Chapter 2

Community Drinking Water Systems in Oregon

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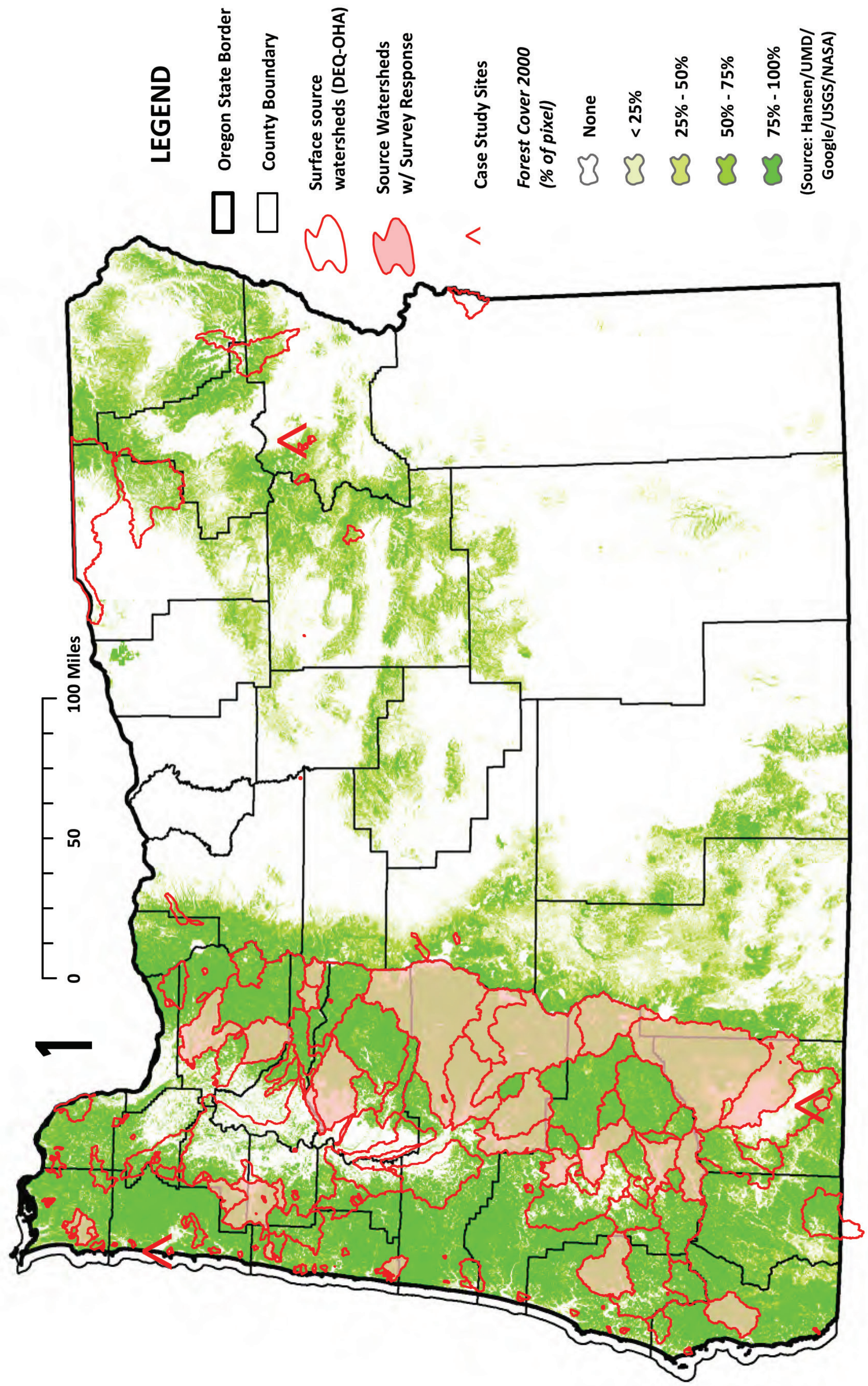
This chapter begins with a summary of Oregon's administrative framework for delivery of clean drinking water, and the state's community water providers and raw water treatment processes they use. Next is an overview of the diversity of landownerships in source watersheds, and commonalities and differences among smaller and larger water providers. There is a particular focus on smaller systems where the source watershed is not owned by the community and is potentially affected by active forest management, multiple uses or both. The chapter concludes with results and findings from a survey of Oregon water providers that was conducted specifically for this report, along with three case studies to help illustrate the diversity, challenges and successes among Oregon's community water systems.

About 35% of Oregonians rely solely on groundwater for drinking, mostly via small public water systems or private wells. About 10% rely solely on surface water. The remaining 55% — mostly large community water systems — rely on both surface water and groundwater, usually with groundwater as an emergency backup. There are 238 source watersheds that feed into 157 water treatment plants operated by 156 community water systems. Community water systems include any operation with 15 or more service connections for at least 25 people year round. These watersheds utilize surface water

Figure 2-1 Drinking water source watersheds showing those that responded to the water provider survey and the case study locations.

(Source: DEQ/OHA ArcGis Shape File 1_OR_SW_DWSAs_ORLAMBERT_Ver5_26JUL2017)



and shallow wells that are influenced by surface water to provide the raw water source for almost 3 million Oregonians. These watersheds are located throughout the state, although communities in eastern Oregon are more likely to depend on groundwater rather than surface water as their source of supply. Figure 2-1 shows these source watersheds. The figure also identifies those specifically that responded to our survey of water providers. Three locations where in-depth case studies were conducted are also noted. Those case studies are reported in Chapter 9.

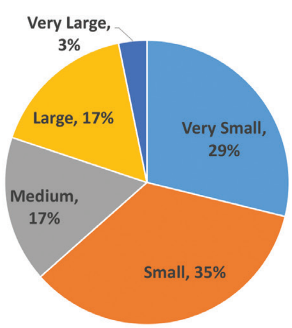
Most community water systems serve small populations. The U.S. Environmental Protection Agency classifies community water systems into five categories:

- Very Small systems serve fewer than 500 people.
- Small systems serve from 501 to 3,300 people.
- Medium systems provide water to between 3,301 and 10,000 persons.
- Large systems provide water to between 10,001 and 100,000 people.
- Very Large systems serve communities of greater than 100,000 population.

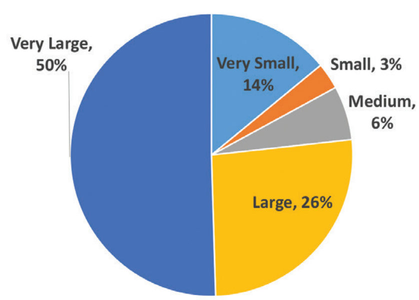
Figure 2-2 shows the proportion of population provided drinking water from surface sources based on the size of the system (a), and the proportion of CWS by their size class (b).

Over 75% of the population reliant on surface water is served by large or very large community water providers. A significant portion of people (14%) are supplied by very small systems. In contrast, these large and very large water systems comprise only 20% of the number of community water providers reliant on surface water, with only seven very large systems supplying half (50%) the population. Almost two-thirds of the community water providers dependent on surface water serve small (35%) or very small (29%) populations that limit their infrastructure capacity.

a. Population served by CWS size class.



b. Proportion of CWS systems by size class.



Source: DEQ/OHA ArcGIS Shape File 1_OR_SW_DWSAs_ORLAMBERT_Ver5_26JUL2017

Figure 2-2. Proportion of population provided with drinking water from surface sources based on the size of the system (a), and the proportion of CWS by their size class (b).

2.1. Regulation and management of drinking water in Oregon

This section discusses federal statutes and regulations that pertain to drinking water, how these statutes are coordinated to address different but complimentary aspects of drinking water protection, and Oregon's administrative framework for interpreting and implementing them. The Oregon Department of Environmental Quality (DEQ) provides reports, general information and technical assistance regarding surface water systems, while the Oregon Health Authority supplies these services for groundwater systems. In addition, the health authority regulates the treatment and distribution of potable water under the federal Safe Drinking Water Act, while the DEQ has regulatory authority under the federal Clean Water Act for point and nonpoint sources of pollution.

2.1.1. The Clean Water Act

The Clean Water Act provides the basic structure for regulating discharges of pollutants into U.S. waters. It does this via national water quality criteria recommendations developed and administered by the EPA and mostly delegated to the states and tribes for implementation. This regulatory framework makes a distinction between *point* sources and *nonpoint* sources of pollution. The Clean Water Act made it unlawful to discharge any pollutant from a point source into waters unless a permit is obtained from EPA or an authorized state or tribe under the National Pollutant Discharge Elimination System permit program. Point sources are discrete conveyances such as pipes or ditches. (EPA 2018a.)

The EPA defines nonpoint source pollution as pollution from diffuse sources resulting from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modifications. (EPA 2018b.) Nonpoint-source pollution is caused by rainfall or snowmelt moving over and through the ground. The precipitation picks up and carries natural and human-made pollutants into surface waters and groundwaters.

Logging operations are typically dispersed across large areas and are affected by weather, channel morphology, geology and watershed soil characteristics. This presents challenges in clearly distinguishing harvesting impacts from natural factors. Thus, it was relatively straightforward for the EPA to define silvicultural activities such as thinning, harvesting, site preparation, reforestation, prescribed fire, wildfire control and pest control as nonpoint source pollution. (EPA 2018c.) The EPA also defines forest road construction, use and maintenance as nonpoint source pollution, which has been more controversial. Chapter 3 provides a more detailed discussion of this issue.

Owing to its generally dispersed nature, nonpoint source pollution is addressed through area-wide management planning processes and voluntary incentive-based, quasi-regulatory, or regulatory programs. Oregon and other western states have addressed nonpoint source pollution from forest operations through forest practice acts since the 1970s. Nonpoint source pollution causes about 60% of water quality impairments, so Congress amended the Clean Water Act in 1987 to establish the Nonpoint Source Pollution Management Program under Section 319. This program provides states and tribes with grants to implement controls described in their approved nonpoint source pollution management programs. (EPA 2018c.)

