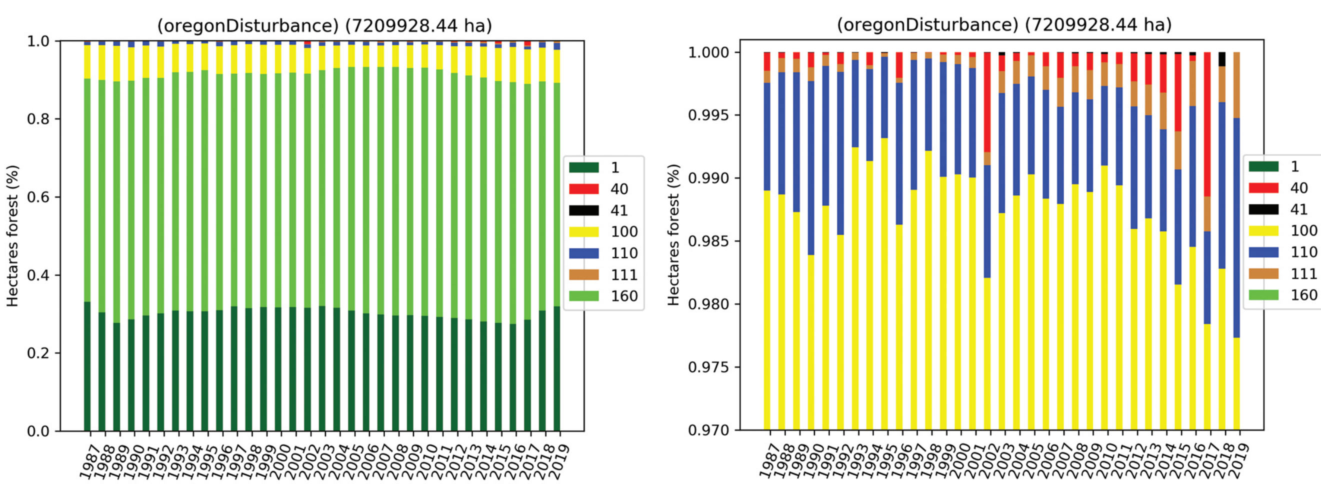


Figure 1-4. Oregon forest cover change 1987–2018. Note scale change on right chart to highlight disturbances.

Raw drinking water quality for any given community water system is likely to be affected by large disturbances (and even recovery) in the source watershed. The Resource Atlas accompanying this report provides information identical to Figure 1-4 for each of the 156 community water systems (some of which have multiple source watersheds). This was an unbudgeted add-on to the project, and the results have not been thoroughly calibrated and so should be considered estimates and trends.

1.3. Overview of active forest management in Oregon

This report divides forest management activities into three categories: harvest, forest roads and revegetation. While these activities are interconnected, distinguishing among them makes our analysis clearer. Forest management operations that result in harvest start when crews build or rebuild roads into the site, conduct harvest activities, and then revegetate if needed. Each category has management activities associated with it. These activities may affect water quality at the intake for community water systems.

The Oregon Department of Forestry (ODF) uses the web-based, electronic Forest Activity Electronic Reporting and Notification System (FERNS) for landowners and operators to notify the state forester of forest management activities as required under the Oregon Forest Practices Act. This system went online in October 2014, replacing the traditional paper notifications and providing digital, geospatial information on forest management activities, including forest harvest activities on federal lands. A single notification can include multiple harvest units and management activities. For each activity, a method used to accomplish the task is also identified. Beginning and ending dates for the operation are required. A notification lasts for the specific calendar year (ending 12/31), unless ODF approves an extension until all the operations are completed. An extension can be for multiple years.

We used data from ODF notifications from 2015 to 2018 to identify the types and magnitude of forest management activities during this period. This data included 59,625 notifications for 112,839 units and activities. There is no set protocol for how many units and activities are included in a single notification. A notification may contain all the units and activities that a land manager anticipates during the year. The landowner can also submit multiple notifications for the same unit, each covering a single activity. The number of units and activities covered in a single notification ranges from one to 81; 57% of notifications contained a single unit and activity, 27% contained two units or activities (typically two activities on the same unit); and 98% had six or fewer units or activities. Not every activity notified is actually conducted. Also, there is duplicate information in differently numbered notifications. Consequently, our results should be interpreted as estimates, trends and comparative magnitudes of forest management activities.

