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Fighting water with water: Behavioral change versus climate change

Water sustainability depends on alternative infrastructure and landscapes designed to accept water into the constructed environment, with a universal theme of making all water infrastructure more visible. Unfortunately, our nation understands little about the tour water takes from its origin, to treatment, to household, to treatment again, and back to the source. For most individuals, water has taken on a dichotomous persona: either falling from the sky and flowing along an engineered or uncontrolled path or being provided indoors and flowing controlled from a spigot with a somewhat ambiguous but secure origin. Modern lifestyles have compartmentalized these views into liabilities and resources.

CRITICAL CHANGES ARE NEEDED IN ORDER TO ACHIEVE SUSTAINABLE WATER RESOURCE MANAGEMENT, WITH COMMUNITY INVOLVEMENT PLAYING A VITAL ROLE IN EMBRACING THE NEW STRATEGIES NEEDED TO RESTORE WATERSHEDS.

Free-falling water that soaks the landscape is often addressed by flood control, shuttled away into expensive and maintenance-intensive infrastructure. Quickly replacing it is energy-demanding potable water used to quench the surfeit thirst of nonnative landscapes. Regional differences have also entrenched our view of water. The desert southwest has inherited a perception that there's too little water; the wetter Great Lakes region has the perception of too much—but too little and too much exist in both regions.

Although cities surrounding the Great Lakes, such as Toronto, Ont., have begun campaigns to enhance rainwater catchment (Accetturo, 2005) because of a decline in drinking water quality, regions throughout Canada and the United States are starting to rethink water resource management (WRM) and are looking to low-impact development (LID), green infrastructure, rainwater harvesting, and graywater reuse as parts of a solution. With a heightening community awareness of WRM and LID, we can begin to manage water by slowing, spreading, and cycling more of its flow instead of paving, piping, and polluting it.

REFRESHING GENERATIONAL MEMORY

Capturing and retaining water where it lands are not revolutionary ideas, but they have escaped our generational memory. Buried cisterns seem to litter the backyards of many homes built before the 1940s in midwestern neighborhoods. They are often found during excavations, demolitions, and renovations and quickly discarded with the same unabashed excitement as finding an old landmine (Kibbel, 2009). Similar archaic structures can be found in sites around Tucson, Ariz., on old homesteads and in other areas that are off the water grid.

In the 1950s, major steps were taken to enhance public safety and improve public drinking water supply and stormwater management. In many parts of the United States, piped water systems had replaced large cisterns that provided much-needed protection against fire hazards. In addition, piped infrastructure was enhanced to support treated potable water distributed from emerging facilities. These changes were often complemented by a post-World War II motto of "bigger is better." By inflating the nation's ego, our consumerism was sparked: average home size, appliances, and cars all became larger. In response, streets were widened to accommodate larger domestic vehicles and even larger municipal nonporous vehicles such as compacting trash trucks and fire trucks. More development meant more pavement, which meant more runoff. To deal with this additional water, pipes and infrastructure were installed to intercept runoff and divert it away—sight unseen—to local waterways.

Chicago, Ill., residents have few reminders of the marshland that once lay beneath the present-day skyscrapers and dense urban corridors. When large rain storms hit the now-paved surfaces, runoff has nowhere to go. Since the 1970s, Chicago has been working to address these flooding and water quality issues through a 50-year tunnel and reservoir plan that consists of a complex 93-mile tunnel system up to 33 feet in diameter that is used to store runoff during rainstorms (Shore, 2011). This imperative storage helps lessen the burden on Chicago's combined sanitary and stormwater sewer system. Hidden below ground, the tunnels also reduce the frequency of raw sewage discharges into the Chicago River and connected waterways. Excess runoff is retained in the tunnels during a storm to avoid overwhelming the city's seven wastewater treatment plants and is later brought back to the surface through the use of energy-intensive pumping.

