REPORT IN BRIEF

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Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits

Graywater and stormwater capture and use can expand local water availability while providing additional benefits, such as reduced water pollution (for stormwater) and a drought-resistant year-round water supply (for graywater). Treatment can help address contaminants in the water, but a lack of risk-based treatment guidelines hinders the broader use of stormwater and graywater. There is no single best way to use graywater or stormwater to address local water needs, and many important considerations—including legal and regulatory constraints, potential applications, and source water availability—vary widely with local conditions. Additional information about these factors could make it easier for businesses, households, and water authorities to use stormwater and graywater to augment water supplies.

Alternative water sources such as stormwater and graywater could help supplement scarce water supplies.

In many regions of the United States, water is in short supply. Climate change is causing shifts in patterns of precipitation, and multi-year droughts in California and the Colorado River Basin have drained reservoirs to near record-low levels. At the same time, rapid population growth is increasing water demand in many of the nation's most water-scarce regions, including California, Nevada, Arizona, Texas, and Florida, which saw population increase between 85 and 400 percent from 1970 and 2009, compared to 50 percent across the United States during the same period. As a result, the potential use of graywater and stormwater to supplement water supplies is gaining increasing attention.

Some households and businesses have already started to use stormwater and graywater for irrigation and toilet flushing. Some communities also capture stormwater at neighborhood and regional scales to recharge groundwater. In addition to augmenting water supply, capturing and using stormwater reduces pollution from flowing into rivers, lakes, and oceans and lessens the overloading of wastewater treatment facilities after heavy rains. Similarly, the reuse of graywater can enhance water supply reliability and extend the capacity of wastewater systems in quickly growing cities.

Figure 1. *The impacts of a recent drought at Folsom Lake, California, which was at 97 percent capacity in July 2011 (*left*), and at 17 percent capacity in January 2014 (*right*).* *SOURCE: California Department of Water Resources.*

However, with little information available on capturing, storing, and using graywater and stormwater, many utilities have been hesitant to integrate these practices into their water resource plans. Potential public health risks from microbial or chemical contamination also raise concerns, and debate continues over the appropriate regulatory framework to protect public health without adding excessive cost and permitting burdens to these projects. To address these challenges, this report assesses the risks, costs, and benefits of graywater and stormwater use to augment water supplies.

HOW MUCH STORMWATER AND GRAYWATER IS AVAILABLE FOR USE?

Potential water savings from graywater and stormwater use vary based on factors such as local climatic conditions, approaches, and scales. The report's authoring committee carried out an original scenario analysis based on medium-density residential development in six U.S. locations to examine these factors. The scenarios considered the use of graywater or stormwater for irrigation of turfgrass, toilet flushing, or both, and considered two graywater systems (whole-house and laundry-to-landscape) as well as two commonly used household-scale rooftop-runoff capture systems: one moderately sized 2,200-gallon storage tank or two 35-gallon rain barrels for a total storage capacity of 70 gallons.

Household-scale stormwater capture leads to the largest potable water savings in locations with year-round rainfall that closely matches the timing of water demands. Using one 2,200-gallon storage tank per house, substantial potential water savings (24 to 28 percent) from the capture and use of roof runoff were calculated for scenario analyses in four eastern or central U.S. cities. In contrast, lower potential potable water savings (5 and 15 percent, respectively) were calculated for the Los Angeles and Seattle scenarios, because of the timing and intensity of rainfall compared to water demands in those locations. Two 35-gallon rain barrels provide much lower potential water savings (less than 2 percent in Los Angeles to up to 10 percent in Newark, for example), because they capture and store a smaller amount of roof runoff.

Neighborhood- and regional-scale stormwater capture projects can contribute significantly to urban water supplies, especially in arid climates where stormwater can be stored in aquifers for use during drought or the dry season. Based on 1995-1999 data for Los Angeles, average stormwater runoff from medium-density residential developments would be roughly sufficient to meet indoor residential water needs in those areas.