1.3.1. Harvests

There are 11 different activities we categorized under “harvest.” Several of these are combined in Figure 1-5 to simplify the chart. Over the four years, harvests covered an average of 1,114,000 acres per year, with a low of 826,000 acres in 2015 to a high of 1.5 million acres in 2016. The amount of harvesting depends on timber prices, which in turn depend on housing starts and export markets. Selective harvests and thinning are twice the acreage of clearcuts (around 400,000 acres compared to 209,000 acres), with salvage (the harvest of dead, down or burned trees) being about half (122,000 acres) of clearcuts. Fuels reduction and juniper treatment — typically found in the drier areas of the state — averages about 167,000 acres per year. The “Special/Other” category

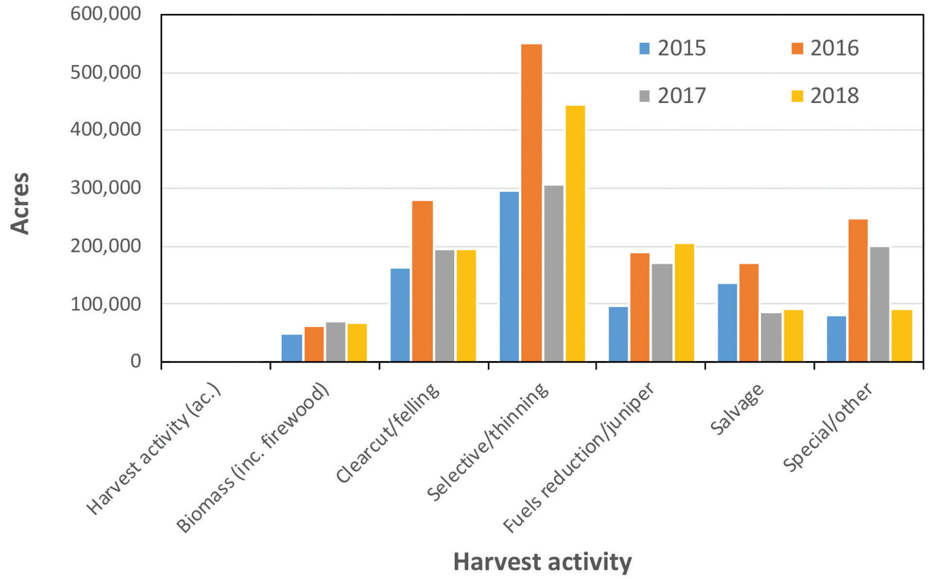


Figure 1-5. Harvest activities in Oregon, 2015–2018 (ODF FERNS).

includes areas (map polygons) that are likely associated with harvest activities, and may occur adjacent to the harvest unit but that need to be cleared for yarding.

1.3.2. Roads

Forest management requires access to the site, and roads must be maintained once they are built. Figure 1-6 shows the amount of road-related work notified in 2015–2018

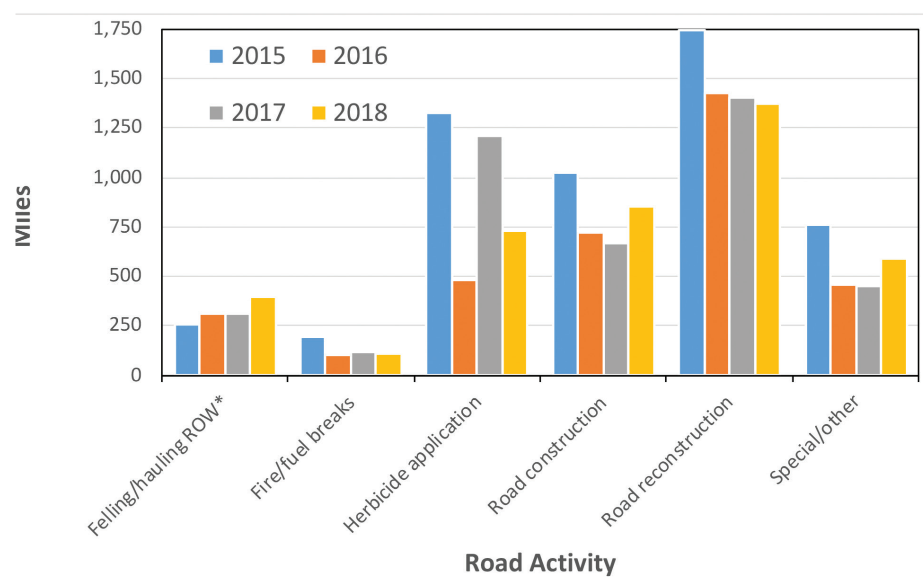


Figure 1-6. Forest road activities in Oregon, 2015–2018 (ODF FERNS).