2.1.2. The Safe Drinking Water Act

The 1974 Safe Drinking Water Act was significantly expanded in 1996 to protect drinking water quality. The law focuses on all U.S. surface water or groundwater sources actually or potentially used for drinking, and requires the EPA to establish and enforce standards to protect tap water. The EPA’s National Primary Drinking Water Regulations are legally enforceable standards, treatment techniques and water-testing schedules that apply to public water systems. The regulations place legal limits —”maximum contaminant levels” — on over 90 drinking water contaminants. The maximum contaminant levels are standards that protect human health and that water systems can achieve using the best available technology. Regulated contaminants are grouped as follows:

- Microorganisms
- Disinfectants
- Disinfection byproducts (DBPs)
- Inorganic chemicals
- Organic chemicals
- Radionuclides

The EPA also established National Secondary Drinking Water Regulations that set nonmandatory water quality standards for 15 so-called “nuisance” contaminants. These “secondary maximum contaminant levels” serve as guidelines to assist public water systems in managing their drinking water for aesthetic effects (such as taste, color and odor), cosmetic effects (such as skin or tooth discoloration) and technical effects (corrosion, staining, scaling or sedimentation in distribution systems or home plumbing). These contaminants can result in significant economic impacts by reducing distribution efficiency but are not considered to be human health risks. (EPA 2017a,b.)

The EPA uses the Unregulated Contaminant Monitoring Rule (UCMR) program to collect occurrence data for contaminants suspected to be in drinking water, but for which health-based standards have not been set under the Safe Drinking Water Act. The data support EPA decisions regarding whether to regulate particular contaminants to protect public health. Every five years EPA reviews unregulated contaminants, largely based on the contaminant candidate list, which includes contaminants that:

- Are not regulated by the National Primary Drinking Water Regulations.
- Are known or anticipated to occur at public water systems.
- May warrant regulation under the Safe Drinking Water Act. (EPA 2017c.)

In 2006, the EPA enacted updated rules to balance the risks of microbial pathogens and disinfection byproducts. The rules were based on evidence that Cryptosporidium and other microbial pathogens are highly resistant to chlorination and other traditional drinking water disinfection practices. Evidence also showed that the disinfectants themselves can react with naturally occurring materials in water to form byproducts that may pose health risks.

Under these rules — the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) and Stage 2 Disinfection Byproduct Rule (Stage 2 DBPR) — surface water systems are required to monitor source water for Cryptosporidium, E. coli and turbidity. System operators must identify and monitor locations in their distribution systems likely to have high levels of disinfection byproducts. If source waters do not meet standards, surface water systems must select from an array of “microbial toolbox” treatment options to meet treatment requirements. Locations identified as disinfection byproducts “hotspots” must be monitored for compliance with maximum residual disinfectant levels for disinfectants, and disinfection byproducts maximum contaminant levels established under the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR). (EPA 2005, 2017a; NACWA 2006.)

The Safe Drinking Water Act allows states to enforce their own drinking water standards if the standards are as stringent as EPA’s national standards. The EPA delegates primary enforcement responsibility for public water systems to states and tribes if they meet certain requirements. Oregon implements these primary (health-related) standards for EPA, and also encourages attainment of secondary standards (nuisance-related). (EPA 2018d.)

2.1.3. How the Clean Water Act and the Safe Drinking Water Act overlap

In the past, the Clean Water Act and the Safe Drinking Water Act had mostly separate goals and functions. The Clean Water Act focused on environmental protection and maintaining “fishable/swimmable” waters by identifying and regulating pollution sources in waterways. The Safe Drinking Water Act focused on municipal water treatment standards and providing clean drinking water at the tap.

However, rising demand for surface water — driven by population growth and associated development — has been accompanied by increases in wastewater and stormwater and reduced in-stream flow volumes available to keep these wastes diluted. These changes escalate loadings of sediment, nutrients, bacteria and other pollutants in community water sources. In response to the increasingly interrelated nature of watershed management and provision of safe drinking water, the Safe Drinking Water Act evolved to encompass environmental as well as consumer protection, resulting in overlaps with the Clean Water Act, and greater emphasis on cooperation and holistic water management among agencies charged with implementing the two statutes. (NACWA 2006).

Coordination across the Clean Water Act and Safe Drinking Water Act is motivated by potential synergisms among goals and outcomes of these policies. Efforts driven by the Safe Drinking Water Act to reduce contamination of drinking water sources can also protect aquatic ecosystems and wildlife, and provide higher quality and safer water-based recreation opportunities. Conversely, using the Clean Water Act to develop Ambient Water Quality Criteria that are protective of aquatic life can also help achieve and maintain safe drinking water (NACWA 2018). Among implementers of both statutes, preventing contamination is widely understood to be much more cost-effective at providing safe drinking water than removing contaminants or finding alternative water sources after the fact.

Collaboration among Clean Water Act and Safe Drinking Water Act implementers also facilitates more effective action to reduce disinfection byproducts in drinking water. These disinfection byproducts can form when a disinfectant (such as chlorine, chloramine, chlorine dioxide) reacts with organic matter — often decomposing plant matter — in source water (EPA 2005). Total trihalomethanes and haloacetic acids are widely occurring disinfection byproducts and have been linked with increased cancer risk, problems with reproductive systems and other human health risks (EPA 2006). Dissolved organic matter from forest detritus is a major precursor to disinfection byproducts in drinking water sources (Bardwaj 2006, Karanfil and Chow 2016). Thus, forest management activities that influence the quantity and mobility of this source of dissolved organic matter in source waters can influence the potential for disinfection byproducts to form during water treatment. Addressing disinfection byproducts issues efficiently requires coordination across the entire drinking water production chain from source water to tap.

2.1.4. The Safe Drinking Water Act Source Water Assessment Program

In 1996, Congress significantly expanded the Safe Drinking Water Act to facilitate prevention of contamination through an increased focus on drinking water source protection. The 1996 revisions were instrumental in pushing the Safe Drinking Water Act into the realm of the Clean Water Act, most notably via the Safe Drinking Water Act’s new Source Water Assessment Program. This program, along with the UCMR Program and the LT2ESWTR (discussed above), extended the Safe Drinking Water Act’s largely post-hoc emphasis on regulating water treatment to include environmental protection focused on source waters. (NACWA 2006).

The 1996 Safe Drinking Water Act revisions required states to develop EPA-approved programs to carry out Source Water Assessments for all public water systems in the state. The source water assessments focused on delineation of drinking water sources, identification of the origins of EPA-regulated contaminants (and any additional contaminants selected by the state) in those source waters, and providing water utilities, community governments, and other stakeholders with information needed to protect drinking water sources. The 1996 amendments outline six steps for conducting source water assessments for public water systems:

Step 1 **Delineate the source water protection area.** Delineation shows the area to be protected based on the area from which the public water system draws its drinking water supplies.

Step 2 **Inventory known and potential sources of contamination**. The contaminant source inventory lists all documented and potential contaminant sources or activities of concern that may be potential threats to drinking water supplies.

Step 3 **Determine the susceptibility of the public water system to contaminant sources or activities within the source water protection area.** Determining susceptibility of the public water system to inventoried threats relates the nature and severity of the threat to the likelihood of source water contamination.

Step 4 **Notify the public about threats identified in the contaminant source inventory** and what they mean to the public water system. Effective programs ensure that the public has information necessary to act to prevent contamination.

Step 5 **Implement management measures to prevent, reduce or eliminate risks to your drinking water supply.** The assessment information can support formulation and implementation of measures to protect the source water. These measures can be tailored to address each threat or array of risks specific to each public water system.

Step 6 **Develop contingency planning strategies that address water supply contamination** or service interruption emergencies. Water supply replacement strategies are an indispensable part of any drinking water protection program in the event of short- or long-term water drinking water supply disruption.

The 1996 revisions also authorized voluntary source water protection partnerships between state and local governments focused on reducing contaminants in drinking water, opportunities for financial and technical assistance, and developing long-term source water protection strategies, usually documented in Source Water Protection Plans. (NACWA 2006; Tiemann 2017.)

2.1.5. Programs for local source water assessment and source water protection planning

In 2015, Congress enacted the Grassroots Rural and Small Community Water Systems Assistance Act, reauthorizing and revising the small water system technical assistance program included in the 1996 Safe Drinking Water Act expansion. Under this act, the Source Water Protection Program is coordinated jointly by the USDA Farm Service Agency and the National Rural Water Association, a nonprofit water and wastewater utility membership organization. The Source Water Protection Program is designed to help prevent pollution of drinking water sources for rural residents. Participation in the program is voluntary. Rural source water technicians work with specialists from the USDA Natural Resources Conservation Service and state and county staff to identify areas where pollution prevention is most needed. These technicians then work with state rural water associations to form local teams comprised of citizens and representatives from federal, state, local and private organizations. They collaborate on Rural Source Water Protection plans to promote clean source water through voluntary actions that local landowners can implement to prevent contamination. The goal is to work at the grassroots level to educate and inform rural residents about practical steps to prevent water pollution and improve water quality.

The Oregon Association of Water Utilities is a nonprofit, independent association of about 700 mostly smaller and rural public and private community water utilities in the state. The OAWU represents their members' interests in the Oregon legislature and coordinates with the National Rural Water Association, which represents rural water systems at the national level. The OAWU also plays an important role in addressing drinking water issues at the local water system level, through onsite technical assistance in areas such as Safe Drinking Water Act and Clean Water Act regulations, water treatment technology, distribution system operation and maintenance, and wastewater treatment and collection. The OAWU Source Water Specialist deals specifically with drinking water protection, working with local water systems to prepare drinking water protection plans that address all state and federal requirements, including specifically addressing potential contaminants through education of local management authorities and best management practices to help reduce the likelihood of contamination.

