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# Evaluating Payments for Watershed Services Programs in the United States

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We review 15 forest watershed protection programs in the United States in which a local government agency or water provider collects payments from downstream service beneficiaries, such as water consumers, and pays upstream forest landowners for provision of watershed services. We describe the features of these Payments for Watershed Services (PWS) programs, focusing on funding sources, how the payment mechanisms work, and outcomes achieved. We also assess the extent to which the programs adhere to the economic principles that are associated with efficient or cost effective PWS schemes. In general, we find that payments in the programs do not closely reflect the marginal value of the service provided. Payments received by landowners mainly reflect the landowners' opportunity costs. Fees paid by water consumers are set to yield revenue targets and/or reflect the avoided cost of additional water filtration and treatment. The programs appear to yield societal benefits, primarily through cost savings, but data from program outcomes is limited and more rigorous analysis of both the benefits and costs would be worthwhile.

*Keywords*: Forest conservation; drinking water; surface water; flood mitigation; payments for ecosystem services.

## 1. Introduction

Forests provide a variety of ecological functions that in turn provide services that have value to humans. Forest soils store water and filter nutrients and other contaminants, thereby improving the quality of water in nearby streams, rivers, and lakes. Forests sequester carbon, and trees in cities can reduce the urban heat island effect. Forested riparian areas slow runoff and can attenuate flooding.

In recent years, policymakers have become increasingly interested in using Payments for Watershed Services (PWS) programs to secure these benefits. PWS programs are a form of Payment for Environmental Services (PES), in which an upstream watershed service provider — typically a forest landowner — voluntarily provides a service to a downstream end user in exchange for financial compensation from that user (Jack *et al.* 2008; Pattanayak *et al.* 2010; Wunder 2007). Provision of the service in many PWS programs involves protection of the land in its natural forested state, but some programs focus on adoption of restoration activities or specific forest management practices.

The extent to which these programs truly fit the PES/PWS model varies. In a "textbook" PES/PWS program payments are made voluntarily and only if/when the landowner engages in the specific activities that ensure the service is verifiably provided — i.e., a "conditionality" requirement must be met (Wunder 2007, 2015). Some authors have also noted that for programs to be effective in achieving their goals, they need to satisfy an "additionality" requirement — i.e., the activities the landowner engages in must be in addition to what he/she would have done in the absence of the program (Tacconi 2012; Wunder 2007). Finally, economists are typically interested in the degree to which PES/PWS programs are efficient — that is, whether the payments reflect the marginal value of the service provided and that marginal value is equal to the marginal cost of providing the service (Ferraro 2011; Ferraro and Simpson 2002). Programs that are not operating based on this equimarginal principle will experience an increase in net benefits by either increasing or decreasing provision of the service. It is therefore important to evaluate these programs by examining costs and benefits in marginal terms and not in absolute terms.

In this study, we review 15 forest watershed protection programs in the United States. We describe program designs and provide summary information about outcomes achieved. In all of the programs, payments are made to the providers of the service (upstream landowners) from watershed service beneficiaries (local water consumers in many cases). We then ask the following questions about the programs to assess the extent to which they fit the PES/PWS model, their effectiveness in achieving watershed service goals, and their economic efficiency, i.e., whether payments appear to reflect marginal values and marginal costs.

(1) Are the payments conditional on the landowner providing the service?
(2) Does the landowner engage in activities additional to what would have been done in the absence of the program?

(3) Do the payments reflect the marginal value of the final service provided — i.e., the value of the additional water services (clean drinking water, surface water, flood attenuation) provided by the forest? If not, what do the payments reflect?

In many of the programs we review, local government agencies or water providers collect payments from downstream end users and pay upstream forest landowners. The programs focus on water quality in surface water bodies such as lakes, rivers, and streams, purification of drinking water supplies, protection of groundwater resources, and flood mitigation. Many of the programs have multiple objectives. We describe the features of the programs, focusing on funding sources, how the payment mechanisms work, and outcomes achieved, to the extent such information is available.

Some recent studies on PWS programs in the U.S. provide background information on some of the programs we review, describing the local factors that led to their adoption and summarizing some program results (Armistead *et al.* 2016; Bennett *et al.* 2013, 2014; Bennett and Ruef 2016; Carpe Diem West 2013; Ecosystem Marketplace n.d.; Gartner *et al.* 2013; Ozment *et al.* 2016). However, they do not evaluate the programs from the conceptual economic framework that is our focus. Specifically, they do not ask questions related to the determinants of the efficiency of PWS schemes.[1] Most other PES/PWS reviews in the literature focus on programs in developing countries. Mexico's Payments for Hydrological Services program and Costa Rica's PSA (Pago por Servicios Ambientales) program, for example, have received a great deal of attention (Alix-Garcia *et al.* 2009; Muñoz-Piña *et al.* 2008; Sánchez-Azofeifa *et al.* 2007). Brouwer *et al.* (2011) perform a meta-analysis of studies analyzing 47 programs in developing countries around the world and analyze the broad program features that affect environmental performance. Martin-Ortega *et al.* (2013) review the design and implementation of 38 programs in 11 Latin American countries and assess some of the features that we address here, such as conditionality. A recent study by Salzman *et al.* (2018) summarizes findings from a review of 550 PES programs worldwide, with a focus on overall size of programs and trends over time.

Evaluating PWS programs using an economic lens is important because economic efficiency provides the conceptual underpinning for using PES/PWS in

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[1] A 2010 report on ecosystem services from national forests published by the US Forest Service approaches the subject using an economics framework but its focus is broader than watershed services and it reports aggregate statistics and does not review individual programs (Mercer *et al.* 2010).

the first place. Private landowners are typically unable to capture the full value of the ecosystem services their lands provide through private market transactions because those services have strong public good characteristics — i.e., they are nonrival in consumption and it is difficult to exclude people from consuming, which leads to free riding. If a standing forest is naturally providing the storage and filtration functions that lead to cleaner source water, for example, it is difficult for the forest owner to exclude downstream water users from benefiting from that service. As a result, the quantity of the service provided by landowners is usually less than the socially optimal level. Environmental economists have shown that establishing a market for the service may help overcome this problem by providing a vehicle for financial compensation to landowners who provide these public goods. The literature that describes the benefits of PWS programs follows a similar logic, highlighting the ways in which these programs mimic markets, which in turn may help communities achieve the same kinds of efficient outcomes that private markets often achieve (Engel *et al.*, 2008; Salzman *et al.*, 2018).

If markets for watershed services are efficient, then the prices in those markets reflect marginal benefits, or values, of the services provided. This means that it might be possible to learn something about the value of the watershed services a forest provides from the prices paid in transactions in PWS programs (in the same way that market prices reflect values of private goods and services). This information could be useful for evaluating the tradeoffs in alternative uses of forests, designing other government policies, including property and other tax rates, and establishing new PWS programs in other locations. However, the markets in which PWS transactions take place can be imperfect, preventing prices from reflecting the marginal value of the services provided by landowners. For example, markets tied to PWS programs can be too thin (i.e., have a small number of participants and transactions) such that a competitive price for the service does not arise. Furthermore, watershed service beneficiaries may not be able to place an accurate value on hydrologically complex services such as water retention and water quality improvements, thus distorting the prices they pay in PWS programs. Yet another reason why payments may not reflect the marginal value of the service provided is a lack of conditionality, such that landowners do not expect to incur the full marginal cost of providing the service. If payments do not reflect the true value of the watershed service provided, for these or other reasons, the programs may be sending the wrong signals to landowners, as service providers, and to end users, as service beneficiaries. As a result, the program may be distorting behavior away from the efficient outcome. It may lead to efficiency gains over having no program at all, but being aware of whether payments are over- or under-compensating landowners may help managers identify ways to improve PWS program design.

One alternative to taking an efficiency perspective when evaluating PWS programs is to take a cost effectiveness perspective, that is, to examine whether the programs are less costly while also achieving a similar level of services as what other options provide. PWS programs may target cost effectiveness rather than efficiency because of the U.S. water quality regulations that underpin the programs; forest conservation and restoration activities typically serve as substitutes for “hard” infrastructure and other more costly alternatives for meeting regulatory requirements. In these cases, we would expect payments observed in PWS programs to be driven in part by these avoided costs.