in terms of length. Many forested areas already have roads, so reconstruction prior to harvest is more common (averaging about 1,500 miles per year) than new road construction (about 800 miles per year). The first step in constructing a new road (and reopening some older roads) is to fell trees in the right-of-way and haul them to the mill; this averages about 300 miles per year statewide. Standard maintenance operations (grading, cleaning ditches, spot rocking and mechanical brushing) do not require a FERNS notification. However, herbicide applications, which average over 900 miles of road annually, require a notification. Around 4,000 acres per year are used for rock pit development and management.

Fire and fuel breaks are constructed on about 130 miles annually. Special activities include brushing (Power-Driven Machinery permit), rocking, road decommissioning, and stream habitat improvements. Utility line and railroad line maintenance within and adjacent to forest lands also require notifications for fire and power driven machinery. These average about 1,400 miles per year for utility lines, and 240 miles per year for rail lines.

1.3.3. Reforestation

The Oregon Forest Practices Act requires reforestation within 24 months after harvest if the remaining stock of trees is below a threshold set based on site class (i.e., the ability to grow trees on a specific area of land). Reforestation is required after clearcutting, and may be needed in selection harvesting depending upon the remaining number of trees and their size. On highly productive land (Site Classes 1–3), the residual requirements are 200 trees per acre for seedlings; 120 trees per acre if they're saplings or poles with 10 inches of diameter at breast height (dbh) or less; or 80 square feet of basal area per acre of trees larger than 10 inches dbh.

Reforestation involves about a dozen different activities that are reported in FERNS. A typical sequence would start with slash treatment and site preparation from the previous harvest. Then the site would be planted (an activity not requiring notification). Prior to and after the planting, herbicide may be used to control competing vegetation to conserve growing space and moisture. Once planted, animal repellants and rodenticides may be needed to insure that the seedlings survive. Depending upon the density of seedlings planted that survive, there may be a need to precommercial thin the stand (usually at 10–15 years of age), and after thinning (both precommercial and commercial) fertilizer may be applied to provide nutrients needed to accelerate height and crown growth. Fire may be used as part of site preparation and slash treatment or to reduce fuel to decrease the likelihood of high-intensity burns.

Figure 1-7 simplifies reforestation activities into six types, eliminating insecticide and fungicide applications since they are so rare (see Chapter 6); and combines commercial thinning and pruning into a single category, and site preparation and slash treatment into another. On average, about 1.5 million acres of Oregon's private and state forests have reforestation treatments annually. By far the greatest extent is herbicide treatments, averaging about 600,000 acres annually. As we'll discuss in Chapter 6, there may be multiple applications of herbicides as part of site preparation and revegetation, which is likely why the area treated with herbicides is 50% greater than the acreage of site preparation/slash treatment (about 400,000 acres annually). Stand growth is accelerated through pre-commercial thinning (averaging 170,000 acres annually) and fertilization (about 100,000 acres annually). Prescribed fire is used on just over 150,000 acres of private and state land annually.

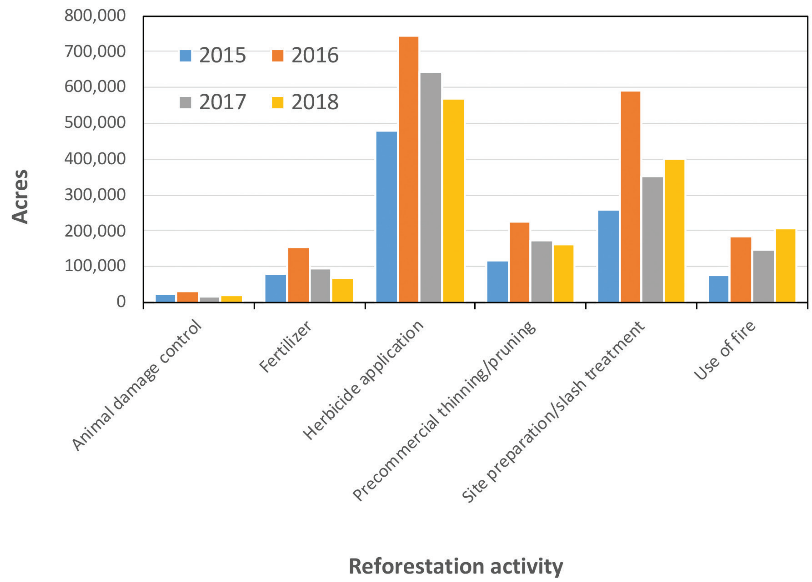


Figure 1-7. Reforestation activities in Oregon, 2015–2018.