For graywater, substantial water savings are possible when used for toilet flushing and/or in areas with near-year-round irrigation needs (as in the arid southwest) when irrigation demand is well-matched to graywater availability. Based on the committee's scenario analyses, graywater

Box 1. Defining Stormwater and Graywater

The report's authoring committee uses the following definitions of stormwater and graywater:

Stormwater runoff is the water from rainfall or snow that can be measured downstream in a pipe, culvert, or stream shortly after the precipitation event. For the purposes of this report, the term "stormwater" is used broadly to include runoff from rooftops, as well as other runoff from small to large source areas.

Graywater is untreated wastewater that does not include water from the toilet or kitchen, and may include water from bathroom sinks, showers, bathtubs, clothes washers, and laundry sinks

These water sources can be collected and treated for nonpotable uses including irrigation, toilet flushing, and laundry and outdoor washing. Stormwater can also be captured and used to recharge groundwater supplies.

reuse in Los Angeles provides larger potential potable water savings (up to 13 percent) than household-scale stormwater capture (up to 5 percent), because graywater provides a steady water source during summer months with little or no rainfall.

If water conservation is the primary objective for stormwater and graywater investments, strategies that reduce outdoor water use should first be examined. Significantly reducing irrigation demand, for example through the use of water-efficient landscaping, would provide much larger reductions in water demand than stormwater or graywater use in arid regions. In these circumstances, graywater could be used to supply irrigation water to meet specific small irrigation needs. Otherwise, graywater and stormwater may help facilitate the continued use of landscaping that is inappropriate for local climate conditions and not sustainable in the long term.

WATER QUALITY, TREATMENT, AND RISKS

Risk assessment provides a means to determine "fit for purpose" water quality criteria or treatment needs based on human exposures. Considering the low exposures in most non-potable graywater and stormwater applications, pathogens represent the most significant acute risks. However, little is known regarding the occurrence of human pathogens in graywater and stormwater. More work is needed to characterize their occurrence and fate, particularly for commonly-used roof runoff systems. Available risk assessments and the committee's risk calculations using the pathogen data available and various possible exposure scenarios suggest that disinfection is necessary for many uses of graywater, including spray irrigation, food crop irrigation, and toilet flushing, to protect human health. Limited data suggest that treatment may also be needed when using roof runoff for toilet flushing, even with the low levels of human exposure, although more research on pathogens in roof runoff is needed.

More research is also needed to characterize the occurrence of organic chemicals in stormwater and their fate during various uses. Enhanced infiltration of stormwater for groundwater recharge poses risks of groundwater contamination and necessitates careful design to minimize those risks.

Box 2. Graywater Use in an Arizona Prison

The Eloy Detention Center, located in Arizona, reuses graywater from showers and hand-washing to flush toilets. This system was the first large scale (i.e., multi-residential rather than single-home) application of graywater use for toilet flushing in Arizona, and because the state lacks a standard regulation for such systems, the permitting process was lengthy. Since the permit was issued in 2008, the facility has observed water savings of 20 gallons per day per inmate. This equates to approximately 130,000 gallons of water saved per day at full prison capacity (6,492 inmates).

COSTS AND BENEFITS

Some costs and benefits of stormwater and graywater use can be readily estimated in monetary terms—for example, the value of water savings or the cost of installing a stormwater tank. However, there are also important social and environmental benefits that may be difficult to quantify, and there is a lack of cost information for many applications.