Our findings suggest that the 15 programs we review are generating positive societal benefits but mainly in the form of cost savings for providing clean water services, not from additional water quality benefits. Downstream user fees in drinking water programs appear to be based on costs, not beneficiaries’ willingness-to-pay for clean water, and payments to upstream landowners appear to be based on opportunity costs of land in its next best use. The programs appear to meet conditionality requirements in that landowners receive payment only when they provide forest conservation and restoration activities, but the extent to which those activities contribute to clean water services is difficult to measure. None of the programs undertake this kind of evaluation; drinking water quality is tested and measured as required by regulations but measurements are not linked directly to forest watershed protection activities. Finally, we find that there are serious deficiencies in data and documentation of outcomes from the programs. Better program evaluation is needed, based on detailed data and careful analysis.

We begin in the next section with a description of the conceptual underpinnings for PWS programs and the important role played by US federal laws and regulations in motivating demand for watershed protection. In Section 3, we summarize the features of the 15 PWS programs that we review, including their funding mechanisms, target activities, and acres of land protected. Section 4 describes how prices are set in the PWS programs, focusing on prices charged to beneficiaries such as water users and tax payers and prices paid to forest landowners. Section 5 assesses the degree of conditionality and additionality observed in the programs, and Section 6 addresses the question of whether observed payments reflect the value of the service provided and the likely efficiency of the programs. Section 7 provides concluding remarks.

## 2. Motivations for Watershed Protection Programs

Forested lands are ideal for storing water on the landscape and thus regulating the flow to streams, rivers and other water bodies. The leaves in a tree canopy catch water and slow its arrival to the ground. Forest soils typically have a high organic matter, porosity, and permeability, thus the infiltration capacity in a forest is nearly always enough to capture the amount of rainfall, in contrast to areas with compact soils and impermeable surfaces. Trees in riparian areas provide structural support for stream banks, preventing erosion and thus lowering sediment loads in waterways, and the shade helps keep water temperatures cooler, which lowers dissolved oxygen levels (and improves fish habitat).

These hydrological functions can contribute to clean drinking water and surface water and attenuate flooding — all watershed services that have direct value to end users. A PWS program in which the end users pay providers of the service — i.e., the forest owners or managers — is one way to capture these values. In theory, the prices in these transactions should reflect the marginal value of the watershed services provided — i.e., the market clears at a price that reflects the value of the last unit provided. In the U.S., local governments and water service providers typically act on behalf of end users (Vatn 2010). Such arrangements are clearly beneficial as they reduce transaction costs of providing water services, especially in densely populated areas. But do these entities transact with forest owners in PWS programs in an efficient way — i.e., paying prices that reflect the marginal value of the water service provided? To answer this question, it is important to understand the regulatory environment in which water service providers operate. In the U.S., two pieces of legislation — the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) — are key.

### 2.1. *The Clean Water Act*

The CWA, passed in 1972, establishes the basic structure for setting water quality standards for water bodies in the U.S. and regulation of discharges into those water bodies. Point sources from industry and municipal wastewater systems cannot discharge any pollutant into a waterway without a permit issued under the EPA's National Pollutant Discharge Elimination System (NPDES) permit program. The permit sets limits on discharges and requirements for monitoring and reporting. Some permits also lay out "best management practices" that must be adopted.

#### 2.1.1. *Total maximum daily loads* (*TMDLs*)

A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. The CWA requires states to develop TMDLs for all the waters identified on their list of impaired waters. PWS programs have been set up in some locales as a way to help meet TMDL requirements.

### 2.1.2. *Stormwater management*

The CWA also covers municipal stormwater runoff. In many urban areas, stormwater runoff is transported through municipal separate storm sewer systems — so called MS4s; other cities have combined sanitary and stormwater sewer systems, in which rainwater and sewage flow into a single system of pipes that transports the wastewater to a sewage treatment plant before being discharged into a waterbody. In both cases, the EPA requires cities to have permits that define the stormwater management programs the city must adopt to minimize runoff and/or regulate combined sewer overflows (CSOs).

In recent years, municipalities have been turning to “green infrastructure” approaches to manage stormwater runoff and CSOs, and EPA has been working with the municipalities to design guidelines for the use of these options instead of, or as a complement to, the gray infrastructure system of pipes, tunnels, holding tanks, pumps, and wastewater treatment plants (U.S. EPA 2008). Green infrastructure consists of many small-scale options such as rain gardens, bioswales, green roofs, and permeable pavements, but forest conservation, particularly in riparian areas, plays an important role in many locales.

## 2.2. *The Safe Drinking Water Act*

The SDWA, originally passed in 1974, authorizes the EPA to set national health-based standards for naturally-occurring and man-made contaminants that may be present in public drinking water supplies. EPA currently sets legally enforceable maximum levels for individual contaminants and defines treatment techniques for some others through its National Primary Drinking Water Regulations (NPDWR). A 1989 EPA rule requires most public water systems to filter surface water and groundwater under the direct influence of surface water unless specific filtration avoidance criteria are met. These criteria include source water quality conditions for turbidity and fecal coliform or total coliform density and various site-specific conditions (EPA 2010). If a public water system develops a plan for meeting these criteria, EPA may allow the system to obtain their water supply from surface sources under the provisions of a filtration waiver. Forest conservation and management activities are typically key components of these filtration waivers.

Major cities that have obtained such waivers include Boston, New York, Portland (Oregon), San Francisco, and Seattle (Hanlon 2017).[2]

## 2.3. *Cost savings*

Avoiding filtration obviously lowers the costs of treatment; thus, cities with waivers have a strong motivation for protection of source water to retain the waiver. Even without a waiver, cities have an incentive to protect source water as the higher the quality of the water entering a drinking water treatment facility, the lower the costs of treatment. If the raw water is particularly clean and free of sediment, treatment plants may be able to bypass some steps in the treatment process. If the raw water quality is poor, additional treatment methods may be needed, such as membrane filtration or activated carbon treatment. EPA regulations passed in 2006 target cryptosporidium levels in source water, providing another impetus for purifying the water before it reaches the treatment facility. Postel and Thompson (2005) found that seven U.S. cities with excellent water quality saved $500,000 to $6 billion in water treatment infrastructure costs. Variable operating costs can also be lower when the raw water entering the system is cleaner due to the need for fewer chemicals.

A 2004 study by The Trust for Public Land (TPL) and the American Water Works Association (AWWA) used data from a survey of water suppliers and conducted a statistical analysis that revealed that, for watersheds with less than 60% forest cover, a 10% increase in forest cover was associated with a 20% reduction in drinking water treatment and chemical costs (Barten and Ernst, 2004). A follow-on TPL study found similar results for a slightly larger sample of water treatment plants but with less statistical significance (Freeman *et al.*, 2008). Two recent econometric studies in non-U.S. settings find that more forest land is associated with lower drinking water costs (Abildtrup *et al.* 2013; Vincent *et al.* 2016). The Vincent *et al.* (2016) study is particularly interesting as it used a rich panel dataset in Malaysia; results suggest that protecting 10% more virgin forest reduced treatment costs by an average of 4.8%. However, there was significant spatial variability in the impacts.

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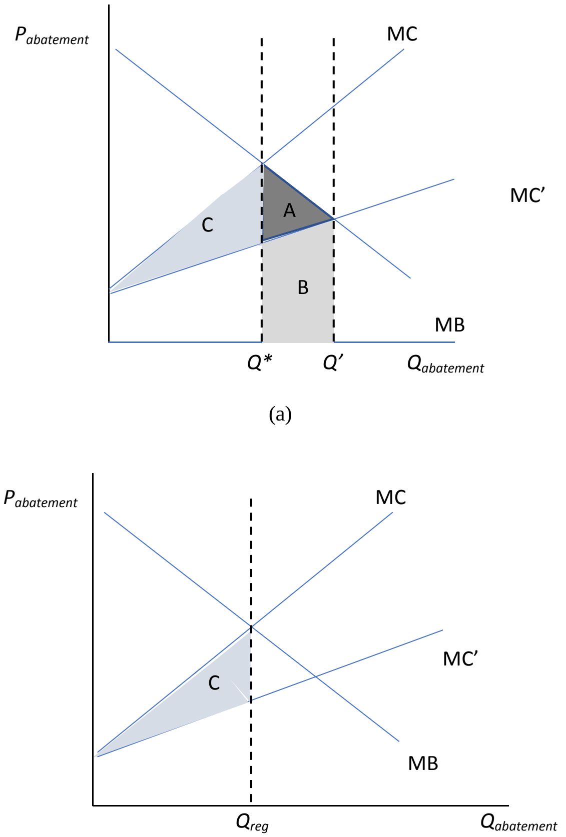
[2] Perhaps the most prominent example of a filtration waiver is the one issued to the Catskills/Delaware portion of the New York City water supply, which has met the criteria for waivers from the filtration requirement of the Surface Water Treatment Rule (SWTR) from January 1993 to the present. The waiver requires the city to undertake a land acquisition program, a watershed forestry program, which seeks to maintain unfragmented forested land and promote the use of management practices to prevent non-point source pollution during timber harvests, and a riparian buffer protection program, which provides assistance to streamside landowners who seek to implement stabilization and planting plans to enhance riparian buffers (EPA 2007).