1.4. Context matters

At numerous points in this report we will conclude our analysis of the potential effects of active forest management on source water quality with various qualifications or caveats that can be summarized as “it depends.” This is because the diversity of source watershed sizes, land uses, geographic regions, geomorphic conditions and other factors makes generalizations difficult. Much of the research on active forest management effects on overall water quality has been conducted in upper watershed areas. It hasn’t focused on tracing effects sufficiently downstream to raw source water intakes to infer cause and effect. The paucity of research on forestry and drinking water connections (Figure 1-8) stems from difficulties accounting for the effects of land uses below forestry activities but above the raw drinking water intake. We highlight possible linkages and allow readers to make inferences based on their situation. There are three categories that we emphasize in contextualizing our findings.

1.4.1. Size of watershed versus scale of forest management activities

The size of the source watershed in relation to the scale and frequency of forest management activities matters. The smallest community water supply, the Bay Hills Water Association in Lincoln County, has a source watershed of only 0.04 square miles, or slightly over 26 acres. In contrast, the largest source watershed, the City of Wilsonville, is 1,641 square miles, or 40 thousand times as large! A similarly sized management activity will have vastly different potential effects on a smaller compared to a larger watershed. Similarly, cumulative effects of management activities are likely to have greater effects in smaller compared to larger source watersheds. Larger source watersheds are also more likely to have a higher diversity of land uses, which we saw in Figure 1-1 affects water quality. The forest cover change information derived from satellite imagery presented in the atlas will be reported as the percent (%) of the source watershed affected.

1.4.2. Geography and geomorphology

The source watershed location and landforms within the drainage basin also have an effect. Coastal watersheds tend to be rainfed, with peak flows in the winter during storms and pronounced dry periods in the late summer. Conversely, watersheds draining into the valleys (Willamette, Umpqua, and Rogue) are more likely to have snowpacks at upper elevations that retain moisture into the spring and early winter, moderating and lengthening flows. Finally, source watersheds in Central and Eastern Oregon also have snowpacks (albeit holding less water), but rainfall patterns shift to the summer "monsoon" season. Thus, precipitation and runoff patterns vary by geography, and these variations influence how forest management activities affect source water quality.

The landforms and underlying geology of the source watershed also shape how active forest management influences source water quality. Steeper slopes and shallow soils are more likely to landslide. Higher gradient watersheds transport streamflow more rapidly downstream all other things being equal. Basalt geology transports groundwater more rapidly than sandstone geology, which again influences annual streamflows as well as source water quality. Some soil and rock types are much more erodible than others, which directly affects the amount of sediment mobilized by harvesting activities and forest roads. So understanding landforms and its underlying geology is important to evaluate the effects of active forest management on source water quality.

1.4.3. Land ownership

Who owns the drinking water source watershed affects the types, intensity and scale of forest management activities. From the water utility's perspective, having control over activities in their source watershed provides the best insurance of maintaining future water quality and quantity. This can be achieved by owning their source watershed; coming to agreement with landowners in their watershed on how the lands will be managed; or increasing regulatory oversight to prevent undesirable outcomes. Public ownership provides opportunities for water utilities to participate in planning processes, and generally involves environmental analyses that highlight management effects on water quality. In contrast, with private ownership, the water utility may not be able to cooperatively plan forest management activities in its watershed and instead may have to rely on the regulatory process. Thus, who owns the source watershed affects the likelihood that one of these arrangements will be available.

Ownership also affects various types and intensities of forest management activities. Important factors, such as the age of harvest and harvest types, vary by owner. Revegetation, particularly the use of forest chemicals, differs among owners too. Finally, the regulatory process varies by ownership: federal lands have to be managed by the responsible agency's regulations, as well as laws such as the National Environmental Policy Act. State lands operate under a different set of criteria, but have their own management plans that outline permissible activities. Management actions on private lands, as well as state lands, are governed by the Oregon Forest Practices Act and its regulations. Therefore, the types and diversity of land ownership within a source watershed will influence the types and intensities of forest management activities that can potentially occur, and by extension, influence the effects of these management actions on source water quality (Figure 1-8).