The American Water Works Association (AWWA) mission is to support water utilities in evaluating and improving their water quality, operations, maintenance and infrastructure. The AWWA has developed detailed guidance for local municipalities to use in developing their source water assessments and protection plans — Utility Management Standard G300, Source Water Protection (AWWA 2014). This American National Standards Institute (ANSI)-approved standard and its accompanying operational guide (Gullick 2017) outline six primary components of successful source water protection programs and requirements for meeting the standard:

- A source water protection program vision and stakeholder involvement
- Source water characterization
- Source water protection goals
- Source water protection action plan
- Implementation of the action plan
- Periodic evaluation and revision of the entire source water protection program

2.1.6. How Oregon agencies coordinate to provide safe drinking water

In Oregon, the Safe Drinking Water Act is directly implemented by Oregon Drinking Water Services (DWS), within the Environmental Health Section of the Public Health Division, Oregon Health Authority (OHA) under ORS 338.277 and 448.273. Under Safe Drinking Water Act, DWS is primarily involved with administering and enforcing drinking water quality standards for public water systems, but also with source water protection, primarily for groundwater systems. The Oregon Department of Environmental Quality

(DEQ) implements Clean Water Act authorities to address pollutants that affect the quality of drinking water source waters, primarily surface waters. In practice, the DEQ Drinking Water Protection Program coordinates with OHA's DWS through an interagency agreement to carry out provisions of the two acts and jointly provide clean drinking water. Although OHA is the primary implementer of the Safe Drinking Water Act, DEQ took the lead on the source water assessments mandated by the 1996 Safe Drinking Water Act revisions, conducting all surface water assessments and assisting on the groundwater assessments.

The DEQ also administers the Oregon Coastal Nonpoint Pollution Control Program (CNPCP). Coastal states are required to develop such programs to be eligible for federal funding to mitigate nonpoint source pollution under the federal Coastal Zone Management Act Reauthorization Amendments of 1990 (CZARA). Coastal states are also required to implement a set of management measures based on guidance published by the EPA. These programs are designed to restore and protect coastal waters from nonpoint source pollution and to mitigate impacts to beneficial uses of these waters, including use for municipal drinking water. Oregon's CNPCP was developed in cooperation with the Oregon Department of Land Conservation and Development (DLCD) Oregon Coastal Management Program (OCMP). The CZARA, and how it intersects with drinking water protection in Oregon, are discussed in more detail in Chapter 4.

The DLCD also coordinates with DEQ to offer guidance to communities that may wish to enhance protection of their source watersheds through improved land-use regulations such as comprehensive plan and zoning ordinance updates. (Oregon DEQ 2017.)

2.1.7. Source water assessments in Oregon

As stipulated by Safe Drinking Water Act and Oregon Regulations (OAR 333-061-0020(125)), Source Water Assessments (SWAs) were completed between 1996 and 2005 for community water systems in Oregon serving at least 15 hookups or more than 25 people year round (OAR 333-061-0020(25). Under the Safe Drinking Water Act, smaller systems and transitory uses are also called public water systems (see OAR 333-061-0020(107) for a definition of these), but these are beyond the scope of this report. In following years, Oregon agencies significantly expanded their capabilities for analyzing natural characteristics and potential pollutant sources. With this expanded capacity, Updated Source Water Assessments (USWAs) with more detailed data, maps, and technical information were completed for roughly 50% of these systems in 2016-2017.

The assessments:

1. Defined groundwater and surface water source areas that supply public water systems.
2. Inventoried each area to determine potential sources of contamination.
3. Determined the most susceptible areas at risk for contamination.

For surface water systems, DEQ prioritized the 52 coastal community water systems under the rationale that these systems are challenged by geographic setting, climate, geology and seasonal tourism in ways that other areas in Oregon do not necessarily experience.

As part of the USWAs, DEQ developed a statewide land use/ownership Geographic Information Systems (GIS) layer to evaluate land cover in drinking water source areas. Maps for each individual public water system are provided in that system's USWA report.

Information from the source water assessments for surface water systems is available to the public via a database maintained jointly by the DEQ and OHA. In 2018, after consulting with stakeholders, the DEQ also finalized a Surface Water Resource Guide to provide additional technical assistance and information to surface water community water systems. (Oregon DEQ 2018c.) This document (and a companion Groundwater Resource Guide) will continue to be updated and improved as source water protection efforts in Oregon move forward. The USWAs and Resource Guides are ultimately intended to assist public drinking water providers, community governments and others in the development of community-based Drinking Water Protection Plans to protect their upstream source waters.

Several rural water providers in Oregon have voluntarily worked with the Oregon Association of Water Utilities to take advantage of the USDA Farm Service Agency Source Water Protection Program. Most utilize groundwater, but some are surface water systems. The protection plans are based on interviews with water utility personnel, local managers and land owners, information from the source water assessment or updated assessment and a visit to the source water intake and source watershed. The plans include (Collier 2018):

- A map of the planning area.
- An inventory of potential contaminant sources, and characteristics and sensitivity of the source water.
- A definition of areas and community profile that align with participating local entities and organizations.
- A definition of voluntary measures and best management practices that may be initiated.
- Identification of public education initiatives, entities and resources to facilitate plan implementation and sustainability.
- A contingency and emergency response plan in the event of problems with the local drinking water supply.

2.2. Raw water treatment processes

2.2.1. Overview

The conversion of raw source water into finished potable water entails a series of steps called the "treatment train." These steps, along with source water protection activities such as identifying and reducing contamination in watersheds, are designed to provide an integrated "multiple barrier" approach so that if any one step fails there is redundancy to reduce the likelihood of contamination reaching the tap. There are various permutations of these steps depending upon the quality of the source water and the expectations of the utility's customers, but all processes are designed to at least meet the Safe Drinking Water Act standards for maximum contaminant levels (MCLs) as discussed in the prior section. Treatment is a combination of physical operations, such as screening, mixing, sedimentation and filtration; operations such as precipitation and disinfection resulting from chemical additions; and biofiltration to remove nitrogen and organic matter. Because treatment processes may be simpler for groundwater sources, our focus will be on the treatment of surface water rather than groundwater.

Our discussion highlights how raw water is treated to remove impurities, kill pathogens, and provide safe water at the drinking water tap. General concerns include turbidity and particles; hardness and total dissolved solids (TDS); color, odor, and taste; dissolved minerals such as manganese and iron; bacteria, algae, protozoan cysts, and viruses; and anthropogenic sources such as pesticides, herbicides, volatile organic compounds and pharmaceuticals; and natural organic matter and disinfection by-products. We will focus on treatments affecting our three high-priority concerns (turbidity/sediment; forest chemicals; and natural organic matter/disinfection byproducts) as they are most likely to be affected by active forest management.

Permutations of treatment processes among the 157 treatment plants that rely on surface water can be grouped into five major categories as shown in Table 2-1. Table 2-1 separates these different types of treatment processes by the size of the population served by the system, using the EPA population size categories.

The most common treatment process is the conventional and direct process with either rapid or pressurized sand filtration, utilized by 96 (over 60%) of the water treatment plants that rely on surface water. The next most common process is membrane filtration, used by 28 (18%) of the treatment plants. Nineteen plants (12%) used a slow sand filtration process, with one subsequently applying membrane ultrafiltration. Alternative methods, approved by OHA, are employed in eight treatment plants, most commonly a cartridge filtration system that uses polypropylene as a filter (discussed below) to catch sediment.

Finally, three community water providers do not filter their drinking water (Portland, Baker City, and Reedsport), although it is disinfected prior to entering their distribution systems. Another three providers (Monmouth, Monument, and the Shangri La Water District) are currently not filtering their surface water, but have been required to install equipment [Note: Baker City may be in this same situation].

Very small and small community water systems are more likely to use membrane filtration, slow sand filtration, and alternative methods. This is largely due to scalability of membrane and cartridge systems, and the comparative ease of operation of slow sand filtration. Most all (71%) of the slow sand filtration treatment plants are located in small systems, with over half serving populations of 501 to 3,300 persons; the one slow sand treatment plant in a very large system is Salem.

Figure 2-3 shows process diagrams of the two most common treatment processes: (a) conventional filtration; and (b) membrane filtration. All systems that rely on surface water have an intake structure that controls the amount of raw water entering the treatment plant. Usually, this structure incorporates bars (called “trash racks”) and screens that intercept debris coming into the plant. Depending upon the system, there may be settling ponds just after the intake to reduce suspended particles prior to the water entering the plant.

Screens come in two varieties: *coarse screens*, to remove large particles from 20 to 150 mm and larger, commonly used at the entrance of the plant; and *micro screens*, to remove small particles 0.025 to 1.5 mm commonly used to remove filamentous algae. When stream conditions exceed the capacity of the plant to treat the raw water, the intake is commonly closed until conditions improve. High levels of turbidity, sediment or debris that clog screens are common reasons to close the raw water intake, although spills or other incidents may also result in closure. When this occurs, the water utility is dependent upon alternative sources (such as wells) if available, and its storage capacity to maintain service. (Crittenden et al. 2005.)

Table 2-1. Drinking water treatment plant technology by EPA system size category.