### 2.4. *Regulations and PWS programs*

How might U.S. water service providers use PWS Programs to comply with regulations, and how do these compliance strategies relate to (a) cost savings from source water protection through forest conservation and management activities, and (b) potential benefits from water quality improvements? Figure 1 is a stylized representation of a water pollution reduction scenario. The horizontal axis in each graph in the figure measures the quantity of pollution reduction, or abatement; the curve labeled *MB* represents the marginal benefit of an extra unit of abatement and the curve labeled *MC* represents the marginal cost. The marginal benefit declines with increasing abatement — total benefits rise with abatement but at a decreasing rate — and the marginal cost rises — abatement gets increasingly costly as



(a)

(b)

**Figure 1.** (a) Socially Optimal Pollution Abatement Before and After Decline in Marginal Cost. (b) Regulated Amount of Pollution Abatement Before and After Decline in Marginal Cost

cleanup levels rise.[3] The optimal level of pollution abatement is $Q^*$, where marginal benefit equals marginal cost.

The introduction of source water protection lowers marginal cost at any given level of abatement — by reducing the need for filtration or chemicals in drinking water treatment plants, for example — and is shown on both graphs as a shift in the marginal cost curve from $MC$ to $MC'$. Figure 1(a) shows that this lower cost moves the optimal level of abatement to $Q'$. The additional benefits of this change are represented by the area under the $MB$ curve between $Q^*$ and $Q'$ — Areas A and B in the graph. The additional costs are the costs of abating more units — i.e., Area B, the area under the $MC'$ curve between $Q^*$ and $Q'$ — net of the cost savings on the units of abatement up to $Q^*$, which is shown by Area C. In total, there are positive net benefits equal to area A from the drop in marginal costs.

Private markets will not achieve these optimal outcomes on their own because the benefits of abatement are not fully captured by private individuals. In the U.S. setting, we can think of regulators as setting an abatement standard to try to induce the optimal outcome. We illustrate such an abatement standard in Figure 1(b) for the same pollution reduction scenario as in Figure 1(a). We assume, for simplicity in the graph, that the regulator sets a regulated amount $Q_{\text{reg}} = Q^*$.[4] When watershed protection activities lower the marginal cost curve, however, the service provider has no incentive to increase abatement beyond $Q_{\text{reg}}$ because it increases costs. Thus, the amount of abatement stays at $Q_{\text{reg}}$, and Area C, which is the difference between the two cost curves at the regulated abatement level, measures the cost savings. The benefits are the same as before the source water protection activities were undertaken because the level of abatement stays the same. Overall, there is a net benefit to society, but that net benefit comes in the form of lower abatement costs, not any change in water quality.

Therefore, in the U.S. regulatory setting, it is the cost savings that motivate water service providers to engage in forest conservation activities, not additional water quality benefits from those activities. This suggests that the prices paid to forest owners in PWS programs are also more likely to reflect cost savings. We return to this point below in describing the motivations for the programs in our survey.

## 3. PWS Programs in the United States

Salzman *et al.* (2018) maintain that the obvious connection between land management in an upper watershed and water quality and flooding downstream can

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[3] The $MB$ and $MC$ curves are drawn as linear in the figure for simplicity.

[4] Our points hold regardless of where $Q_{\text{reg}}$ is set. We set $Q_{\text{reg}}$ at the point where $MB = MC$ for simplicity and to avoid additional lines and notation in the graph.

make it relatively easy to gain support for PWS programs, at least in comparison with programs focused on other environmental outcomes such as biodiversity. Moreover, transactions costs can be low because intermediary institutions such as local governments and water service providers collect funds from diffuse beneficiaries. In this section, we summarize and analyze the features and outcomes of 15 PWS programs in the United States in which downstream beneficiaries pay upstream landowners, generally via local government representatives or water utilities, for activities that provide watershed benefits. Most of our review focuses on programs tied to the provision of drinking water; however, we include four programs whose aims are to reduce stormwater runoff, meet TMDL requirements, and mitigate flooding.

## 3.1. *Data collection*

Information on PWS programs was collected from several sources. We began with several of the studies in the reports listed in the introduction (Armistead *et al.* 2016; Bennett *et al.* 2013, 2014; Bennett and Ruef 2016; Carpe Diem West 2013; Ecosystem Marketplace n.d.; Gartner *et al.* 2013; Ozment *et al.* 2016), followed by searching in online sources for additional programs. We gathered updated information, when it was available, from municipal government and utility websites and published documents. We then conducted interviews with city and utility officials, and where possible, we collected data on individual land transactions.

Our inventory is not a comprehensive list of PWS programs in the U.S. The programs we review are the ones for which we were able to gather reasonably complete information on both program design and details about results such as acres protected and program expenditures.[5] They are representative of the types of programs that exist in the U.S.; for example, the prevalence of drinking water programs in our inventory is consistent with the relatively large number of those programs in the broader universe of PWS programs. Nonetheless, because program costs and outcomes are not publicly available from many programs, we cannot claim that our conclusions carry over to all PWS programs in the U.S.

## 3.2. *Summary information*

Table 1 presents the programs in our review. For each program, we list the community in which it operates, the year the program started, size of the

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[5] A list of several additional U.S. watershed protection programs is available from the authors upon request but many details and results from these programs are unavailable. Ecosystem Marketplace (n. d.) maintains a list of watershed protection programs (not all of which are PWS programs) but for many of the programs, only minimal information is provided.

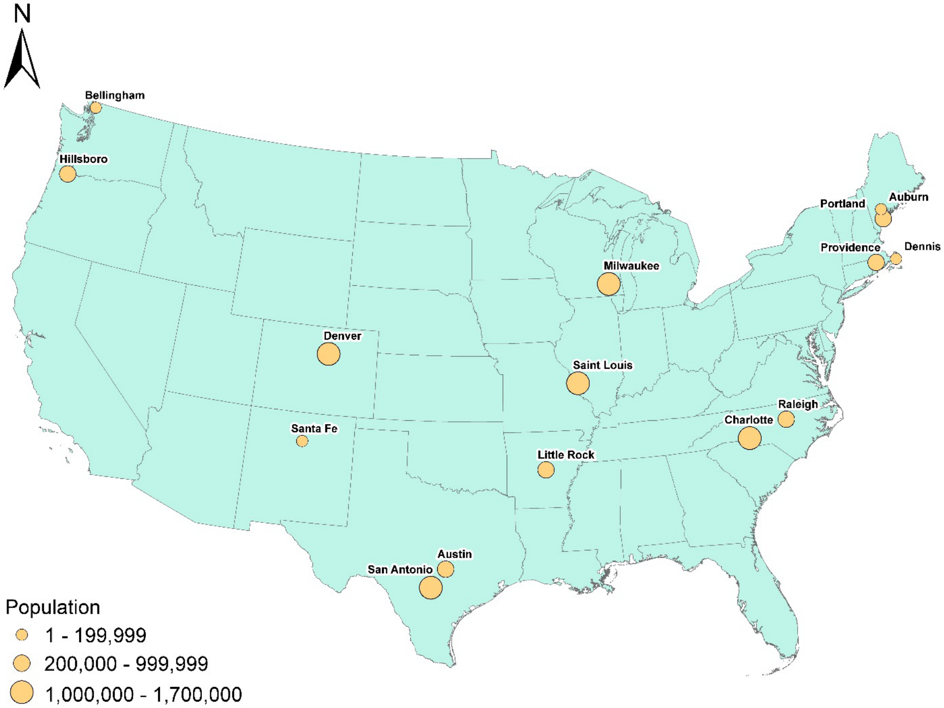

**Figure 2.** Location of 15 Payments for Watershed Services (PWS) Programs in the United States

population served or affected by the program, funding mechanism, total expenditures, primary program objectives, and when available, acres of land conserved, managed, or treated. The adoption of PWS programs by water suppliers and local governments in the U.S. is a relatively recent phenomenon, but the numbers have been growing over time. Of the 15 programs we review, only 3 were in place before 2000. Figure 2 is a map that shows the location of the programs, with the size of the dots indicating the size of the population served.

Protection of source water for drinking water systems is the primary objective for 10 of the programs; for some programs, this is a groundwater resource but for most, the focus is a reservoir or set of reservoirs. The other programs are focused on surface water quality and flood mitigation.