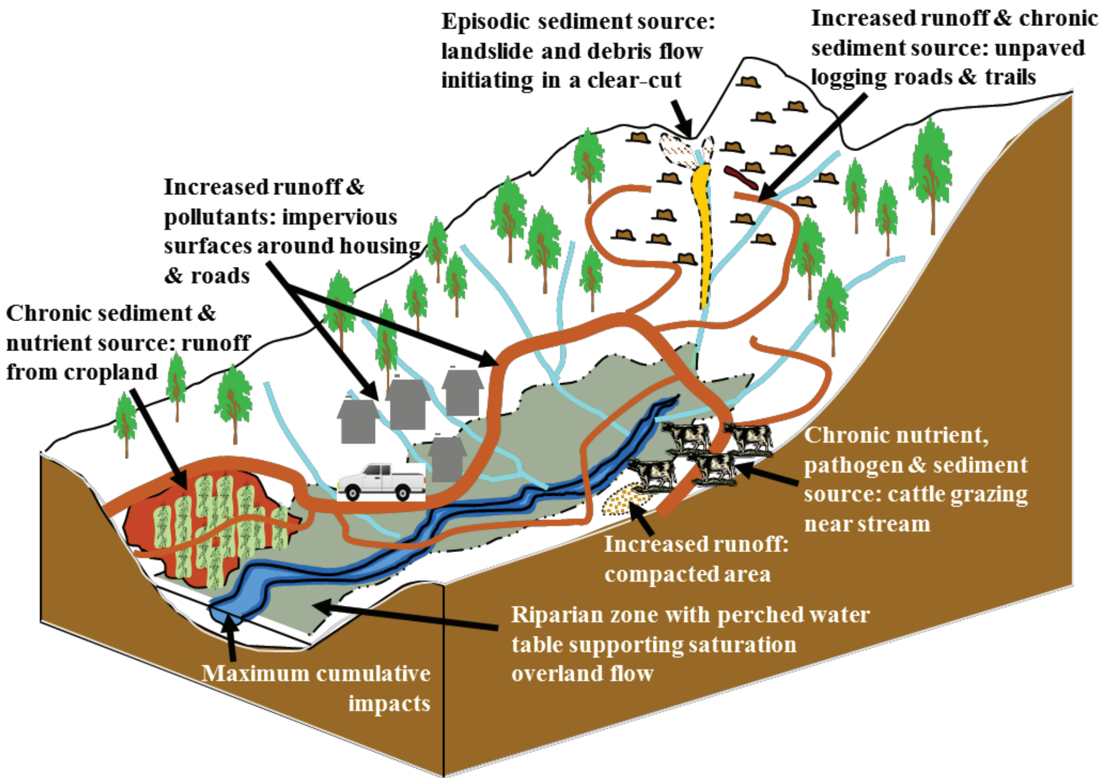


Figure 1-8. How multiple land uses within a watershed can generate cumulative effects related to streamflow regime, sedimentation, and nutrient/pollutant fate and transport. Source: Sidle, R.C., and Gomi, T., 2017.

1.5. Organization of the report

The body of this book will include 10 chapters. Available separately will be three major appendices as well as the Atlas of Community Water Systems. Chapter titles and a brief summary of their contents follow.

Chapter 2, Community Drinking Water Systems in Oregon: characteristics, regulations and management, treatment processes, community water system survey results.

Chapter 3, Active Forest Management and Community Water: Issues and Interactions: stream sediment, water production, forest chemicals and nutrients, natural organic matter and disinfection byproducts, best management practices, implementation of BMPs in Oregon, controversial and unresolved issues.

Chapter 4, Water Quantity: context, annual yields, peak flows, low flows and timing.

Chapter 5, Sediment and Turbidity: effects on water treatment, harvesting effects, forest roads, increased landslides.

Chapter 6, Forest Chemicals: background, chemicals used in Oregon forestry, chemical descriptions, review of effects, prevalence of forest chemicals in streams, chemicals in raw water supplies and potable water treatment.

Chapter 7, Natural Organic Matter (NOM) and Disinfection Byproducts (DPB): overview, chemistry and issues, NOM and potable water treatment, review of forest management effects, prevalence of standards exceedance, drivers and effects by region.

Chapter 8, Assessment of Wildfire Exposure to Public Water Supply Areas in Oregon: modeling approach, statewide and regional patterns, incorporation into planning.

Chapter 9, Case Studies of Community Water Systems: background, Ashland Water Department, Baker City Water Department, Oceanside Water District, lessons learned.

Chapter 10, Key Findings and Recommendations

1.6. Literature cited

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