Agricultural and Resource Economics
ARE UPDATE

Giannini Foundation of Agricultural Economics, University of California
Vol. 27, No. 2 Nov/Dec 2023

ALSO IN THIS ISSUE

The Cost-Effectiveness of Using Rebates to Incentivize Groundwater Recharge

Molly Bruce, Luke Sherman, Ellen Bruno, Andrew Fisher, and Michael Kiparsky

Managed aquifer recharge has emerged as a popular supply-side management tool for basins facing groundwater overdraft. We studied the effectiveness of an incentive structure similar to net energy metering that subsidizes private parties who conduct recharge on their land. A pilot program in the Pajaro Valley demonstrates that the strategy is more cost effective than many other groundwater management options.

Correcting our groundwater issues will likely require some combination of supply augmentation and demand management. When wet winters come around, common questions arise: How can we capture that water and store it for later use? And, how can we incentivize farmers, water managers, and other private individuals to help? In part because of the lack of clear answers to these questions, groundwater is in crisis throughout the world—new tools and approaches are sorely needed.

Managed aquifer recharge can enhance aquifer conditions and increase locally available groundwater supply. Managed aquifer recharge diverts available water (e.g., stormwater, excess flood water, recycled water) to either engineered (e.g., injection wells) or natural infrastructure (e.g., flood plains) to increase infiltration. But often, locations with hydrogeologic conditions amenable to managed aquifer recharge are located on private land. Individual landowners have little incentive to use their land to undertake recharge for the benefit of the basin at large if they must bear all the cost.

In this article, we explore the potential for incentives to encourage the development of distributed managed aquifer recharge—catchment systems spread throughout a groundwater basin, rather than centralized in a single location. As we detailed in a recently published article in *Nature Water*, we used a case study of recharge net metering (ReNeM), a novel rebate program deployed in the Pajaro Valley of California, to demonstrate the cost-effectiveness of these incentives relative to other groundwater management alternatives. We also used this case study to demonstrate the potential for use of ReNeM rebates elsewhere.

Akin to net energy metering, which compensates program participants with at-home solar power systems for the energy they feed to the electric grid, ReNeM incentivizes the construction and operation of managed aquifer recharge projects on private property by compensating participants based on the measured quantity of water each project infiltrates. The program engages three parties: 1) the water agency that runs the program, 2) the operators that facilitate recharge on their properties, and 3) a third-party certifier that helps identify viable sites, assists in project design and monitoring, and, importantly, measures the infiltration quantity that informs rebate payments.

Groundwater 101

Groundwater can be a replenishable resource in the sense that groundwater pumping can deplete it, but precipitation can recover it; when rain, snow, or other surface water sources collect in an area with appropriate conditions, that water percolates through the soil into the aquifer and groundwater levels recover. However, much more groundwater is removed in a given year than gets replenished, leading to declining groundwater supplies.

Groundwater overdraft is a major concern in California and in many other groundwater-dependent agricultural regions. In California, groundwater extraction is largely unmetered; landowners have historically faced few pumping restrictions. This has led to the chronic lowering of groundwater levels, which in turn has led to higher pumping costs, land subsidence, deteriorated water quality, and other negative outcomes.

In response to these concerns, at the end of 2014, California passed groundwater legislation that is changing the way groundwater is being used and managed throughout the state. The Sustainable Groundwater Management Act requires local water agencies to manage their basin's groundwater for long-run sustainability. To meet this mandate, these agencies are deploying a range of supply- and demand-side management strategies, finding additional surface water supplies to offset groundwater pumping when possible, and limiting groundwater use where necessary.

California's climate features an oscillating pattern of wet and dry years. Groundwater serves as a critical buffer to surface water shortages during those drought years but needs to be replenished during wet years. Managed aquifer recharge could be an important part of the solution, and strategies for incentivizing landowners to participate in groundwater recharge will likely be necessary.

The Pajaro Valley Case Study

The Pajaro Valley is an agricultural region on California's central coast that relies almost exclusively on groundwater to irrigate a variety of high-value crops like berries and vegetables. Agriculture accounts for about 90% of the region's water demand.