The programs vary greatly in size and scope. The San Antonio program has protected the most acreage: over 147,000 acres through fee acquisitions or purchase of conservation easements. The Denver program is the next largest in terms of acreage. However, in this program, the acreage refers to acreage treated and managed for fire prevention, as we explain below, and not land acquisitions or easements. The Charlotte–Mecklenburg and Tualatin River programs show the smallest amount of acreage protected but these programs focus on restoration of riparian buffers, which will naturally lead to smaller amounts of land protected. A total of 57 stream miles were treated between 2004 and 2016 in the Tualatin River program (Clean Water Services 2016). The Charlotte program also buys out some developed properties in the floodplain. We were able to obtain an estimate of total spending for all but 3 of the programs. Total spending varies greatly because of differences in the size of the programs and the communities they serve. Differences may also be related to other factors such as local property values. We elaborate on these determinants of PWS program characteristics below.

## 3.3. *What are the drivers of PWS programs?*

All of the programs we reviewed have a common goal, which is the protection or restoration of upstream forested land in watersheds to benefit downstream communities, including water consumers. Beyond that general objective, a number of specific drivers are often at play.

### 3.3.1. *Development threats*

Conversion of private forested lands to residential development, and the impermeable surfaces that come with that development, is a growing threat to water quality in many areas of the U.S. The U.S. Department of Agriculture (USDA) projects that over 11% of private forests will be affected by housing density increases by 2030 (Stein *et al.* 2005). In addition, development often brings disruption of stream banks, which increases sediment loads in the water source (Song *et al.* 2014). New road construction leads to fuel and tire wear residue runoff which leaches into soils and contaminates nearby water sources.

The San Antonio, Austin, Central Arkansas, Scituate Reservoir (Providence, Rhode Island), Upper Neuse River (Raleigh, North Carolina) and Lake Whatcom (Bellingham, Washington) programs are all concerned about the impacts of development on their water supplies. In the Central Arkansas Water system, which serves the Little Rock metropolitan area, the population is growing outward towards Lake Maumelle, an important water source. The city of Austin experienced 35% population growth between 2001 and 2015; its program purchases land and easements to stem development pressures near Barton Springs, which is outside the city limits and is the primary discharge point of a key segment of the Edwards Aquifer, which the city relies on for its drinking water. San Antonio relies on the same aquifer and is also working to stem development pressures and protect recharge of the groundwater resource. The Dennis, Massachusetts, program also targets groundwater resources. Population growth in the Upper Neuse River basin, near Raleigh, North Carolina, is expected to result in an additional 50,000 acres of land developed by 2025, which comprises 76% of the remaining undeveloped land in the Basin (Colorado State Forest Service 2017).

### 3.3.2. *Insufficient drinking water filtration capacity and outdated treatment technologies*

Water filtration demand is predicted to outpace filtration capacity in areas that have aging and outdated drinking water treatment plants. Plants built many decades earlier for much smaller populations, fewer contaminants, and healthier riparian barriers are expensive to upgrade and municipalities are looking for low-cost alternatives to reconstruction (Crockett Consulting 2010). The city of Raleigh, North Carolina, noted rising population, water demand, and sedimentation as key motivators for the Upper Neuse PWS program (Hart 2006). Older plants are also ill-equipped to disinfect cryptosporidium and other dangerous bacteria. Traditional disinfectants can react with cryptosporidium to create harmful byproducts, which pose additional threats to public health.

As described earlier, EPA will grant filtration waivers to public water systems that implement watershed protection programs that meet certain requirements. Two of the 11 drinking water programs in Table 1 — the Lake Auburn and Portland programs in the state of Maine — have acquired filtration waivers that they maintain, in part, through their PWS programs.

### 3.3.3. *Surface water quality*

Drinking water treatment plants may be able to filter and purify water before it comes out of the tap, but that process does nothing for water quality in the surface water bodies that supply the system. Those water bodies must meet the requirements of the CWA, and some PWS programs are primarily focused on this objective. This includes those programs in Table 1 that use forest conservation and protection of riparian areas to reduce stormwater runoff, such as the Charlotte-Mecklenberg and Milwaukee programs, and to lower water temperatures to meet TMDLs, such as the Tualatin River program in Oregon. Even programs designed for drinking water may focus on forest protection to obtain the ancillary benefits of improving surface water quality. This is true for the Lake Whatcom program. In 1998, the EPA deemed Lake Whatcom's water quality violated the CWA limits for dissolved oxygen levels, fecal coliform, and phosphorous content. The PWS program was designed to rectify these problems along with improving drinking water quality.

**Table 1.** Summary Information on Selected Payments for Forest Watershed Services (PWS) Programs in the United States

| Name and Location | Population | Date Started | Funding Mechanism | Expenditures | Program Objectives | Acres Conserved, Managed, Treated |
|---|---|---|---|---|---|---|
| Austin Watershed Protection Plan (Austin, Texas) | 912,000 | 2001 | Drainage fee (based on impervious surface area) & bonds | NA* | Limit development in area near aquifer recharge zone | 28,354 |
| Central Arkansas Watershed Management Program (Little Rock, Arkansas) | 400,000 | 2007 | Drinking water utility fee increase (flat fee per meter per month) | $1 million/year | Reduce development pressures near reservoir for drinking water | 1,781 |
| Charlotte-Mecklenburg County (Mecklenburg County, North Carolina) | 1,034,000 | 1999 | Stormwater fee (based on impervious surface area) | $4 million/year** | Repair riparian buffers and buy out properties in floodplain to reduce flood damages | 203 |
| Dennis Watershed Protection Fee (Dennis, Massachusetts) | 15,000 | 2006 | Drinking water utility fee increase (flat fee billed twice a year) | $190,000/year | Protection of groundwater resources | 1,068 |
| Denver "From Forest to Faucets" Partnership (Denver, Colorado) | 1,300,000 | 2010 | Drinking water utility fee increase (volumetric) | $3.3 m/year; $16.5 m committed for 2017–2021 from utility fee | Forest management for fire prevention | 48,000 |
| Lake Auburn Watershed Protection Program (Auburn & Lewiston, Maine) | 59,088 | 1992 | City and drinking water utility budget allocation | NA | Protect forested land near reservoir for drinking water; maintain filtration waiver | 2,200 |

**Table 1.** (*Continued*)

| Name and Location | Population | Date Started | Funding Mechanism | Expenditures | Program Objectives | Acres Conserved, Managed, Treated |
|---|---|---|---|---|---|---|
| Lake Whatcom Watershed Land Acquisition and Preservation Program (Bellingham, Washington) | 95,000 | 2001 | Drinking water utility fee increase (flat fee + volumetric) | $25.3 million since 2001 | Reduce development pressures near reservoir for drinking water | 2,150 |
| Meramec Greenway (St. Louis and St. Charles Counties and St. Louis City, Missouri) | 1,700,000 | 2000 | Sales tax (1/10th of one cent) | $459,700/year (avg over 2003–2016) | Mitigate flooding, improve water quality in river | 28,000 |
| Milwaukee "Green-Seams" Program (Milwaukee metropolitan area, Wisconsin) | 1,100,000 | 2001 | Wastewater discharge/sewer bills | $1.2 million/year | Mitigate flooding, reduce stormwater runoff and CSOs | 3,400 |
| Portland Watershed Protection (Portland, Maine) | 200,000 | 2006 | Drinking water utility budget allocation | $450,000 | Protect forested land near reservoir for drinking water | 4,000 |
| San Antonio Source Water Protection Program (San Antonio, Texas) | 1,300,000 | 2000 | Sales tax (1/8th of one cent) | Over $325 million | Limit development in area near aquifer recharge zone | 147,782 |
| Santa Fe Watershed Investment Program (Santa Fe, New Mexico) | 32,000 | 2013 | Drinking water utility fee increase (volumetric) | $220,000/year | Forest management for fire prevention | 8,400 |

**Table 1.** (*Continued*)

| Name and Location | Population | Date Started | Funding Mechanism | Expenditures | Program Objectives | Acres Conserved, Managed, Treated |
|---|---|---|---|---|---|---|
| Scituate Reservoir Water Quality Protection Program (Providence, Rhode Island) | 600,000 | 1991 | Drinking water utility fee increase | $2.1 million (in 2015) | Protect forested land near reservoir for drinking water | 18,000 |
| Tualatin River (Washington County, Oregon) | 570,000 | 2004 | Wastewater utility budget allocation | NA | Restore riparian buffers to reduce temperatures in river, meet TMDL requirements | 660 |
| Upper Neuse Clean Water Initiative (Raleigh, North Carolina) | 600,000 | 2011 | Utility fee increase (volumetric) | $1.3 m/year since 2011 | Protect forested land near reservoirs for drinking water | 7,698 |

*Sources*: Charlotte-Mecklenburg Stormwater Services (n.d.); City of Austin (2016); City of San Antonio (2001); City of Bellingham (2016a,b); City of Raleigh (2017); City of Santa Fe (n.d.); Clean Water Services (2016); Colorado State Forest Service (2017); Conservation Trust for North Carolina (2017); Dennis Water District (2016); Great Rivers Greenway (2003–2016); Gharpurey (2017); Hart (2006); Kousky and Walls (2014); Lake Auburn Watershed Protection Commission (2016); Lawson (2017); Milwaukee Metropolitan Sewerage District (2016); Portland Water District (2016a,b); Providence Water (2015); Providence Water Supply Board (2012); Tualatin Soil and Water Conservation District (n.d.).