Treatment process	EPA drinking water system service population size					
	Very small	Small	Med	Large	Very large	Process total
1. *Conventional/direct*						
Filtration, rapid sand	16	40	13	18	4	91
Filtration, pressure sand	4	1				5
2. *Slow sand*						
Filtration, slow sand	3	10	2	2	1	18
Filtration, slow Sand & ultrafiltration				1		1
3. *Membrane*						
Filtration, Microfiltration	1	1		2		4
Filtration, Ultrafiltration	9	6	5	3	1	24
4. *Alternative Methods*						
Filtration, Cartridge	4	2				6
Filtration, Diatomaceous Earth	1					1
Natural Filtration	1					1
5. *Unfiltered*						
Unfiltered, Avoiding Filtration			2		1	3
Unfiltered, Must Install Filtration	2		1			3
Systems by Population Size Total	41	60	23	26	7	157

Source: DEQ/OHA ArcIS Shape File "Treatments_07Sep2017"

Common among treatment processes is the control of pH and addition of oxidants or other disinfectants once the raw water passes through the intake screens (Figure 2-3). In the initial treatment process, pH control is used to assist in removing undesirable

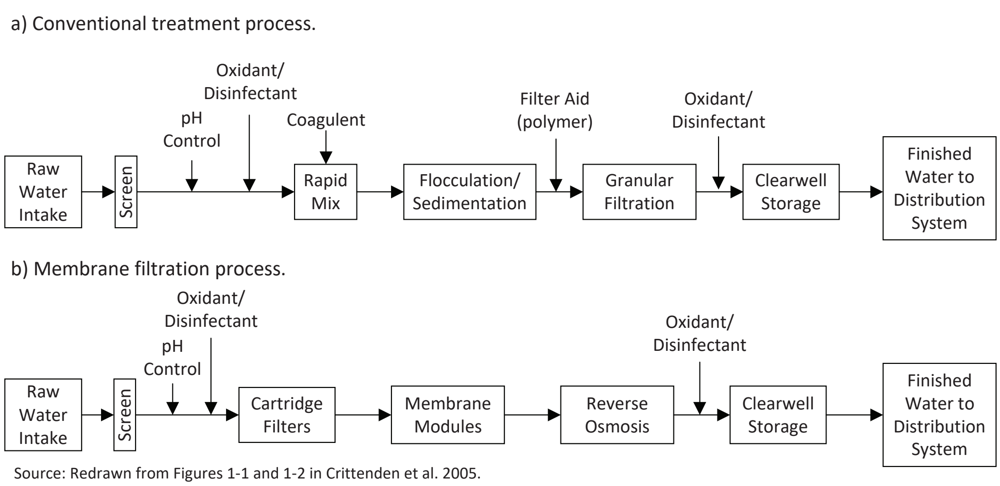


Figure 2-3. Conventional (a) and membrane (b) filtration drinking water treatment processes.

particles through either precipitation or coagulation. Common oxidation additions are chlorine, ozone, chlorine dioxide, permanganate, and hydrogen peroxide. They are primarily used to control taste and odor, remove undesirable solutes (hydrogen sulfate, color, iron and manganese), and disinfect (i.e., kill pathogens such as bacteria and viruses). If ozone is used to disinfect the water, then the pH is usually lowered to avoid the formation of brominated organics — undesirable disinfection by-products — through reaction with natural organic matter in the water.

2.2.2. Conventional and direct treatment processes

Conventional and direct treatment processes have evolved since the first ones were created in the early 1800s. These treatments are typically comprised of coagulation, flocculation, sedimentation and filtration (Figure 2-3a). The difference between "conventional" and "direct" treatment is that there is a sedimentation step between flocculation and granular filtration in the conventional process, while this step is skipped in the direct process. The filtration process removes suspended particles and dissolved substances during the treatment process.

Rapid mixing is important for coagulation and the addition of chlorine. Rapid mixing is used when chemicals need to be added to the water being treated, there needs to be uniformity in the blending, and there may be competitive consecutive reactions among the chemicals added and there is a desire for the reaction to be irreversible (or not occur, as in the case of natural organic matter and disinfection byproducts). Coagulants are used to condition the suspended, colloidal and dissolved matter for subsequent removal. Most particles in natural water are negatively charged, so they naturally repel each other. This charge has to be removed before the particles coalesce sufficiently large to be removed through filtration. Coagulants provide adsorption and reaction locations for colloidal and dissolved natural organic matter; have electrical charges that neutralize small suspended or colloidal particles so that they aggregate into larger particles; and enmesh small suspended, colloidal and dissolved particles as they settle. Typically these are alum and iron salts (but sometimes polymers), as they produce positive charges to neutralize the negative charges on particles so they can clump and be more easily removed.

Flocculation is the process of forming larger aggregates by mixing smaller particles so that they come close enough to attach to each other. This process occurs in moving water, with higher velocities in the early stages of flocculation where aggregates are smaller (micro-flocculation), and progressively moving slower water to avoid breaking up larger aggregations (macro-flocculation). Water (and aggregates) then move to a sedimentation (settling) basin if the particles are heavier than water, or a floatation basin if they are lighter. Polymers — natural or synthetic long-chain (high molecular weight) organic molecules that can have different levels of positive (cationic) or negative (anionic) charge—may be added as a filter aid. Cationic polymers are used instead of (or in addition to) metallic salts to neutralize charged particles in both the coagulation and flocculation steps. In general, polymers act slower than the inorganic metallic salts. The remaining water is decanted for further processing while the flocculants are removed.

Granular filtration strains fine suspended particles (sand, clay, and iron and aluminum flocs) during the treatment process. Typically, granular filtration is accomplished through sand filter beds, with particles larger than the space between sand grains remaining in the sand. Filter media (usually sand) ranges in grain size from (0.5 –1.2 mm diameter), with the tradeoff being that smaller sizes remove more particles, but get clogged more quickly, and the vice versa with larger grain sizes. Some treatment plants overcome these constraints by using multiple sand filter beds so that water progresses from coarse-grained beds to finer-grained beds. Unfiltered water input above the bed and the filtered water drawn from below with water velocities of about 5 to 15 meters per hour (m/h) from a hydraulic head of 1.8–3 meters (Crittenden 2005). Treatment operators periodically backwash filters to clean out the filtered particles and coagulants and then dispose of the waste and backwash water.

The filtered water in conventional and direct treatment is dosed with disinfectants (typically chlorine) to kill pathogens. Clearwells temporarily store filtered water for a sufficient time to provide chlorine contract for disinfection. They are also used to buffer variations in finished water demand. The finished water may have its pH adjusted again to prevent dissolving toxic metals used in distribution pipes and household plumbing (for example, the Flint, Michigan problem due to lead pipes). Finished water is also required to have some chlorine residual throughout the distribution system to protect against contamination. If this residual chlorine remains in contact with dissolved organic carbon in stagnant water, then undesirable disinfection byproducts may be created.

2.2.3. Slow sand treatment process

While conventional rapid sand filtration is a physical and chemical treatment process, slow sand filtration is a physical and biological treatment process (Crittenden 2005). The treatment train for slow sand systems does not typically include the flocculation/sedimentation steps found in conventional and direct filtration. It also differs in that the sand filter media is smaller (0.3–0.45 mm diameter), and the hydraulic head used to push the water through the filter is less (0.9–1.5 m), resulting in a water velocity of between 0.05 and 0.2 m/h. Most particles are physically removed in the upper inches of the filter bed. Additional particle straining occurs in the *schmutzdecke*, a complex layer that consists of decomposing organic matter, iron, manganese and silica (Ranjan and Prem 2018) that includes a gelatinous biofilm containing algae, bacteria, fungi, protozoa, rotifer and various invertebrates. The *schmutzdecke* and the remainder of the filter bed contribute to water purification through four mechanisms:

1. It creates a hostile environment for intestinal bacteria because of low temperatures.
2. The bioactivity in the layer competes for food needed by these pathogens.
3. Predatory organisms feed on the pathogens.
4. Microorganisms in the slow sand filter produce compounds poisonous to intestinal bacteria (Huisman and Wood 1974).

Slow sand gravity filtration systems have a filter capacity of 0.005–0.018 m^3/h per square meter of granular filter area, compared to rapid sand filtration that has a throughput capacity of 5–15 (m^3/h per square meter of filter area (Crittenden 2005). Thus, a slow sand filtration process requires approximately 100 times the area as rapid sand filtration, but requires less expertise and has fewer operational costs. Other than land area, the primary limiting factor for slow sand filtration is that the turbidity of the raw water should be less than 50 NTU, preferably less than 10 NTU, and optimally less than 5 NTU (Crittenden et al. 2005).

2.2.4. Membrane filtration treatment process

Membrane filtration is a physiochemical process that uses a semipermeable membrane as a mechanism to remove suspended particles. The treatment train for membrane filtration is shown in Figure 2-3b. In Oregon, both microfiltration (0.1 µm pores) and ultrafiltration (0.01 µm pores) treatment plants exist. Microfiltration will remove particles, sediment, algae, protozoa, and bacteria; ultrafiltration will additionally remove small colloids and viruses. Membrane filtration is typically used to process water containing less than 1,000 mg/L of total dissolved solids (TDS) (Crittenden et al. 2005).

Cartridge filters are used in membrane filtration for pretreatment to remove solids (Figure 2-3b). Systems are pressurized to force the water through the filters, generally moving from the outside to the inside of the cartridge. Cartridge filters consist of a filter media consisting of micro-denier (screen size) polypropylene fiber, typically with coarser outer layers and finer inner layers down to 0.2 microns (filtrasystems.com). Cartridge filters can remove turbidity (if source is less than 1 NTU and without fine colloids or clays), and remove *Cryptosporidium* and *Giardia* cysts from source water, although they do not remove bacteria or viruses. Used by themselves, cartridge filters are typically used in systems of less than 100,000 gpd; as shown in Table 2-1, there are six water treatment plants in Oregon that utilize only cartridges.

Whether or not cartridge filters are used, water undergoing treatment then moves to the membrane modules. Membrane filters are usually manufactured as flat sheet stock or as hollow fibers and then formed into different types of membrane modules. Module construction typically involves potting or sealing the membrane material into an assembly, such as with hollow-fiber module. These types of modules are designed for long-term use over the course of a number of years. Spiral-wound modules are also manufactured for long-term use, although these modules are encased in a separate pressure vessel that is independent of the module itself (MNRWA 2009).

Reverse osmosis is generally only used in drinking water treatment when the raw water is high in total dissolved solids, such as seawater or brackish groundwater (TDS = 1,000 – 20,000 mg/L), or the water is highly colored (TOC > 10 mg/L). As a type of membrane filtration, reverse osmosis uses a semipermeable membrane to remove dissolved ions and molecules, as well as larger particles from drinking water. However, the membrane pores are quite a bit smaller (< 1 nm). Reverse osmosis has the capability to remove hardness, natural organic matter, heavy metals, radionuclides and pesticides (Crittenden et al. 2005). The final treatment steps for membrane filtration — disinfection and clearwell storage — are similar to those in conventional treatment. At this time, no water treatment plants in Oregon use reverse osmosis.

A few systems in Oregon utilize powdered activated charcoal (PAC) and granulated activated charcoal (GAC) treatments to remove contaminants such as pesticides and volatile organic compounds. It should be noted that these treatments do not provide complete removal of targeted contaminants.

2.2.5. Sensitivity of various process types to sediment and turbidity

Sediment and turbidity levels in the raw surface source water limit available treatment processes and affect operational costs (coagulants and requirement for backwashing filters). Table 2-2 compares threshold sediment and turbidity levels for the various types of treatment processes described above.