The Pajaro Valley's basin-wide pumping exceeds recharge, contributing to chronic groundwater overdraft at a rate of roughly 12,000 acre-feet per year. A key impact of this overdraft is seawater intrusion, which can increase the salinity of the water used to irrigate crops. The local water agency, the Pajaro Valley Water Management Agency (PV Water), has been striving to resolve this problem for many years because of its threat to the viability of the local agricultural industry. Groundwater-dependent agricultural regions throughout California and the world face analogous water-management challenges because supplies are inadequate to meet current and projected demand.

Table 1. Pajaro Valley Water Management Agency's Priority Projects

Water Management Project and Description	Cost Per Acre-Foot (2021 U.S. Dollars)	Yield Estimate (Acre-Feet Per Year)
(D-6) Increased Recycled Water Deliveries	0	1,250
(D-7) Conservation	229	5,000
Recharge Net Metering (ReNeM)*	570	375
(S-22) Harkins Slough Recharge Facility Upgrades	572	1,000
(R-6) Increased Recycled Water Storage at Treatment Facility	801	750
(S-2) Watsonville Slough With Recharge Basins	1,145	1,200
(S-3) College Lake With Inland Pipeline to CDS	1,259	2,400
(S-1) Murphy Crossing With Recharge Basins	1,602	500
(R-11) Aquifer Storage and Recovery	1,717	3,200
(S-11) River Conveyance of Water for Recharge at Murphy Crossing	1,717	2,000
(G-3) San Benito County Groundwater Demineralization at Watsonville Wastewater Treatment Plant	2,862	3,000
(S-4) Expanded College Lake With Pinto Lake, Corralitos Creek, Watsonville Slough, and Aquifer Storage and Recovery	3,319	2,000
(SEA-1) Seawater Desalination	3,892	7,500
(S-5) Bolsa de San Cayetano With Pajaro River Diversion	4,006	3,500

Source: Bruce et al. 2023. Available at: https://www.nature.com/articles/s44221-023-00141-1.

Note: *ReNeM estimates are based on two pilot sites for comparison with other PV Water projects.

How Does ReNeM Work?

Unlike most irrigators in California, irrigators in the Pajaro Valley already pay volumetric water-extraction fees, so ReNeM acts as a rebate on these charges. Annual payments to rechargers in the Pajaro Valley are currently based on a simple formula:

$$\text{Payment} = \lambda Q_t C_t$$

where Q_t is a project's net infiltration in acre-feet in a given year t, and C_t is a per-unit groundwater pumping fee in year t. Payments are scaled by a factor, λ, which 1) accounts for uncertainty, and 2) could in principle be adjusted to alter the incentives for participation, the distribution of benefits, or other elements of program performance and outcomes. The scaling factor (λ) is currently set to 0.5.

Because the rebate payment corresponds to infiltration volume (Q_t), factors such as site selection, system design, and project management decisions can each influence a project's performance and therefore the size of the rebate payment. Additionally, infiltration volume depends on hydrologic conditions, which vary both within and across years.

How Does ReNeM Compare to Other Projects?

In our evaluation of two pilot sites in the Pajaro Valley, we found that ReNeM has the potential to reduce overdraft at a lower unit cost than most alternative water management methods under consideration in the region.

The local water agency has identified numerous possible water management methods as part of its long-term basin management planning, has modeled these methods' annualized costs, and has prioritized these options, largely based on fiscal and political feasibility. Table 1 lists these various projects, their estimated costs, and their projected yields. Project codes included in parenthesis correspond with those used in PV Water's 2014 Basin Management Plan—see PV Water's Basin Management Plan for full descriptions of each project. We similarly calculated ReNeM's annualized costs and compared it to the annualized costs of alternative methods.

Our calculation of ReNeM's costs included 1) operation and maintenance costs such as equipment, labor, permitting, and third-party certifier services, 2) capital costs such as design and construction, and 3) opportunity costs of land used for recharge. Though ReNeM's costs also included transaction costs associated with finding a third-party certifier, landowner outreach, and overall program management, these costs were unable to be quantified and therefore were not included in our analysis. Importantly, the cost of water supply to PV Water's ReNeM program was zero because rechargers used hillslope runoff.

ReNeM's total annualized cost from the two pilot sites was $570 per acre-foot, which falls well below that of seawater desalination ($3,892 per acre-foot) and nine other projects the agency has prioritized that range in cost from $801 to $4,006 per acre-foot.