*Revenues from drainage fee in Austin used for multiple watershed management purposes and we were unable to separate the portion used for land and easement acquisitions from other activities.

**Charlotte-Mecklenburg County reports spending $4 million per year on the floodplain property buyout program; we are unable to ascertain the additional amount spent on stream restoration activities.

NA = not available.

### 3.3.4. *Flood mitigation*

The reduction in runoff that results when forests are preserved and managed and riparian areas are restored often provides a flood attenuation co-benefit. As we explained above, stormwater management programs often invest in green infrastructure for this reason. In our review, flood mitigation is the primary objective of the Meramec River program in the flood-prone St. Louis metropolitan area. It is also a dual objective of the Milwaukee and Charlotte-Mecklenberg programs.

### 3.3.5. *Wildfires*

Threats of water quality deterioration from destructive wildfire regimes drive some PWS programs in the Western states. Fires denude the landscape, which exacerbates runoff, and the ash residues from fires can clog and damage drinking water facilities. The barren landscape also increases the risk of flooding because the burned soils contain waxy substances that are less able to absorb water (USGS 2012). Precipitation following a wildfire exacerbates surface water quality problems (Song *et al.* 2014). Denver's PWS program provides funding to the U.S. Forest Service for treatment of national forests in the city's watershed. Forest restoration activities such as thinning, clearing, and establishing fuel breaks have been performed on 48,000 acres of designated high priority areas as of 2015, with plans to restore another 40,000 acres in upcoming years (Colorado State Forest Service 2017). This PWS program was developed following two devastating incidents, the 1996 Buffalo Creek and 2002 Hayman wildfires (Dodd 2013). The city of Santa Fe started a fire treatment effort after a major wildfire that damaged its water supply in 2002, the Cerro Grande Fire; the city's PWS program began later, in 2013, as a way to supply continuous funding for the program.

### 3.3.6. *Summary*: *Cost avoidance*

A desire to avoid, or reduce, costs while complying with government regulations or mandates underlies almost all of these individual drivers of PWS programs, consistent with the discussion in Sections 2.3 and 2.4. Water utilities and municipalities engage in forest conservation and restoration to avoid spending on additional filtration and treatment, whether that spending be in the form of capital costs, such as for larger capacity systems, or operating costs if, for example, more chemical disinfectants are required to reduce contaminants. In the case of wildfires and cryptosporidium outbreaks, a utility invests in source water protection to lower the likelihood that they will have to deal with these problems in the future in the event a wildfire or cryptosporidium outbreak occurs. Rather than build costly dams and levees, communities may invest in forest conservation to reduce flooding.

Estimates from the PWS programs that we surveyed suggest that these avoided costs can be significant. Denver spent an estimated US$27.7 million on repairs to its water collection system after two serious wildfires (Colorado State Forest Service 2017). Santa Fe estimates that the cost to dredge, haul and dispose of 2,000 acre-feet of ash from the city's reservoirs as a result of fire would be between US $80 and US$240 million (City of Santa Fe n.d.). In the 1990s, New York City estimated the cost of upgrading its filtration infrastructure to reach water quality standards at US$8–10 billion, and opted instead for forest conservation in the watershed, which the city estimated to cost less than US$2 billion (Kenny 2006). Gartner *et al.* (2013) report that the PWS program in Portland, Maine, saved the city US$12–111 million.

## 3.4. *Funding mechanisms in PWS programs*

All PWS programs involve payments to landowners to provide watershed services on their land. Agencies may purchase the land outright, in a fee simple acquisition; more often, they purchase an easement, which then limits the uses on the land and restricts development opportunities. While rental contracts in which payments are made year-by-year, or for a fixed term multi-year period, are used extensively in developing country PES programs (Martin-Ortega *et al.* 2013), this approach is less common in the U.S. Some of the PWS programs pay landowners to engage in best management practices, restoration activities, or adopt a forest management plan. The funding for these payments may come from governments, water utilities, or third parties, such as philanthropic donors; we focus our attention on programs with a local source of funding, coming more directly from end users or beneficiaries consistent with the principles of PES/PWS.[6]

### 3.4.1. *Utility fee*

One way that PWS programs are funded is through added fees to household water utility bills. The fees are assessed on a monthly basis, sometimes explicitly as a separate fee and sometimes combined with the rest of the water bill. Fees tied to PWS programs can be a fixed amount per meter per month, a volumetric rate (charged per unit of water consumed), a rate dependent on impermeable surfaces

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[6] Some programs supplement funding with money from government programs and philanthropy often plays a major role, especially at the outset. The Common Waters Partnership protected forest land in the Delaware River Watershed using money from foundations (Pinchot Institute for Conservation n.d.). The program intended to develop into a true PWS program in which downstream beneficiaries — the Delaware River is a drinking water source for 15 million people — would pay for upstream conservation activities, but because of free-rider problems and a perception that there was not a serious water quality problem, the program never developed (Dalke 2017).

**Table 2.** Water Utility Fees for Watershed Protection, Selected PWS Programs

| PWS Program Location | Fee | Normalized Rate* ($/household/month) |
|---|---|---|
| Denver, CO | $.04 per 1,000 gallons | 0.272 |
| Little Rock, AR | $0.45/meter/month | 0.45 |
| Bellingham, WA | $5/month + $0.64/CCF | 10.81 |
| Raleigh, NC | $0.1122/CCF | 1.02 |
| Santa Fe, NM | $0.13/1000 gallons | 0.884 |
| Dennis, MA | $20/meter/year | 1.67 |
| Providence, RI | $0.0292/100 gallons | 1.99 |

*The amount paid by a residential household with a typical meter size (5/8th inch by 3/4th inch) that consumes 6,800 gallons per month (see text).
CCF = hundred cubic feet. 1 CCF is equal to approximately 748 gallons.
*Sources*: See Table 1.

on the rate payer's property, or a combination. For example, Bellingham, WA charges a base rate of US$5.00 with an additional volumetric rate of US$0.64 per CCF (hundred cubic feet, or 748 gallons). Central Arkansas' program charges a flat fee per meter per month, Raleigh, NC, a volumetric fee (per hundred gallons), and Austin a "drainage charge" that varies by a property's amount of impervious surface. Gartner *et al.* (2013) analyzed five utility fee programs and found that the fees increased the average bill amount by 1.67% across all programs. The largest observed increase was 3.75% and the smallest increase was 1%.

Table 2 lists rates from utility fee-based PWS programs in our inventory. Because it is difficult to compare the magnitudes of different types of fees (e.g., fixed versus volumetric), we also calculated a normalized rate for each program that represents the price for a residential household with a typical meter size of 5/8th inch by 3/4th inch, that consumes 6,800 gallons per month, the approximate average for a U.S. household.[7] The minimum monthly charge is a mere US$0.27 (in Denver), and the maximum rate is just under US$11 (in Bellingham). The median across all seven programs is US$1.02; the average is higher (because of the very high fee in the Bellingham program) at US$2.44.