Table 2-2. Surface water thresholds for turbidity and color for various treatment processes.

Treatment process	Turbidity range (NTU)	Color range (CU)	General design references
Established Technologies			
Conventional Filtration	Unlimited	< 75	Kawamura 2000
Direct Filtration	< 15	< 40	Kawamura 2000
Pressure Filtration	< 5	< 10	Ten State Standards 2007
Diatomaceous Earth Filtration	< 10	< 5	AWWA 1999; Fulton 2000; WSDOH 2003
Slow Sand Filtration	< 10	< 10	Hendricks et al. 1991, WSDOH 2003
Alternative Technologies			
Bag and Cartridge Filtration	< 5	See Note 4	EPA 2003
Membrane Filtration	< 10	See Note 4	Crittenden et al. 2005

Source: Washington Department of Health 2009. Water System Design Manual, Table 12-3 p. 155. [Membrane filtration changed]

Other potential impacts of excess sediment include filling of reservoirs and intake ponds (requiring dredging with associated permitting), shorter filter life, and extra staff time to manage water quality and treatment processes. There are also regulatory compliance problems if MCLs cannot be met and the potential for treatment plant shutdowns, which can cause finished water supplies to run low.

2.2.6. Diversity of community water suppliers in Oregon

Community water suppliers in Oregon range in size from the Portland Water Bureau with over 500 employees and an organized, multi stakeholder working group that collaborates on management and produces an annual report, to very small rural systems serving only a handful of households and managed by a single staff member. Some of the smallest systems in Oregon are staffed by volunteers only.

Regardless of size, every community water system requires a certain minimum level of infrastructure and treatment capability. Economies of scale often work against smaller water providers because treatment costs per unit [gallon] of finished water typically decline as system size and volume treated increase. Larger systems also usually have correspondingly larger budgets and dedicated staff. Smaller systems, in contrast, usually face higher costs per unit of finished water delivered, have smaller budgets and operate with fewer dedicated staff. One important consequence of this disparity is that smaller systems have correspondingly less capacity to identify, publicize and mitigate threats or impacts to the quality and quantity of their drinking water sources.

2.4. Results and findings from survey of Oregon drinking water providers

This section explores some of this diversity among Oregon community water systems, and the issues they face by summarizing results from a survey of water providers conducted in 2018. A key component of the *Trees to Tap* project was a survey of Oregon drinking water providers that utilize surface waters as part or all of their supply. The survey was modeled after, but expanded upon, a similar survey by Adams and Taratoot (2001) and solicited input from utility managers regarding the issues they face in managing and protecting their drinking water sources. Details regarding methods used in the water provider survey are provided in the appendices.

The following section provides detailed results and findings from the survey, including:

- Respondent characteristics.
- Governance of respondent water systems.
- Partnerships and activities.
- Data collection and notifications.
- Reported issues of management concern in drinking water source watersheds.
- Lessons learned.
- A summary and discussion of survey results.

2.4.1. Summary of respondent characteristics

Final survey responses totaled 54 systems, or 35% of the 156 systems in Oregon. We examined respondent location by several characteristics. These figures help contextualize the data by identifying which types of systems are better represented by survey results. We did not conduct initial sampling based on any characteristic, but conducted follow-up to target respondents with highest percentages of private industrial timberland, public land and local government ownership based on interest of the steering committee.

The majority of survey respondents (58%) were from the Valleys region, and approximately one-third of all Valley systems responded (Table 2-3). Thirty-eight percent of respondents were from the Coast region and 39% of the systems in this region responded. Only 4% of responses were from the Dryside region and 17% of all systems in that region responded. Relative to their total proportion in the state, survey responses over-represent Coast and Dryside systems, and underrepresent Valley systems. Size of populations served by respondent systems ranged from 29 (Weiss Estates Water System) to 183,523 (Eugene Water and Electric Board) with a mean population service size of 15,985. Population quintiles were fairly equal in percentage of response, excepting systems serving populations of 1,801 to 3,000 (Table 2-4). Respondents from smaller primary source watersheds (less than 10 square miles) composed the largest proportion of responses at 41%, and larger watersheds exceeding 350 square miles were the smallest proportion at 11% (Table 2-5). Responses were fairly equal across size classes of public and private industrial forest land ownerships (Table 2-6 and Table 2-7).

Table 2-3. Respondent affiliation and response rate by major region. Due to rounding, totals may not consistently be 100%.

	Survey respondents	Proportion of responses	Systems in region	Proportion of systems	Proportion of systems responding
Coast	21	38%	54	35%	39%
Dryside	2	4%	12	8%	17%
Valleys	31	57%	90	58%	34%
Total	54		156		

Table 2-4. Respondent affiliation and response rate by population quintile size served. Due to rounding, totals may not consistently be 100%.

Population quintile	Number of respondents from quintile	% of respondents from quintile
0 to 235	12	22%
236 to 1,800	11	20%
1,801 to 3,000	4	7%
3,001 to 10,700	13	24%
10,701 to 184,000	14	26%
Total	54	

Table 2-5. Respondent affiliation and response rate by size of primary source watershed. Due to rounding, totals may not consistently be 100%.

Primary source watershed size class	Number of respondents from size class	% of respondents from size class
0 to 10 square miles	22	41%
10.1 to 100 square miles	11	20%
100.1 to 350 square miles	13	24%
350.1 to 1,150 square miles	6	11%
Left blank	2	4%
Total	54	

Table 2-6. Respondent affiliation and response rate by % of primary source watershed in public land ownership. Due to rounding, totals may not consistently be 100%.

% of primary source watershed in public land ownership	Number of respondents from class	% of respondents from class
0 to 10 %	17	31%
10.1 to 40 %	12	22%
40.1. to 80 %	12	22%
80.1 to 100 %	13	24%
Total	54	

Table 2-7. Respondent affiliation and response rate by % of primary source watershed in private industrial timberland ownership. Due to rounding, totals may not consistently be 100%.

% of primary source watershed in private industrial forestland ownership	Number of respondents from class	% of respondents from class
0 to 10 %	17	31%
10.1 to 25 %	11	20%
25.1 to 75 %	11	20%
75.1 % to 100 %	13	24%
Left blank	2	4%
Total	54	

2.4.2. Governance of respondent systems

We asked respondents questions about how their drinking water system was governed, including organizational model, average annual operating budget dedicated to drinking water supply, number and type of employees and access to the watershed.

First, the majority of respondent systems (56%) were organized as departments or units of municipal government (Figure 2-4a). A little more than a quarter were special districts, while less than 10% respectively were nonprofits or private for-profits. No respondents were from tribal systems or joint (regional) entities of multiple governments. The survey population therefore largely represents public rather than private or nonprofit entities that manage Oregon's drinking water supply. Size of budget is also important to understand, as providers with larger budgets may have correspondingly larger capacity to manage their drinking water supplies. Fifty-eight percent of Oregon CWSs operated on a budget of $500,000 per year or less. Twenty-three percent reported annual budgets of $500,001 to $2 million. Only six percent exceeded $10 million (Figure 2-4b).

We also asked respondents to identify the number and type of staff employed in drinking water provision (Table 2-8). Like provider budgets, staff size and type may be an indication of the capacity that a provider has to manage their drinking water supplies. Total staff sizes ranging from zero to 200 were reported. A majority (64%) had one to 10 total staff. Seven respondents indicated that they had no paid employees, relying solely on volunteer homeowners or board members, and 10 had only one or two staff. The mean total staff size was 13, with an average of 11 full-time employees.

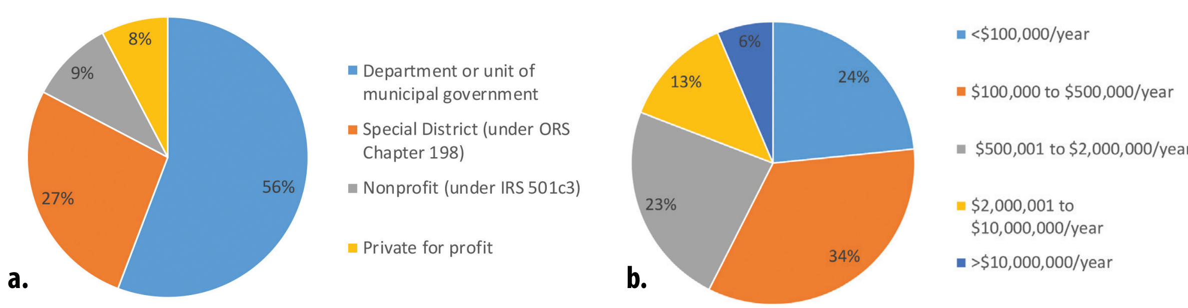


Figure 2-4. Water utility survey responses for type of organization (a) and annual budget (b).

Table 2-8. Number of staff employed in drinking water provision. Due to rounding, totals may not consistently be 100%.

Total staff employed in drinking water provision	Number of respondents	% of respondents
0	7	14%
1-10	32	64%
11-20	5	10%
21-30	2	4%
>30	5	10%
Total	50	

Respondents were also asked about the type of access available to their primary source watershed (Figure 2-5). Access to source watershed areas may pose management issues to drinking water suppliers, but recreation on forested lands is also an important activity in Oregon. Respondents were able to choose all types that applied. Nearly one half allowed open access to the public at all times, while 20% allowed no public access. A few responding "other" indicated access approaches such as voluntary permits, hours of access and limits on types of uses (e.g., motorized).