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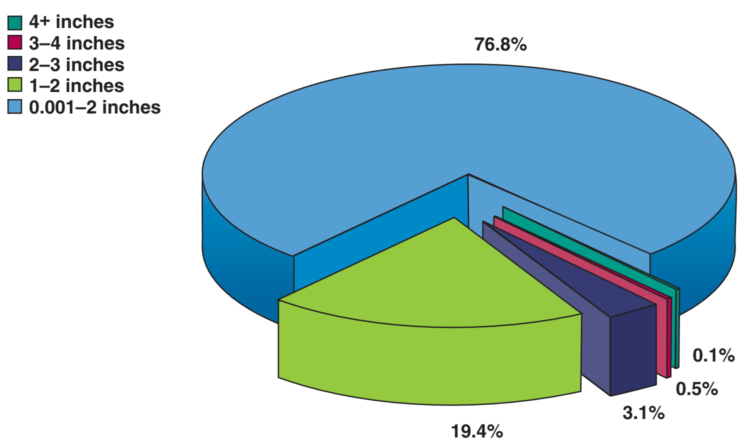
Today, some of the measures implemented in that era have overshot the target and are doing more harm than good. The infrastructure designed to drain large-capacity events all too often drains all events, including the smaller more common ones. This is considered dehydration infrastructure. In Ann Arbor, Mich., stormwater management and its

FIGURE 1 Rainfall volume by storm magnitude for Ann Arbor, Mich. (1902–2007)



Adapted from Cahill Associates Environmental Consultants & JFNew Ecological Consultants, 2007 related regulations were designed to target large storms, yet the frequency of these events is nominal (fewer than 20%), whereas smaller events (less than 1 inch of rainfall) occur more than 76% of the time (Figure 1; CAEC & JFNEC, 2007).

Historically, periods of rapid growth have had negative effects on WRM because of a rush to develop land and the need for public safety. The engineers, architects, technicians, and public service workers who provide water and sewer infrastructure must be expeditious in guaranteeing public health and safety. With hindsight, we can see that some of these hastily planned communities are the result of anxious anticipation instead of thoughtful preparation. Today the cost of resources needed for operating, maintaining, treating, and distributing water—along with the calamitous changes to microclimates from artificially shifting water from one area to another—has made WRM professionals begin to rethink their approach.

How could it be done differently? LID principles and designs provide solutions that not only increase public safety by reducing the view of water as a liability, but also ensure sustainability. LID solutions provide infrastructure that rather than draining all flow, drains only the overflow. Overflow from LID strategies allows us to harvest and use the smaller flow events farther up and throughout the watershed.

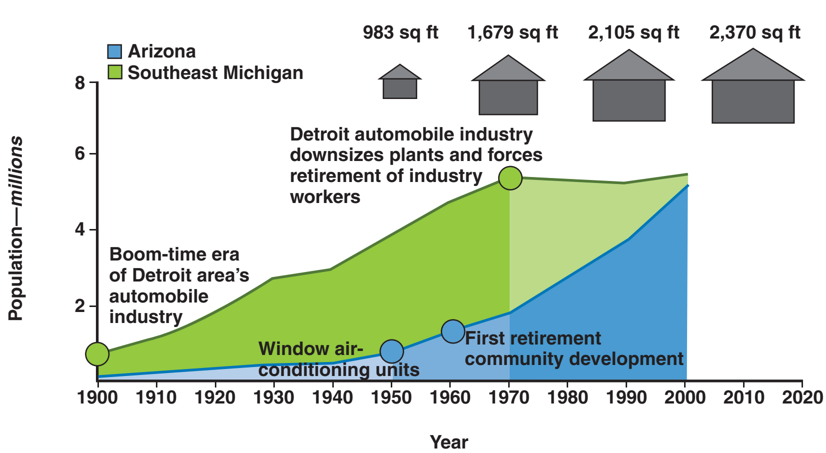
BITING THE HAND THAT WATERS US

When comparing population growth, development, and water resources in the Midwest with those in the southwestern United States, Michigan can provide Arizona with great insight through lessons learned. The two states have traded places in that the growth that Michigan experienced in the first part of the twentieth century is now Arizona's burden to carry. Water resources and availability are vastly different, but they are equally constrained. Arizona may battle over western water rights and have a growing population and economy that will increase competition for water availability, but a half-century of paving and pollution has left Michigan battling to restore many of its degraded water resources.