### 3.4.2. *Other "user pays" based programs*

Charging water consumers a fee to provide revenues for the PWS program is a form of the "user pays" principle, i.e., people who benefit from consistent and

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[7] According to the EPA, an average American consumes 88 gallons per day (see https://www.epa.gov/watersense/statistics-and-facts). Assuming 30 days in a month and 2.58 people per household, the U.S. average according to the US Census Bureau (2012), yields an average monthly consumption of approximately 6,800 gallons.

clean water are paying the costs of acquiring those services. There are other payment schemes that also operate within a "user pays" framework — namely through wastewater discharge, or sewer, fees and local taxes. The Charlotte-Mecklenberg, Milwaukee, and Tualatin River programs all charge households an extra fee on their sewer bills to pay for land acquisitions or restoration of riparian buffers. The city of San Antonio uses proceeds from a 1/8th US cent sales tax to purchase sensitive properties located atop the Edwards Aquifer recharge zone. The San Antonio City Council initially put this sales tax increase on the ballot for voters to approve in 2000. The tax has been subsequently put to a vote every five years since and approved each time. Since 2000, the sales tax has raised over US $300 million and financed the protection of 147,782 acres through either fee simple acquisitions or as conservation easements. The Meramec Greenway is also financed through a sales tax that has been approved by voters. A proposition created a special district called Great Rivers Greenway (GRG) financed by the tax; GRG is the agency that engages in conservation along the Meramec and other rivers in the region.[8]

### 3.4.3. *Budget allocations*

Three of our surveyed PWS programs are funded from a revenue source that is not tied to a specific utility fee or tax, but comes out of local government or utility budget allocations. This is the case for Austin, Texas, which charges households a "drainage fee" based on the amount of impervious surface but the fee revenues are not targeted to the watershed protection program but are used for a number of administrative functions associated with local water services. The Lake Auburn program is supported out of the city budgets of Auburn and Lewiston, Maine, and the local water utility; the program in Portland, Maine, is funded out of the local water utility budget.

## 4. How Prices are Set in PWS Programs

Two sets of prices exist in many PWS programs: (a) the price charged to beneficiaries, such as water users or tax payers, to generate a revenue source for the program, and (b) the price paid to forest landowners to conserve, restore, or manage their land to provide watershed services.

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[8] The Meramec Greenway predates creation of the GRG in 2000 but since passage of the sales tax, funding and management has come from the GRG (St. Louis County Department of Parks and Recreation 2003). The sales tax was increased in part of the region in 2013 and the GRG is engaged in developing the "River Ring" of protected lands and developed parks and trails along all of the rivers in the region.

### 4.1. *Prices paid by beneficiaries of watershed protection*

Our review of prices charged to water users, or tax payers, suggests they are typically based either on what the utility or government feels that citizens are willing to accept or to cover, at least in part, the costs of program operations. Lawson (2017) reports that the Central Arkansas prices were based on an assessment of what the local government assumed citizens would willingly pay. The sales tax amount (1/8th US cent) in San Antonio was decided based on a city council review, which estimated the costs of the program and included a consideration of rate levels that would likely receive voter approval (Gharpurey 2017). Austin's drainage charge is decided by structuring the base rate around future costs (in 5-year plans), though prior to 2015, the fee was fixed over time (Gharpurey 2017).

The Santa Fe program formally assessed consumer WTP prior to establishment of the program in a study carried out by The Nature Conservancy.[9] Four hundred people were interviewed by phone in 2011, and the majority stated that they were either "definitely" willing to pay, or "somewhat" willing to pay up to US$2 per month (58% of respondents were "definitely willing to pay" US$1 per month) (McCarthy 2011). These values are roughly in line with the median of US$1.02 for the seven programs in Table 2 above, but higher than the fee eventually implemented in Santa Fe, which is equivalent to approximately US$0.88 per month for the average household.[10] Some experts have reported that Santa Fe, as well as some other cities, intentionally set ratepayer fees below what residents appeared willing to pay, and less than the amount needed to cover the full cost of the program, as a way to buy time for a public campaign that would generate support for the program (Carpe Diem West 2011).

It is not clear exactly what baseline assumptions underlie the survey responses in the Santa Fe, and other, WTP studies. Key to interpreting a WTP estimate is the definition of the change in the state of the resource that is being valued (Kling *et al.* 2012; Mitchell and Carson 1989). In the context of PWS programs, a clear

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[9] Whittington and Pagiola (2012) review 25 contingent valuation WTP studies in developing country PES programs.

[10] Other WTP studies have been carried out in Eugene and Clackamas County, Oregon, with findings similar to those in Santa Fe. However, PWS programs in which local water consumers pay for forest conservation have not been implemented in either location, to the best of our knowledge. A program in Eugene, which targets protection of land in the McKenzie River watershed, is funded and carried out by a nonprofit partner with a variety of funding sources but has protected minimal acreage (Eugene Water and Electric Board 2001). Similarly, land protection in the Clackamas River watershed is deemed a priority but a local land trust relies on donated easements rather than funding from the local government or water utility (Clackamas River Water Providers 2010).

definition of the change in water quality that is expected from the program must also include the water quality levels that would result in the absence of the program, i.e., the baseline. It does not appear that such information was presented in the survey. In addition, if survey respondents were not expecting a change in water quality relative to the baseline — perhaps realizing that regulations would ensure standards are met with or without the watershed program — then it is unclear what a positive elicited WTP represents.

A similar logic applies to the fees we observe being charged in utility-based PWS programs. The fact that the utility charges a fee to support a PWS program does not imply that the size of the fee represents customers' WTP for the water quality improvements to be obtained by the program, even if the fee is implemented in response to a referendum or ballot measure. Instead, customers may be thinking of various co-benefits that would arise from the PWS program, such as improved ambient water quality and associated improvements in ecosystem health, improved recreational fishing opportunities, or benefits unrelated to water at all such as recreation opportunities from a protected forest. Alternatively, customers may be valuing the *means* by which the water quality improvement is achieved rather than the actual water quality improvement. Studies have found, for example, that WTP for electricity that is generated using renewable sources ("green electricity") is higher than for electricity generated using nonrenewable sources, and that WTP for green electricity varies by source, i.e., solar versus biomass (Borchers *et al.* 2007; Sundt and Rehdanz 2015). Studies have also identified consumers willing to pay price premiums for environmentally certified wood products (Aguilar and Vlosky 2007; Cai and Aguilar 2013). Thus it is difficult to interpret the meaning of the limited number of WTP studies for watershed protection that have been conducted.

### 4.2. *Prices paid to watershed service providers*

Payments to landowners are the heart of the PWS approach. Do these payments reflect the value of the watershed service provided on the land? Based on our review, most programs seem to target particular parcels of land for protection based on projected water quality benefits but base their payments more on the opportunity costs of the land in its next best use — i.e., on what the landowner is willing to accept to enter the program.

Table 3 summarizes how some PWS programs in our survey prioritize which lands to buy. Common themes among priority ranking systems are preference toward properties close to water flows and water bodies that interact with drinking water supply and areas with steep slopes, which are subject to high runoff rates.

**Table 3.** Prioritization of Land Protection in Selected PWS Programs

| PWS Program | How Land Tracts are Prioritized |
|---|---|
| From Forests to Faucets (Denver, CO) | Collaboratively designed assessment that analyzes and ranks wildfire hazards, flooding or debris risks, soil erodibility and water uses. |
| Lake Whatcom Watershed Land Acquisition and Preservation Program (Bellingham, WA) | Score assigned; prioritization of proximity to water bodies, to Lake Whatcom, agricultural and extractive land use, steep slope, if adjacent to other acquired property, mature forest cover and city zoning. |
| San Antonio Source Water Protection Program, TX | GIS models considering recharge features, prioritizes proximity to water source and land use, includes geologic assessment. |
| Central Arkansas Water, AR | Score assigned; priority based on developer potential, steep slope, soil type, proximity to paved roads, residences, river tributaries or Lake Maumelle. |
| Upper Neuse Clean Water Initiative (Raleigh, NC) | GIS model prioritizes proximity to water source, critical area such as wetlands, and land use. |

*Sources*: See Table 1.

Land use is also considered, with programs prioritizing areas with resource extraction, such as timber harvesting, and agriculture.

Once land parcels are targeted for protection, the local governments or utilities need to reach an agreement with landowners. Table 4 summarizes how four PWS programs in our survey set prices for land acquisitions.[11] The Central Arkansas Water program allows landowners to come to the utility with an initial price, and then the two parties negotiate. The utility uses a purchasing matrix that guides how much it is willing to pay; the matrix weights several considerations including development pressures, distance to a paved road, slope of property with respect to runoff potential, soil type, distance to major tributary or smaller water flow. On the other hand, San Antonio and Portland purchase land parcels at fair market value. This generally means that the land is valued in its highest economic use, which is determined by professional appraisers (and sometimes multiple appraisers). In easement purchase programs, the difference in the value with and without the easement restrictions on the property generally determines the easement purchase price.

Only three programs have data on individual transactions available for analysis, the Lake Whatcom program in Bellingham, WA, the Central Arkansas program,

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[11] We were unable to obtain similar information for the other programs.

**Table 4.** Land Price Setting in Selected PWS Programs

| PWS Program | How Land Acquisition Prices are Set |
|---|---|
| Lake Whatcom Watershed Land Acquisition and Preservation Program (Bellingham, WA) | Fair Market Value, with additional value added for timber, structures, and development potential |
| Central Arkansas Watershed Management Program, AR | Initial price suggested by landowner, negotiated using Purchasing Matrix |
| San Antonio Source Water Protection Program, TX | Fair Market Value for fee simple acquisitions and separate value calculated by geologic assessment for Conservation Easements |
| Portland, ME | Fair Market Value |

*Sources*: See Table 1.