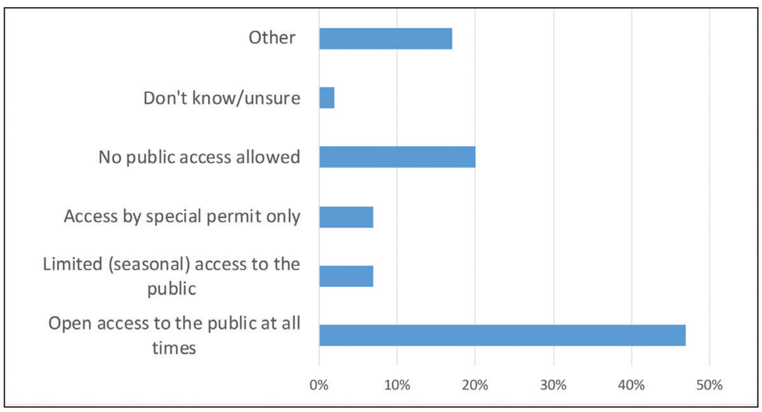


Figure 2-5. Type of access allowed on primary source watershed. N=59 for question (choose all that apply).

2.4.3. Partnerships and activities

Respondents were first asked if they worked together with other landowners in their primary source watershed, and to explain any mechanisms for doing so. A majority (51%; 27 respondents) indicated that they did, and 42% (22) did not (Figure 2-6). Additional open-ended information was provided about these approaches, showing that they range from more minimal relationships such as contacts for access through large, multi-agency and organizational partnerships to collectively manage the watershed. These included informal information sharing as needed and general "good neighbor" practices, and more formal venues such as regular meetings and established collaborations. Open-ended responses included the following:

- Combined watershed management plan for city.
- U.S. Forest Service is sole landowner, but we work with city parks and recreation and area schools on fuels, trails, access and education programs.
- Have contacts for access through locked gates.

- Attend meetings about watershed health.
- Share information and current events.
- Discuss every aspect of management with the private landowners.
- Required to go through NEPA process with U.S. Forest Service and consult with resource specialists.
- Work with ranchers to keep runoff out.
- Not much interaction.
- Coordinate with the Port with vehicle access, overnight camping and transient camp enforcement.
- Cooperative arrangement for notification and monitoring of impacts of herbicide spraying with private timberland company.
- Land trade with private timberland owners currently underway to transfer ownership of entire watershed.
- Pesticide education.
- Logging and herbicidal applications notifications.
- Biannual meetings with private timberland owner.
- Have watershed management plan and communicate frequently with other landowners and stakeholders. Also use overarching basin action plan.
- Monitor activities of neighboring landowners, communicate and coordinate with them if their activities have a potential impact to our watershed.

Respondents were then asked to name the top five partners that they interacted with most closely in the management of their primary source watershed, with No. 1 being the most important (Table 2-9). Table 2-9 is sorted by number of total mentions in any rank. Weighted rankings account for both number of mentions and rank of mentions; each entity was given five points for every time mentioned as No. 1 to one point for every time mentioned as No. 5. Not all respondents named all five entities; the most responses were provided for the No. 1 partner and descended in quantity with each subsequent ranking. The most common type of No. 1 partner was private timberland owners, followed by watershed councils and SWCDs. If considering top partners by combined No. 1 and No. 2 rankings, private timberland owners were first (14 respondents) followed by the U.S. Forest Service (11 respondents). The most commonly named partner for any ranking was also private timberland owners (21 respondents), followed by county or city government entities (19 respondents), and other (18 respondents). “Other” type entities included local fire districts, Oregon Department of Fish and Wildlife, ranchers and consulting foresters. Although not all respondents participated in this question, these data suggest the likely importance of interaction

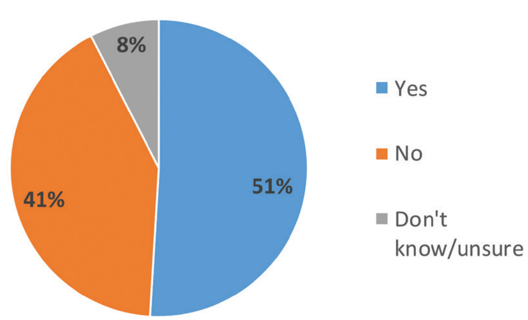


Figure 2-6. Do respondents work together with other landowners in their primary source watershed (n=53)?

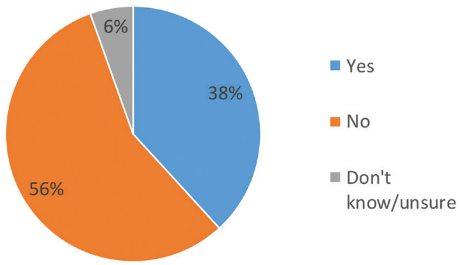


Figure 2-7. Respondent participation in forest restoration or fuels reduction activities for source water protection. n=55 for question.

Table 2-9. Top five partners with which respondents interact in management of primary source watershed, with No. 1 being most important.

Entity	Ranked No. 1	Ranked No. 2	Ranked No. 3	Ranked No. 4	Ranked No. 5	Total mentions	Ranked weight
Private timberland owner	10	4	4	3	0	21	1
County or city entity	5	3	5	2	4	19	2
Other	2	3	4	4	5	18	5
Watershed council or SWCD	7	2	0	4	2	15	4
U.S. Forest Service	5	6	1	1	0	13	3
Oregon Health Authority	4	2	2	0	0	8	6
Nonprofit organization not including watershed councils)	0	3	2	1	1	7	8
Oregon Department of Forestry	1	1	1	2	1	6	11
Oregon Water Resources Department	1	3	1	1	0	6	7
Other federal agency	1	0	2	1	2	6	10
Oregon Department of Environmental Quality	0	3	1	2	0	6	9
n =	36	30	23	21	15		

We also asked respondents if they funded or participated in forest restoration or hazardous fuels reduction activities in the primary source water watershed for the intent of drinking water protection (Figure 2-7). A majority of 56% (31 respondents) did not, while 38% (21 respondents) did. Some respondents provided open-ended information about these activities, including the following:

- Noxious weed control.
- Participate in Forest Stewardship Council.
- Large multi-partner project to reduce fuels.
- Perform own burning of ground fuels.
- Watershed protection sign project with the U.S. Forest Service using a Drinking Water Protection grant.
- Brush clearing.
- Plant vegetation to reduce temperatures and runoff.
- Contract local operator to perform thinning.
- Contract forester to manage watershed.
- Participate in local watershed association/council or forest protection association; pay dues or provide funding to these entities.
- Annual meeting with forest landowners in area about logging practices.
- Riparian vegetation restoration projects with watershed council.

2.4.4. Data collection and notifications

Respondents were asked a series of questions about assessments, plans, and data for their primary source watershed, and how they use these (Table 2-10). A majority had updated source water assessments, but not Drinking Water Source Protection plans or collection of optional raw water quality data. Nearly a quarter respectively were unsure if they had updated source water assessments or Drinking Water Protection plans. Follow-up questions allowed respondents the option of explaining how they used each of these (Appendix 2). Generally, source water assessments were reportedly used to build understanding of potential risks and vulnerabilities, and as the basis for strategies to mitigate them. Drinking water source protection plans were also used to identify potential risks and strategies; but also for grant applications, program development and outreach. Optional raw water quality data were gathered for a variety of chemicals, algae and conditions/levels, and used for purposes including planning operational water treatment decisions, learning about potential effects of herbicide spraying, informing the public, and creating baselines.

Table 2-10. Plans and data collection

	Have updated source water assessment	Have drinking water source protection plan	Collect optional raw water quality data beyond legal requirements
Yes	62%	33%	40%
No	16%	41%	58%
Don't know/unsure	22%	26%	2%

Respondents were also asked if they were aware of and how they utilized the Oregon Department of Forestry's online Forest Activity Electronic Reporting and Notification System (FERNS), which allows users to search, query and subscribe to receive notifications of proposed forest operations on private timberland upstream of a raw water intake (Figure 2-8). Nearly half were not aware of this service, and less than 20% had a subscription. A small number of respondents had searched it for forest operations or were aware of the service, but did not use it. "Other" options filled in included USFS notices, BLM letters, private landowner notifies, observation and word of mouth. Neither of the two Dryside respondents was aware of this service, likely because their primary source watersheds were in public land ownerships. Forty-three percent of Valley respondents were not aware of the service or did not use it. Coastal respondents were the most likely to have a subscription or to have queried or searched for pending forest operations.

2.4.5. Reported issues of management concern in drinking water source watersheds

We asked survey respondents about issues of management concern in their source watersheds in several different ways. First, they were asked to rank 10 general issues from 1 to 10 in order of current concern to their raw water source supply (1 being the most concerning and 10 the least concerning). The intent of this question was to observe relative levels of concern about general categories of activities that can affect source watersheds before asking about more specific management issues in following questions. This included options for "other" concerns that could be provided by the respondent, should the provided list have not included them. Responses and additional feedback were assessed and it was determined that data were most reliable for the top five concerns. Not all respondents felt that all issues were concerning. We therefore report

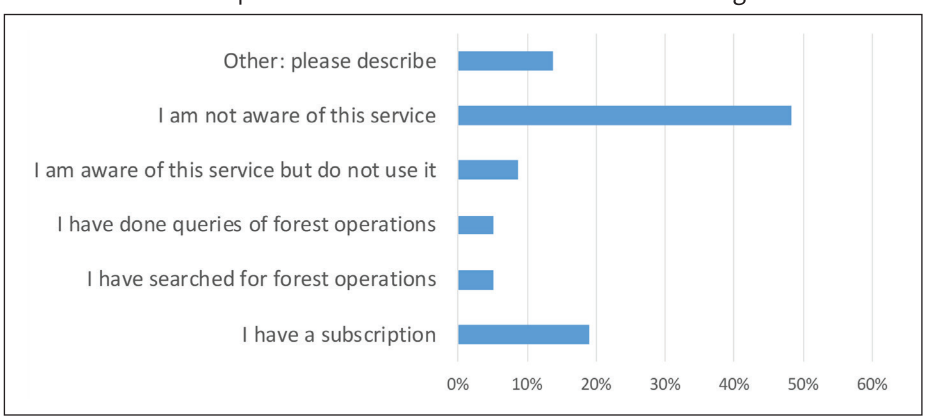


Figure 2-8. Respondents' use of FERNS notification system (n=58, multiple responses possible).

only these top five concerns. Table 2-11 shows the results from this question. The table is sorted by weighted rankings. Weighted rankings account for both number of mentions and rank of mentions; each entity was given five points for every time mentioned as No. 1 to one point for every time mentioned as No. 5.