Figure 1 compares costs across projects by ordering them from lowest to highest unit cost. Each block in this figure represents a project that the local water agency has under consideration, its estimated cost per acre-foot, and its volumetric contribution to addressing chronic groundwater overdraft. The red vertical line shows the Pajaro Valley's overdraft volume–the amount by which groundwater extraction in the basin outstrips replenishment. To correct overdraft, the agency plans to undertake all projects to the left of this red line (displayed in yellow). ReNeM, outlined in black, may yield a relatively small contribution to the water balance, but does so at relatively low cost.

Positive Net Benefits

We next calculated ReNeM's net present value (NPV) over a 25-year project lifespan, discounted to the present at a 6% discount rate:

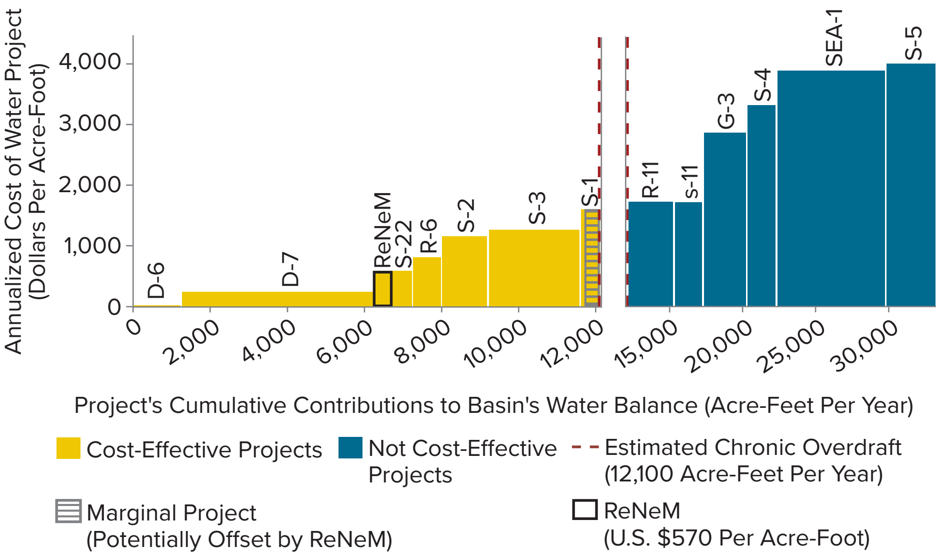
$$\text{NPV}=\sum_{t=1}^{25}\frac{\text{benefits}_t-\text{costs}_t}{(1.06)^t}$$

where benefits and costs are estimated in each year, t.

ReNeM's primary monetized benefit was its relative cost savings—the money saved by avoiding other, more costly groundwater management projects that would otherwise be necessary to correct overdraft in ReNeM's absence. This benefit was calculated by multiplying the amount of water ReNeM infiltrated by the value of that water, which was estimated to be $650 per acre-foot by the third-party certifier using the average of a group of low-cost projects described in PV Water's Basin Management Plan. Plugging in the estimated costs and benefits using values shown in Table 2 (on page 4), we estimated that the project would generate net benefits equivalent to $1.9 million over the project's lifespan. Benefits would be even greater if we used the marginal water-replacement value of $1,602 (project S1—see Table 1) to quantify the value of avoiding other, more costly groundwater management projects.

After calculating the program's overall NPV, our analysis then considered how ReNeM's benefits and costs were distributed separately between rechargers and the agency. ReNeM's

Figure 1. Comparison of Annualized Costs Across PV Water Projects



Source: Bruce et al. 2023. Available at: https://www.nature.com/articles/s44221-023-00141-1.

NPV of $1.9 million was distributed between rechargers and PV Water, acting on behalf of the groundwater basin, to the tune of $270,000 and $1.63 million, respectively, as shown in Figure 2. Error bars show 95% confidence intervals based on a Monte Carlo simulation that modeled the impact of hydrologic variability on infiltration and, as a consequence, on the NPV. The amount that accrues to landowners is driven by the rebate payment formula and the magnitude of λ, which can be adjusted.

Generalizing Beyond the Pajaro Valley

ReNeM is particularly well-suited for use in regions that levy extraction fees on groundwater users: payments can be pegged to extraction fees, which can, in turn, make the program revenue-neutral, or even revenue-positive for the agency. But fees are not necessary—an incentive scheme can still work in the absence of extraction fees.