In theory, simple laundry-to-landscape graywater irrigation systems can offer reasonable financial payback periods but these estimates assume graywater for irrigation actually offsets potable use—an assumption that remains to be demonstrated. Small roof runoff harvesting systems, such as rain barrels, have shorter payback periods (5–26 years in the committee's scenarios) compared to large cisterns (14 to more than 50 years, not accounting for labor), even though the water supply savings are much smaller. The longer payback periods in each range reflect locations where distinct wet and dry seasons do not coordinate well with irrigation demands—for example, the

Figure 2. *Several impoundments in California capture and store stormwater for groundwater recharge. The Rio Hondo Spreading Grounds, pictured here, receive controlled releases from the San Gabriel Canyon, Santa Fe, and Whittier Narrows dams. SOURCE: Department of Public Works, Los Angeles County.*

arid Southwest. The report also notes that more research is needed on the impact of installing on-site water systems on homeowners' overall water-use behavior.

Economies of scale are evident for large stormwater and graywater use projects. Several regional stormwater capture and recharge projects in Southern California, for example, can pay back large dividends by avoiding the cost of expensive imported water in addition to other social and environmental benefits. Based on available unit cost data, stormwater alternatives designed to recharge groundwater at neighborhood and regional scales tend to be much less expensive than on-site or neighborhood tank capture.

Depending on the stormwater or graywater system design, energy savings are possible compared with conventional water supplies, but data for a comprehensive assessment are lacking. Conventional water systems in the United States that depend on pumping water from its source to a water treatment plant have energy costs from less than 1 kilowatt hour per cubic meter (kWh/m^3) to almost 5 kWh/m^3. In theoretical studies, rooftop stormwater capture systems used only 0.2 kWh/m^3, although the limited practical studies available report median energy demand of 1.4 kWh/m^3. Many of the potential variables that affect the lifecycle energy demands, such as scale, pumping, treatment, material inputs, remain poorly understood.

LEGAL AND REGULATORY ISSUES

Graywater and stormwater reuse is being incorporated into law in a variety of respects at the federal, state, and local levels, but not quickly enough to keep up with advances in the technology and its use. Several legal and regulatory constraints remain, hindering the capacity for graywater and stormwater to significantly expand the nation's water supplies.

In most western states, acquisition of water rights is a requirement for large-scale stormwater capture and use projects. In addition, water rights may limit widespread implementation of smaller-scale stormwater and graywater projects for uses, such as irrigation, that have the potential to reduce surface water availability to those downstream. Unless water rights can be acquired or legislative solutions developed, large-scale stormwater capture projects would be limited to coastal regions with no downstream users, or to non-consumptive uses such as toilet flushing.

There is substantial variation in on-site graywater and stormwater regulations at the state level with respect to design and water quality for household-scale projects, which leads to varying exposures and risk. The lack of authoritative, risk-based guidelines for the design and potential applications of graywater and stormwater in the United States is a major impediment to their expanded use.

Developing rigorous, risk-based guidelines for graywater and stormwater across a range of possible uses and exposures could improve safety, build public confidence in the practices, reduce expenditures on unnecessary treatment, and assist communities that lack an existing regulatory framework for on-site water supplies. Such guidelines could be developed by the Environmental Protection Agency, a collaboration of states, or a collaboration of U.S. water organizations working with the Environmental Protection Agency. This guidance could then serve as a basis for developing standards of practice for on-site non-potable water use. Oversight and enforcement of water quality standards for applications with significant exposures is also important but challenging, and local enforcement agencies would benefit from additional guidance on appropriate, cost-effective maintenance, monitoring, and reporting strategies.

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The National Academies of Sciences, Engineering, and Medicine appointed the above committee of experts to address the specific task requested by the Environmental Protection Agency Office of Water and Office of Research and Development, National Science Foundation, Water Research Foundation, Water Environment Research Foundation, Los Angeles Department of Water and Power, WateReuse Foundation, City of Madison, Wisconsin, National Water Research Institute, and the National Academies' President's Fund. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the Academies. This report brief was prepared by the Academies based on the committee's report.

For more information, contact the Water Science and Technology Board at (202) 334-3422 or visit **http://dels.nas.edu/wstb**. Copies of *Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits* are available from the National Academies Press, 500 Fifth Street, NW, Washington, DC 20001; (800) 624-6242; or as free PDFs at **www.nap.edu**.