For their No. 1 general issue of concern, 37% of respondents selected forest harvest and management, followed by stormwater runoff, which was selected by 20% (Table 2-11). This was mirrored in the most commonly selected No. 2 issues of concern, with nearly a quarter of respondents choosing forest harvest and management and 16% choosing stormwater runoff. Only 2% of respondents ranked cannabis cultivation or residential or commercial development in the watershed as top two concerns. “Other” responses provided for the No. 1 issue of concern (8%) included forest fires, algal blooms, hazardous material spills, culvert crossings and landslides. Weighted rankings were also calculated, which account for both number of mentions and rank of mentions; each entity was given five points for every time mentioned as No. 1 to one point for every time mentioned as No. 5. Forest harvest and management, stormwater runoff and ability of watershed to meet supply demands were the top three in both weighted ranking and number of mentions.

Table 2-11. Top 5 issues of general concern for management of source watersheds, with No. 1 being most important.

Concern	Ranking					Total mentions	Weighted ranking
	1st	2nd	3rd	4th	5th		
Forest harvest and management	37%	24%	8%	6%	12%	43	162
Stormwater runoff	20%	16%	12%	12%	14%	37	119
Ability of watershed to meet supply demands	18%	14%	16%	12%	16%	38	117
Public access and use of the watershed	4%	10%	12%	22%	8%	28	74
Climate change	2%	10%	18%	6%	18%	27	67
Agricultural land management	6%	4%	14%	14%	8%	23	62
Rural residences and septic tanks	2%	10%	6%	12%	6%	18	49
Other: please describe	8%	8%	2%	4%	0%	12	46
Residential and commercial development in the watershed	0%	2%	6%	6%	8%	11	23
Cannabis cultivation	2%	0%	2%	4%	8%	8	16

We then examined if there were differences in issues of top concern by general region (Coast, Valleys, or Dryside) by averaging the rankings given to these issues for each region (Table 2-12). A lower value indicates that an issue was more of a concern. Forest harvest and management was the top-ranked issue for all three regions, and Dryside respondents were the most concerned with this issue, although there were only two Dryside respondents.

Table 2-12. Average rankings of issues of general management concern by regions. A lower value indicates that an issue was more of a concern.

General management issue	Coast	Dryside	Valleys	Total
Forest harvest and management	2.5	1.5	3.1	2.8
Ability of watershed to meet supply demands	3.4	2.5	4.5	4.0
Stormwater runoff	3.7	7.5	4.2	4.2
Public access and use of the watershed	4.9	4.0	5.4	5.1
Agricultural land management	6.3	4.5	4.8	5.4
Climate change	5.7	5.5	5.4	5.5
Rural residences and septic tanks	6.9	9.0	5.7	6.3
Residential and commercial development in the watershed	6.7	8.0	6.4	6.6
Cannabis cultivation	7.7	7.0	7.4	7.5

Next, we asked respondents to identify their *level of concern* about a series of *more specific source water protection issues* as they may affect raw water supply by rating each issue on a five-point Likert concern scale (with 1 not a concern at all to 5 being an extreme concern; higher values indicate higher concern). These more specific issues were drawn from the literature review, prior survey/report, and input and expertise of the project steering committee. The highest average rankings, indicating issues of most concern, were for potential wildfire impacts, turbidity or suspended sediment, forest chemicals and increased wildfire risk (Table 2-13). The issues related to wildfire (potential impacts, increased risk and response impacts) together averaged a rating of 3.7. A few "other" responses were provided naming additional issues of an extreme concern: cyanotoxins, earthquakes and recreation use. Issues that were the least frequently rated as an extreme concern were dissolved organic carbon, pH levels and issues related to direct human use of the watershed (fecal contamination, unhoused people and off-highway vehicle use). The latter three issues together averaged a rating of 2.7, making direct human use less of a concern than almost all other issues.

Table 2-13. Ratings of level of concern for various source water management issues. Higher values indicate higher concern.

Specific issue of concern	Coast	Dryside	Valleys	All respondents
Potential wildfire impacts (e.g., erosion, cover loss)	3.8	5.0	3.9	3.9
Turbidity/suspended sediment	3.5	3.5	4.1	3.9
Increased wildfire risk	3.5	5.0	3.7	3.7
Forest chemicals (pesticides, fertilizers)	4.0	3.0	3.5	3.7
Future water quantity	3.7	3.0	3.6	3.6
Wildfire response impacts (e.g., retardants, pumping)	3.7	5.0	3.3	3.5
Other point source pollution	3.5	2.5	3.5	3.4
Flood events	3.3	3.0	3.5	3.4
Landslides and slope instability	3.6	3.0	3.0	3.2
Transportation-related fuel and hazardous material spills	2.6	3.0	3.6	3.2
Potential fecal contamination	3.1	3.0	3.1	3.1
Temperatures	3.4	1.5	2.9	3.1
Nutrient levels	3.1	3.0	3.0	3.0
Riparian buffer blow-down	3.2	3.5	2.8	3.0
Dissolved organic carbon	3.1	3.0	2.9	2.9
pH levels	3.1	2.0	2.8	2.9
Invasive species	2.9	3.0	2.8	2.9
Homeless/unhoused people using watershed	2.3	2.0	2.7	2.6
OHV impacts	1.9	3.5	2.5	2.3

Issues that were the least frequently rated as an extreme concern were dissolved organic carbon, pH levels and issues related to direct human use of the watershed (fecal contamination, unhoused people and off-highway vehicle use). The latter three issues together averaged a rating of 2.7, making direct human use less of a concern than almost all other issues.

Respondent concerns showed some variability by region. For example, the highest concern for wildfire impacts, increased wildfire risk and wildfire response impacts was from Dryside respondents. For turbidity, Valleys respondents had the highest concern, and for forest chemicals, Coastal respondents had the highest concern. Respondent comments in text and in instances where the survey was completed by phone also suggested that for some of these issues, concern varied temporally. For example, turbidity could be more of a concern in the winter season for coastal systems; or, forest chemicals were not currently a concern, but would be in the future after a planned herbicide application.

We also attempted to identify issues of concern by asking respondents to select the *top two issues* that currently concerned them most from the same series of *more specific source water protection issues* as they may affect raw water supply (Table 2-14). Just over a quarter of respondents selected turbidity/suspended sediment as a top concern, and forest chemicals were the second most common top concern at 12%. Every other issue was selected by 10% or less of respondents as a top issue.

For additional insight, we asked respondents to offer open-ended comment on why those issues concerned them and how they managed them. Full text from these responses is provided in Appendix 3; prominent themes are summarized here:

- *Impacts of prior wildfires and concerns about future fire events*: Reported challenges related to wildfires included post-fire effects such as erosion, sediment, turbidity, infrastructure destruction and needs for filtration systems. Activities to address these risks have included participation in forest collaborative group projects on federal lands, meetings with agencies about forest conditions and risks, pursuit of alternative water sources and support of forest thinning projects.
- *Forest harvest and management activities*: Several respondents described concerns about logging, particularly "clear-cutting" practices, and use of herbicides. They have observed or anticipate future impacts such as invasive species growth, landslides, increased turbidity/sedimentation and chemicals in drinking water supply. Few described how to address these impacts beyond increased monitoring and communicating with forest landowners about timing of activities so that mitigation actions could be taken.
- *Turbidity:* Many respondents described concerns and experiences with turbidity as a result of a variety of events such as wildfires, forest harvest activities (particularly "clear cutting"), winter storms and landslides. Approaches to managing and responding to turbidity range from mitigation to emergency response and include reducing wildfire risk in the watershed, diversifying water sources, having dams that reduce runoff amounts, pre-sedimentation preparation treatments before storms, new filtration systems, physical removal of silt, new storage capacity and plant shutdowns.
- *Algae:* A few respondents described issues with algae, including its growth after increases in turbidity/temperature/nutrients, resulting production of cyanotoxins, and clogging of fish screens. Responses have included new monitoring, disinfection treatments and building buffering wetlands.

Table 2-14. Top two specific source water protection issues chosen.

Source water protection issue	Percent of respondents that selected as a top issue
Turbidity/suspended sediment	26%
Forest chemicals (pesticides, fertilizers)	12%
Future water quantity	10%
Potential wildfire impacts (e.g., erosion, cover loss)	7%
Transportation-related fuel and hazardous material spills	7%
Increased wildfire risk	6%
Flood events	6%
Temperature levels	4%
Landslides and slope instability	4%
Other: please describe	4%
pH levels	3%
Nutrient levels	3%
Dissolved organic carbon	2%
Wildfire response impacts (e.g., retardants, pumping)	2%
Riparian buffer blow-down	2%
Invasive species	2%
Other point source pollution	1%
Potential fecal contamination	1%
General public access effects	0%
Homeless/unhoused people using watershed	0%
OHV impacts	0%

- *Water quantity:* Respondents reported concerns about future water quantity as a result of wildfire events, population growth, drought years and forest harvest. Few options for addressing this were mentioned aside from finding additional or alternative water sources.

Next, we asked respondents to identify their *level of control* over the same series of *more specific source water protection issues* as they may affect raw water supply by rating each issue on a five-point Likert concern scale (with 1 = no control at all to 5 = total control). Looking at control and comparing control to concern may help indicate areas where drinking water providers are most concerned about issues that they feel they can or cannot manage effectively. Table 2-15 shows the results from this question.