Though the cost of water supply to PV Water's ReNeM program was zero because rechargers used hillslope runoff, other locations that explore ReNeM may face permitting costs to use hillslope runoff or incur other costs associated with alternative water supplies for recharge. In either case, these locations will want to incorporate the cost of water into an economic analysis of the program.

Concluding Thoughts

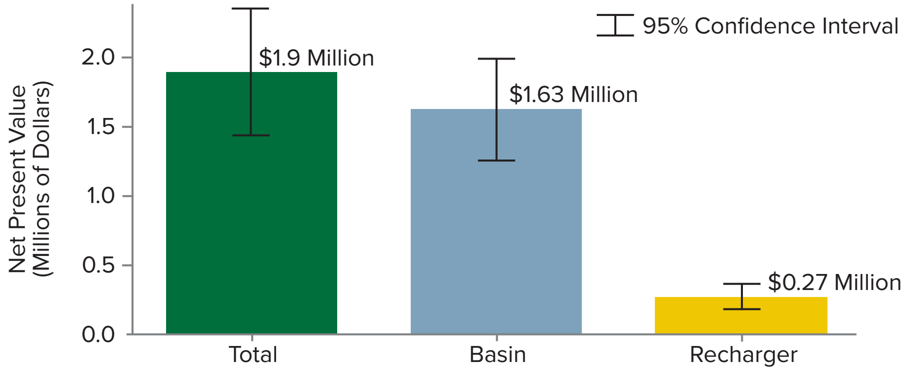
Subsidies for groundwater recharge are one additional tool that can be added to the groundwater management toolkit. ReNeM presents a unique policy tool whereby landowners are financially incentivized to conduct recharge on their land. By studying pilot projects in the Pajaro Valley, we found that ReNeM's incentive structure can be a promising approach to cost effectively promote groundwater recharge. Our analysis suggests that aggregate net benefits remain positive over a range of scenarios beyond that which exists in the Pajaro Valley, suggesting that this type of incentive structure may be beneficial in other regions.

Table 2. ReNeM Parameter Values for Cost-Benefit Analysis

Variable	Value
Project Lifespan	25 years
Quantity of Infiltration	375 acre-feet per year average (varies)
Water Replacement Value	$650 per acre-foot
Discount Rate	6%
Site Management, Operation, and Maintenance	$1,000 per acre per year
Site Supplies, Operation, and Maintenance	$500 per project per year
Opportunity Costs to Land	$1,780 per acre per year
Fixed Project Design Costs	$847,000
Annual Third-Party Certifier Expenses	$13,400 per project
One-Time Third-Party Certifier Expenses	$3,700 per project

Source: Bruce et al. 2023. Available at: https://www.nature.com/articles/s44221-023-00141-1.

Figure 2. Distribution of ReNeM's Net Benefits Among Parties



Source: Bruce et al. 2023. Available at: https://www.nature.com/articles/s44221-023-00141-1.

Suggested Citation:

Bruce, Molly, Luke Sherman, Ellen Bruno, Andrew Fisher, and Michael Kiparsky. 2023. "The Cost-Effectiveness of Using Rebates to Incentivize Groundwater Recharge." *ARE Update* 27(2): 1–4. University of California Giannini Foundation of Agricultural Economics.

Authors' Bios

Molly Bruce is a research fellow and Michael Kiparsky is the founding director of the Wheeler Water Institute at UC Berkeley's Center for Law, Energy, and the Environment. Luke Sherman is a data scientist with UC Berkeley's Global Policy Lab. Ellen Bruno is an assistant professor of Cooperative Extension in the Department of Agricultural and Resource Economics at UC Berkeley. Andrew Fisher is a Distinguished Professor in the Earth and Planetary Sciences department at UC Santa Cruz. They can be reached at molly.bruce@berkeley.edu, kiparsky@berkeley.edu, lsherman@berkeley.edu, ebruno@berkeley.edu, and afisher@ucsc.edu, respectively.

For additional information, the authors recommend:

Bruce, Molly, Luke Sherman, Ellen Bruno, Andrew T. Fischer, and Michael Kiparsky. 2023. *Nature Water* V1: 855–863. Available at: https://www.nature.com/articles/s44221-023-00141-1.