**Table 5.** Summary of Prices in Bellingham, Central Arkansas, and San Antonio PWS Programs

| Program | Type | Number of transactions | Average $/acre | Median $/acre | Minimum $/acre | Maximum $/acre |
|---|---|---|---|---|---|---|
| Bellingham, WA | Acq. | 56 | $72,689 | $38,262 | $0 | $940,476 |
| Central Arkansas | Acq. | 13 | $9,715 | $7,366 | $1,375 | $27,000 |
| San | CE | 71 | $1,901 | $1,203 | $244 | $15,386 |
| Antonio, TX | Acq. | 19 | $14,651 | $8,067 | $1,743 | $102,055 |

Acq. = fee simple acquisition; CE = conservation easement
*Note*: Zero price in Bellingham program was for a single transaction (2-acre parcel).
*Sources*: See Table 1.

and the San Antonio program. Summary statistics are provided in Table 5 and we discuss each in turn.

### 4.2.1. *Bellingham, WA*

The Lake Whatcom Watershed Land Acquisition and Preservation Program has been in place since 2001, and buys both conservation easements and fee simple acquisitions for the purpose of slowing development, and protecting forestland, around Lake Whatcom, a drinking water source for the city of Bellingham. Only six conservation easements have been bought out of 62 total transactions; the program is focused mostly on buying land outright. We omit the easements from our summary of the data below because acreage information was not available.

The frequency of transactions per year was high near the start of the program, in 2002, but decreased in 2004 and remains relatively stable into 2017. Price per acre did not significantly increase or decrease over time. The average price across all transactions is US$72,689 per acre, but this average is relatively high because of a handful of very high-price transactions; the median is lower at US$38,262 per acre.[12] While prices have mostly been below US$39,000 per acre, one transaction sold at over US$940,000 per acre, and another at over US$420,000. The US $940,000 per acre purchase was made for a parcel of only 0.42 acres and was for a lakefront property. The location of the parcel that sold for more than US$420,000 per acre is unclear but the parcel was very small at only 0.14 acres.

### 4.2.2. *Central Arkansas Water*

Central Arkansas water, which is attempting to slow development around Lake Maumelle, a water source for the city of Little Rock, has purchased 13 properties through fee simple acquisitions since the program began in 2007. Conservation easements will be fully integrated into the program structure by 2018, but have not occurred to date (Lawson 2017). The number of transactions per year has been relatively constant over time, and the average and median prices are US$9,715 and US$7,366 per acre, respectively. Prices range across the 13 properties from US$1,375 to US$27,000 per acre.

### 4.2.3. *San Antonio, TX*

San Antonio's PWS program has relied primarily on conservation easements — 71 transactions have conserved 140,435 acres — but has also engaged in some fee simple acquisitions — 19 transactions for 7,347 acres. The median price for an easement in the San Antonio program is US$1,200 per acre, almost US$7,000 less than the median price for an acquisition. Easement prices are concentrated below US$2,000 per acre, but there are a few high-price purchases and a maximum price of US$15,386 per acre. Acquisition prices show a tighter distribution than easement prices, with the lowest price at US$1,743 per acre and the majority of sales below US$10,000. The number of acquisitions has dropped over time in the San Antonio program, with only 3 since 2007, as the city has shifted more toward easements.

### 4.2.4. *Program comparison*

Prices are significantly higher in Bellingham than in the Central Arkansas or San Antonio programs. One important factor underlying the differences is likely to be property values, which vary substantially across the three cities and are highest in Bellingham. Property owners are selling their land (or an easement) voluntarily and are unlikely to accept a price below what they can receive for the property in its

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[12] These figures have not been adjusted for inflation.

next best use, which in all three of these programs is likely to be development. The programs also differ in the amount of money they have available for land purchases. As we explained above, the Bellingham program implemented new water fees to pay for the Lake Whatcom program and those fees are the highest of any of the programs in our study, thus the program is able to pay more than the San Antonio and Little Rock programs, which have been constrained by local factors — San Antonio by rules governing sales tax increases and the voter approval process and Little Rock by local residents' acceptance of an increase in fees.

Whether the price differences reflect actual differences in the value of the ecosystem service provided is impossible to determine. This would depend on whether an additional acre protected in the Lake Whatcom watershed generates greater pollution reduction than in the other two watersheds and/or local residents assign a greater marginal value to those improvements than do residents in the other programs. If prices reflect avoided treatment costs, it is possible that the difference in prices reflects difference in costs. Because of data limitations, these questions are outside our scope but are worthy of additional investigation. The wide variation in prices across the three programs suggests that local factors are important in how these programs operate.

## 5. Conditionality and Additionality

In the presence of conditionality, providers of watershed services are paid if and only if they provide the service. In the PWS programs we review here, this means that landowners receive payment only when their land is sold or an easement is placed on the land or when they engage in specific forest management or restoration activities but not under any other circumstances. In other words, the programs follow an "input based" approach in which payments are based on particular land covers or land use practices rather than a performance, or output, based approach (Engel *et al.* 2008). Monitoring and enforcement of landowner practices vary across the programs. Evidence suggests that the New York City Department of Environmental Protection (DEP) engages in significant monitoring activities. In the Catskills/Delaware watershed, where 35% of the land is protected for the city's drinking water system, the DEP deploys 200 police officers to monitor for violations of the many rules on the land (Wisnieski 2015).[13] Monitoring in the PWS programs that focus on fire management is likely to be especially important but

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[13] Lakes and streams are typically off-limits for swimming and motorized boating and the land mostly lacks trails, thus is not used for recreation. Local residents have expressed dissatisfaction over the years with the program, especially as the amount of land protected has increased.

also especially difficult. In these programs, the city or utility is paying for particular fire treatment activities, which can be hard to observe over a large geographic area.

Ideally, in addition to monitoring landowner actions, PWS should monitor environmental performance — i.e., the extent to which the land uses are in fact generating the desired watershed outcomes. While drinking water utilities routinely monitor water quality conditions and screen for contaminants, as required by regulations, they do not link specific water quality outcomes to forest watershed protection activities. In the case of drinking water, the utility will typically have a filtration and treatment plant and those processes also contribute to the water quality outcomes. Linking performance specifically to watershed protection is a challenge as it would require experimental conditions — i.e., the ability to compare outcomes before and after a program is adopted, holding other factors constant. Most PES/PWS programs go no further than monitoring land use compliance (Engel *et al.* 2008).

PWS programs exhibit additionality if landowner actions are over and above what they would do in the absence of the program. Whether additionality is a necessary condition for defining a true PES/PWS program has been debated in the literature. In early studies, additionality was considered a key feature (Wunder 2007) and some authors continue to emphasize it (Sommerville *et al.* 2009; Tacconi 2012), but Wunder (2015) argues that additionality is not a necessary condition for defining PES/PWS. It is, however, a desired outcome and most experts agree that programs should be evaluated on the degree to which the outcomes achieved are additional (Engel *et al.* 2008; Goldman-Benner *et al.* 2012; Wunder 2015).

If land parcels are targeted for conservation, in part, based on development pressures, the additionality requirement is more likely to be met and the marginal ecosystem services obtained per dollar spent is likely to be higher. As we described in Section 3.3, development pressures are key drivers of several of the programs we surveyed — namely the San Antonio, Austin, Central Arkansas, Upper Neuse River, and Lake Whatcom programs — easements are based, in part, on the extent of development pressures. The Lake Whatcom program employs a “land preservation ranking sheet” to calculate a score that is used to identify high priority land areas, and the score depends partially on criteria associated with the threat of development.[14] These programs are thus likely to exhibit a significant degree of additionality. Programs that target stream buffer restoration and fire management activities are also likely to be additional as market failures lead to underprovision

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[14] The Lake Whatcom Land Preservation Ranking Sheet is Available at: https://www.cob.org/documents/mayor/boards-commissions/lake-whatcom/ranking-form-master.pdf.

of these services. However, the true extent of additionality is difficult to know without a reasonable counterfactual.

## 6. Efficiency in PWS Programs: Prices

Most of the PWS programs in our survey have ecosystem service beneficiaries paying landowners, thus that link in the "market" for ecosystem services is typically established in the design of the programs, albeit via intermediaries such as local governments or water utilities. The intermediaries reduce the transactions costs associated with PES/PWS programs (Salzman *et al.* 2018), but make it unlikely that either the fees paid by water users (in programs that set such fees) or the prices paid to landowners reflect the marginal value of the watershed service provided — a feature of efficient market outcomes. Instead, avoided costs play an important role in water user fees and landowner opportunity costs are key determinants of payments to landowners.