Table 2-15. Ratings of level of perceived control over various source water management issues

Issue of concern	Coast	Dryside	Valleys	All respondents
Potential fecal contamination	2.7	3.5	1.9	2.3
Turbidity/suspended sediment	2.7	1.0	1.9	2.2
Future water quantity	2.3	1.5	1.8	2.0
Increased wildfire risk	1.9	2.0	1.7	1.8
Off highway vehicle impacts	2.2	3.0	1.5	1.8
Invasive species	1.8	1.5	1.8	1.8
Homeless/unhoused people using watershed	2.1	2.5	1.6	1.8
Transportation-related fuel and haz. material spills	1.9	3.0	1.6	1.8
Forest chemicals (pesticides, fertilizers)	2.3	2.0	1.4	1.7
Other point source pollution	2.1	1.5	1.5	1.7
Potential wildfire impacts (e.g., erosion, cover) loss	1.9	1.5	1.5	1.7
Wildfire response impacts (e.g., retardants, pumping)	1.8	2.5	1.5	1.7
Landslides and slope instability	1.8	1.0	1.6	1.7
pH levels	2.1	1.0	1.4	1.6
Riparian buffer blow-down	1.7	1.0	1.5	1.5
Dissolved organic carbon	1.8	1.0	1.3	1.5
Flood events	1.5	1.0	1.4	1.4
Nutrient levels	1.5	1.0	1.3	1.4
Temperatures	1.3	1.0	1.4	1.3

Results in Table 2-15 largely indicate a strong sense of lack of control over issues that affect their source drinking watersheds. The top issues that respondents perceived the least control over by mean rating were flood events, nutrient levels and temperatures. Large majorities (exceeding 70%) felt they had no control at all over multiple issues: dissolved organic carbon, temperature levels, pH levels, nutrient levels, riparian buffer blown down and flood events. Percentages of respondents selecting “no control at all” were above 40% for every listed issue and above 50% for all but three issues. The top two issues wherein respondents perceived moderate or a lot of control were unhoused people using the watershed (24%) and turbidity/suspended sediment (20%), but the proportion of responses that saw no control over these issues was much larger.

To compare perceived control of with concern about drinking water issues, we subtracted individual ratings of concern from control. A negative difference indicates that, on average, individuals' concerns over this issue were greater than their perceived control of it. We found this to be the case for every listed issue (Table 2-16). We found the largest differences between control and concern about issues for potential wildfire impacts, forest chemicals, increased wildfire risk and wildfire response impacts.

Table 2-16. Comparison of mean ratings of *level of perceived control* versus *level of concern* over various source water management issues.

Source water protection issue	Avg. control	Avg. concern	Avg. difference
Difference	1.7	3.9	-2.2
Potential wildfire impacts (e.g., erosion, cover) loss	1.7	3.9	-2.2
Forest chemicals (pesticides, fertilizers)	1.7	3.7	-1.9
Increased wildfire risk	1.8	3.7	-1.9
Wildfire response impacts (e.g., retardants, pumping)	1.7	3.5	-1.9
Flood events	1.4	3.4	-1.8
Turbidity/suspended sediment	2.2	3.9	-1.7
Water temperatures	1.3	3.1	-1.7
Future water quantity	2.0	3.6	-1.7
Nutrient levels	1.4	3.0	-1.6
Landslides and slope instability	1.7	3.2	-1.5
Other point source pollution	1.7	3.4	-1.5
Riparian buffer blow-down	1.5	3.0	-1.4
Transportation-related fuel and hazardous material spills	1.8	3.2	-1.3
Dissolved organic carbon	1.5	2.9	-1.3
pH levels	1.6	2.9	-1.2
Invasive species	1.8	2.9	-1.0
Potential fecal contamination	2.3	3.1	-0.8
Homeless/unhoused people using watershed	1.8	2.6	-0.7
OHV impacts	1.8	2.3	-0.5

2.4.6. Lessons learned

Respondents were asked a final reflective open-ended question: "What has been a key lesson learned for your utility about managing a forested watershed for drinking water supply? What would you tell someone else in your position?" Prominent themes across these comments included:

- *The importance of communications:* Multiple respondents discussed the need to know and communicate regularly with landowners in the watershed and other relevant entities. Some specifically suggested communications with the logging foreman and crews who were on the ground in order to have real-time discussions about forest operations as they occurred. Communicating and knowing who to call prior to potential issues was advised. Relationships and communications in a more general sense were mentioned more frequently than more formal partnerships or collaborations.

- *Being proactive and prepared:* Respondents described learning from experiences where they were not prepared, indicating that these taught them to become more proactive and ready for a range of possible events and situations. Activities to foster this preparation included regular examination of the watershed, knowing who to call, practicing scenarios, stocking supplies such as filter bags, updating assessments and plans and having all necessary documentation.
- *Active forest management:* Some respondents recommended hands-on, fully engaged forest management for forest health, with proactive planning, inventory, monitoring and activities such as invasive species control and stand improvements.

2.4.7. Summary of key survey results

We attempted to survey all 156 identified drinking water providers in Oregon about the management of their primary source watershed. We obtained a response rate of 35% (54 respondents). Targeted follow-up was conducted with systems with the largest percentages of private industrial timberland, publicly owned land, or local government ownership of the utility. We found the following key results:

- The majority of systems surveyed were primarily organized as departments or units of municipal government. One-third (34%) had budgets of $100,000 to $500,000. Another 24% had budgets of $100,000 or less.
- Sixty-four percent had one to 10 total staff. Seven respondents relied solely on volunteer homeowners or board members, and 19% had only one or two staff. The mean total staff size was 13, with an average of 11 full-time employees.
- Nearly one-half of respondents have open access to their primary source watershed for the public at all times, while 20% allowed no public access.
- Fifty-one percent of respondents reported partnering with other entities and landowners to manage their source watersheds, using a range of approaches from informal information sharing as needed and general "good neighbor" practices, to more formal venues such as regular meetings and established, multi-partner collaborations. The most important partners that respondents interacted with most frequently were private industrial forestland owners, watershed councils or SWCDs, and the U.S. Forest Service as a public landowner.
- A majority of respondents (56%) did not participate in or fund forest restoration or hazardous fuels reduction in their source watershed. Those that did described a range of activities, including performing their own brush clearing or prescribed burning, or partnering with entities such as watershed councils, forest collaborative groups, or the U.S. Forest Service to support these activities.
- Sixty-two percent of respondents had an Updated Source Water Assessment, 33% had a Drinking Water Source Protection plan, and 40% conducted optional raw water quality monitoring beyond what is required by law. These were variously used to prioritize management activities, write grants, identify potential hazards and support adaptive decision-making.

- Nearly half of respondents were not aware of the Oregon Department of Forestry Forest Activity Electronic Reporting and Notification System (FERNS) online system, and less than 20% had a subscription.
- Respondents were asked about management issues of concern that may affect their raw water supply in several ways:
  - ❏ Ranking *general issues:* Forest harvest and management and stormwater runoff were ranked most important over other general issues such as residential development and cannabis cultivation.
  - ❏ Rating level of concern about *specific issues*: Respondents rated potential wildfire impacts (e.g., erosion), turbidity/suspended sediment, forest chemicals (e.g., herbicides) and increased wildfire risk as most concerning.
  - ❏ Identifying their *level of control* over the same *specific issues*: Respondents largely indicated a strong sense of lack of control over most issues that affect source drinking watersheds. The top issues that respondents perceived the least control over by mean rating were flood events, nutrient levels and temperatures.
  - ❏ Comparing perceived control of specific issues with concern about them: Concern over every listed issue was greater than control of it. The largest differences between control and concern were found for potential wildfire impacts, flood events, forest chemicals and increased wildfire risk.
  - ❏ Identifying the top two *specific issues* of concern: When asked to pick their top two most important issues, approximately a quarter of respondents selected turbidity/suspended sediment and 12% selected forest chemicals.
  - ❏ Respondents' lessons learned generally emphasized the importance of communication with forest landowners, being proactive and prepared rather than reactive in the face of events and challenges, and actively managing for forest health.

2.4.8. Discussion of survey results

Perhaps the most important finding of our survey of drinking water providers was that many perceived a lack of control over issues that affected their drinking water source watersheds and thus the quality and quantity of their raw drinking water. A large majority (over 70%) perceived no control at all over multiple issues. The survey results also present some other crosscutting themes about the intersection of forest management and drinking watersheds, with implications and future questions for management and future research.

First is public water system capacity, and if it is matched to the management needs that providers may have. Smaller systems (in terms of population served or total connections) may run on a single paid staff person or on a volunteer-only basis, yet they may have to address multiple and substantial forest management and other activities that affect their source watersheds. Our respondents often did not provide complete responses about their budgets, perhaps due to an unwillingness to share this information, and our use of larger brackets precludes more fine-grained understanding of smaller budgets. Further examination could help clarify the degree to which the budgets and staff of smaller public water systems align with issues these systems face in their source watersheds.

A second theme is how assessments, plans and monitoring may allow more structured understanding of source water management issues, prioritization of actions and informed partnerships with landowners and other entities. Respondents were more likely to have an Updated Source Water Assessment and/or to do optional raw water quality monitoring than to have a Drinking Source Water Protection Plan. From limited open-ended responses, it seems that assessments may help providers prioritize the risks to address, which may be especially useful in capacity-constrained systems. Monitoring may offer data that allows for anticipation of and more adaptive response to potential impacts of forest management activities, and communication and partnership with a forest landowner could facilitate this. More research would be needed to understand how widespread this type of monitoring and partnership is across all systems in Oregon.

Third, there is growing academic and practitioner interest in partnerships and collaborative approaches for managing forested source watersheds. Some of these are well-publicized, large and formal multi stakeholder efforts in areas serving larger populations (e.g., Denver). Less is known about the functioning and approaches of partnerships that may be informal, in smaller systems, and/or involve private industrial owners. Our results show that private forestland owners were the most important partner to respondents (likely because they own many of the drinking water source areas for providers we surveyed) followed by watershed councils/SWCDs. How providers communicate with private landowners warrants more attention. For example, given that the majority of respondents reported not using the ODF FERNS, are they instead learning about planned forest management activities more informally and directly with landowners? Or does this suggest a lack of communication and awareness of activities that could be improved? How are local entities such as these councils and districts facilitating partnerships with private industrial landowners and accessing funding for source water protection activities?

Fourth, respondents indicated the most concern about potential wildfire impacts, turbidity/suspended sediment, forest chemicals, and increased wildfire risk, and also reported a perceived lack of control over these issues. These concerns fluctuate seasonally, with expectedly more emphasis on turbidity during winter storm events and wildfire risks and impacts during summer seasons. The capacity of providers to anticipate, plan for, and respond to these concerns may depend on the ownership(s) of their source watersheds, and the relationships and communication that they have with landowners and other relevant entities.

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