Michigan's population has remained nearly stagnant at approximately 10 million people for 30 years (US Census Bureau, 2009). However, this was not the case for the nearly 50 preceding years. Between 1920 and 1970, Michigan's population grew nearly 142% (US Census Bureau, 2009), from 3.6 million to more than 8.9 million. Much of this growth was fueled by the auto industry; the economy supported major expansions in the Detroit area and later led to the development of the surrounding suburbs (Figure 2). Providing natural resources such as water, food, and power during this "boom time" meant relying on Detroit's well-established infrastructure to support arterial utility lines farther and farther from the epicenter. The result was massive clear-cutting of trees for subdivisions, planting of nonnative invasive landscapes, 12,500 miles of pipe for water and sewer, and hundreds of miles of ever-widening expressways for shuttling vehicles from the suburbs into the city (Cavanaugh, 2011).

Today, because of the economic crisis and progressive environmental movements, southeast Michigan is trying to revamp its concrete jungle to return some of the predevelopment viability to the land. This means daylighting streams, increasing rain gardens, and undertaking downspout disconnection to name a few. Many of these projects use LID to bring water back into the community's sight, but we have a long way to go to reconnect people with their water sources. The Detroit Water and Sewerage Department service area is more than 1,079 square miles and supplies 43% of Michigan's entire population with water and 35% of the population with wastewater treatment (DWSD, 2011). As a result, many customers live more than an hour's drive from the downtown Detroit and have no idea that their water originates from the Detroit River, rather than lakes, rivers, or streams in their own neighborhoods.

FIGURE 2 Growth rates of sample Michigan and Arizona communities' effect on watershed microclimates*



**These communities' water demands are directly tied to population growth and supporting development (e.g., air-conditioning, retirement community projects).*

Arizona, on the other hand, seems to be a depository for many of those who once lived in southeast Michigan (and other areas of the Midwest) and were looking for a change of climate in retirement. These snowbirds have been a large factor in Arizona's more than 294% population increase since the 1950s. This trend means that as Michigan's population began flatlining, Arizona saw its own boom time. Of the nearly 5.1 million people living in Arizona, the Tucson metropolitan area is home to approximately 16% of them (Pima Association of Governments, 2004), with its own urban density of roughly 2,500 people per square mile. This trend is only expected to increase, putting further constraint on local water resources.

To entice home buyers, Arizona communities have built homes that mimic the size, layout, and drainage schematics seen in planned communities in other areas of the country. Nonnative landscapes are mimicked by planting grasses and plants typically found in wetter regions. To support these unreasonably thirsty plants, elaborate (and leak-prone) irrigation systems are installed. Worse yet is the national reliance on irrigation systems for nearly all landscapes. Almost all single-family (small-scale) household lots in the United States are designed to drain nearly all nonpotable water (precipitation, air-conditioning condensate, and graywater) off site. This total drainage is then replaced by imported potable drinking water, the majority of which is ingested by landscapes, but not people. Nationally, 30–70% (70% for Southern California, Las Vegas, Nev., and Phoenix, Ariz.) of all treated domestic water used for irrigation. Designing systems that account for and use the water that naturally lands on a site could drastically reduce these percentages.

To counter the fervor of nonsensical water use and practices, we look to the meaningful "green" or LID engineering of the past. Around Tucson there are many check dams, contour swales, and other earthworks created by the Civil Conservation Corps in the 1930s to slow, spread, and infiltrate water. These passive strategies capture water as close as possible to where it falls—within the soil rather than on top of the soil—to reduce water loss to evaporation and deny mosquitoes the opportunity to flourish. That harvested water alone then sustains associated native vegetation that in turn increases the rate of water infiltration while sheltering and strengthening the earthwork and creating wildlife habitat, erosion control, and even food production. Although there has been no maintenance of these structures since they were built, many still function.