### 6.1. *Downstream beneficiaries' payments*

In existing reviews of PWS programs, a good deal of attention has been paid to how end users are charged for watershed protection activities, and especially to those programs that charge a watershed protection fee as a separate item on water utility bills (Bennett *et al.* 2014; Gartner *et al.* 2013). In our view, those fees bear little relation to the marginal value of clean water, or to forest conservation as a means of obtaining clean water.

This disconnect is primarily due to the existence of federal laws and rules in the U.S. that set limits on contaminants in drinking water and require water providers to adopt specific abatement technologies, in the case of the SDWA, and require stormwater management and mandated TMDLs for surface water bodies, in the case of the CWA. Water utilities set their fees to recover costs, including the cost of meeting federal requirements; they typically do not have the option of adjusting the fees they charge based on their understanding of ratepayer WTP.

Utilities that engage in forest conservation and management practices do so mainly because those activities are cost-effective ways of complying with regulations. That cost-effectiveness might be related to foregoing a capital investment in a new treatment plant, reducing the need for additional filtration or chemical costs, or lowering the chance of damage to plants from wildfires but in almost all cases, the motivation is related to cost savings, not changes in water quality outcomes. Thus any additional fee charged for these activities, whether as a separate line item or as part of an overall water charge, is essentially like other expenses incorporated in water bills — a price to cover cost-of-service.

It is possible that programs in which there is a ballot measure — for a tax increase or a bond — more closely reflect end users' values. According to the median voter theorem, a majority rule voting system will select the outcome most preferred by the median voter, and voters have an incentive to vote for their true preferences (Black 1948). However, one should keep in mind that ballot measures tied to PWS programs involve a decision surrounding a public good, which is known to lead to incentive compatibility problems in voting schemes, i.e., situations in which each individual voter's best strategy may not be to vote his or her true preferences, perhaps due to free riding and other problems (Cummings *et al.* 1997; Ledyard and Palfrey 2002). Furthermore, in cases in which a specific sales tax increase is on the ballot, the amount of that tax is more likely to reflect a city's or utility's revenue target, and once again, this is often related to costs of meeting federal regulations.

### 6.2. *Payments by government/utilities to landowners*

A payment that a landowner receives to place a conservation easement on her land, or for sale of the land itself, is most likely to reflect that landowner's opportunity costs — i.e., the value of the land in its next best use. A landowner who is able to sell her property to a developer, for example, is unlikely to accept an offer from the government or a water utility for less than what the developer will pay, and she is unlikely to accept an easement payment that is less than the difference in value of the land in development and conservation uses.

It is possible that the prices paid in PWS programs are above landowner opportunity costs. This may be the case when the government or water utility believes that a parcel is highly valuable for protection and overpays because of poor information about the landowner's opportunity cost. In these cases, the additionality requirement is not met; at its most extreme, some landowners may end up being paid for something they would have done for free.

Overpayment might also occur if the programs do a poor job of prioritizing lands for protection. As Table 3 shows, several programs have systems in place for targeting parcels based on measures related to watershed benefits. But several studies have shown that optimal conservation targeting takes both benefits and costs into account (Ando *et al.* 1998; Ferraro 2003); when parcels have different opportunity costs, targeting based only on benefits will lead to greater total program costs and inefficient conservation (Kousky *et al.* 2013).

We do not have enough information to judge whether the PWS programs we review are overpaying or not. However, the programs' reliance on the benefits, but not the costs, in their prioritization schemes suggest this as a strong possibility, and the wide range in prices in the Lake Whatcom, San Antonio, and Central Arkansas programs (Table 5) is a red flag.[15]

## 7. Conclusion

The PES concept has become mainstream and programs with the PES label exist in great numbers around the world (Salzman *et al.* 2018). Many of these programs focus on the provision of watershed services — i.e., downstream benefits in the form of clean drinking water and surface water, along with flood mitigation, but programs in the U.S. have received less attention than those in developing countries. In this study we took a detailed look at 15 PWS programs in the U.S. to evaluate the extent to which their designs fit the textbook PES/PWS model, summarized outcomes realized in the programs, and assessed program efficiency, or whether prices in these created markets appear to reflect the WTP, or marginal value, of the service provided.

Most of the programs satisfy the basic definition of PES/PWS: a voluntary exchange of payments between downstream beneficiaries — albeit through intermediaries such as a local government or a water utility — to upstream service providers, i.e., landowners. This basic recognition that private landowners should be compensated for the public goods their lands provide is fundamental to the PES/PWS concept. In the absence of PWS, local governments may instead impose mandates or restrictions, or downzone land within their jurisdiction, thus restricting development on that land. In these alternative scenarios, landowners would not be compensated for the opportunity cost of their land. PES/PWS programs have merit over these approaches; prices paid in current PWS programs may not reflect marginal values, but they are an improvement over outcomes which place a zero or infinite price on forest protection.

Our review of the programs indeed suggests that prices are unlikely to reflect marginal values. In the U.S., regulations governing drinking water and surface water guide decisions and the prices paid by water users tend to reflect costs of providing the service. Any extra fees for the watershed protection program may reflect the avoided costs of a hard infrastructure alternative but are not likely to reflect marginal values of clean water. The prices paid to landowners most likely reflect their opportunity costs of conserving their land. Thus, we would urge caution against interpreting observed fees and payments to landowners in the growing number of PWS programs in the U.S. as measures of forest watershed service value.

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[15] The very high price paid for a single lakefront parcel in the Lake Whatcom program stands out.

The fact that we are not always able to draw clear links between the design of existing PWS programs and fundamental economic principles driving the PES/PWS idea leads us to call for more program evaluation; more rigorous and systematic evaluations of these programs would be worthwhile so that decisionmakers can more properly evaluate tradeoffs between using forests for watershed protection or for alternative uses, develop financing mechanisms that are consistent with the incentives of buyers and sellers — be it a ratepayer's WTP or a utility's desire to avoid costs — and draw lessons for establishing improved PWS programs in other locations in the future.

Rigorous evaluation of PWS programs is not without its challenges. It will always be difficult to attribute water quality outcomes to specific conservation/land management activities, but more could be done through increased use of fine scale hydrologic modeling of water quality impacts, possibly tied to pilot projects that carefully monitor water quality conditions before and after development of forest land takes place. Additional statistical analysis regarding the relationship between the characteristics of forests in a watershed and drinking water treatment costs, along the lines of those we described in Section 2.2 (Abildtrup *et al.* 2013; Barten and Ernst 2004; Freeman *et al.* 2008; Vincent *et al.* 2016), would also be helpful. An improvement in those methods would be one in which the statistical approach is quasi-experimental in nature — e.g., a difference-in-difference regression comparing "treatment" communities that adopt a PWS program before and after adoption with similar communities that do not adopt (Angrist and Pischke 2009).[16] Rigorous, third-party program evaluations would be ideal and this would require access to better data than is readily available currently. Information on individual land transactions — locations, site characteristics, and prices paid — is necessary to fully evaluate the efficiency of the programs and yet is often not available.

In addition to identifying the water quality improvements that can be attributed to a program, rigorous program evaluations should address the co-benefits of protecting forests — e.g., flood mitigation, surface water quality, and other ecosystem services such as wildlife habitat, recreation, and aesthetics — and try to quantify the benefits and costs of these co-benefits.[17] Understanding the magnitude and nature of these co-benefits is important because, although they are unrelated to drinking water quality, they may be important drivers of the payments that we observe in PWS programs. Importantly, ratepayers may place value on these

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[16] The panel data methods in Vincent *et al.* (2016) are an improvement over some of the previous studies.

[17] It is possible that the co-benefits could be even larger than the primary benefits. In a study of the Meramec Greenway floodplain conservation program, Kousky and Walls (2014) find that co-benefits from the protected lands outweigh the flood benefits.

co-benefits, which can influence their WTP for drinking water treatment strategies that generate these co-benefits. It should be noted that in addition to co-benefits, PWS programs can also impose costs; for example, in some programs, the fact that some areas of the watershed are closed off for recreational use has been a source of contention within local communities. This has been the case in the much-discussed New York City program, for example, and in the Providence, Rhode Island, program that protects land in the Scituate Reservoir watershed (Hill 2015; Wisnieski 2015). Comprehensive evaluations that consider all impacts of forest watershed protection programs would inform future decisions about the design of PWS schemes.

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