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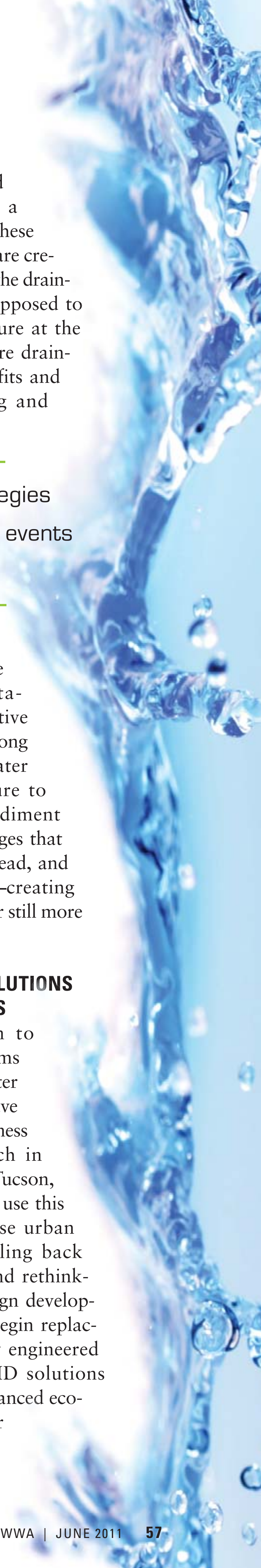
In one drainage system of the dry Tucson Mountains, where many small check dams were constructed in the 1930s, water flows for weeks longer than elsewhere in the area. Check dams (none taller than 3 feet) enhance and build on the natural pattern of stepped pools in a mountain drainage area. Water pours over a dam into a pool of water deepened by another dam below. The pool of water diffuses the force of the falling water. Both dam and pool spread the water over a wider area of the drainage for more soil-to-water contact and more infiltration of water into the soil. More water is infiltrated quickly into the watershed to be more slowly released later. Terraces of soil and organic matter accumulate behind the check dams, creating porous "sand tanks" that rapidly infiltrate water and then slowly release it. In many instances, ephemeral seepage springs have appeared just below the check dams as the water rapidly absorbed in the terrace above is slowly released for weeks after a storm. Because these small structures are created throughout the drainage system, as opposed to one large structure at the bottom, the entire drainage system benefits and overall flooding and blowouts are reduced. Vegetation, such as native grasses, grows along the lingering water and soil moisture to create living sediment combs and sponges that further slow, spread, and sink the water—creating the conditions for still more plants to grow.

TAKING THE SOLUTIONS TO THE STREETS

One solution to drainage problems is to manage water with water. We have seen the effectiveness of this approach in the hills above Tucson, but how can we use this theory in a dense urban setting? By peeling back the pavement and rethinking how we design developments, we can begin replacing traditionally engineered systems with LID solutions that provide enhanced ecosystems, greater flood control, improved water



quality, reduced heat island effects, and decreased carbon emissions. Rethinking street design and developments can have the largest effect on WRM. These solutions can be as simple as inserting curb cuts, creating bowl-like vegetated catchments in rights of way rather than mounded ones, and integrating rainwater catchment into irrigation design. Using such practices can be better defined as integrated WRM, which ensures that social, economic, environmental, and technical dimensions are taken into account in the management and development of water resources (Biswas, 2004). Promoting this process can be difficult because it means cross-sector communication and integration. Whether communicating with government organizations, the private sector, or both, a high level of coordination and cooperation is required to develop integrated plans, projects, and management. Yet the results can yield sustainable outcomes that outweigh the inputs in the form of future community satisfaction and far exceed the individual water elements.

Ann Arbor's solution. The city of Ann Arbor recently took on a challenge to review its own effects on stormwater by using geographic information system software to estimate what portion of total impervious surface area was the result of street cover. The answer was astounding: Ann Arbor public rights of way contain 2.9 square miles of impervious surface area, which is equivalent to 26% of the city's total impervious surface area. Remarkably, if a quarter of the streets are the primary conduit of stormwater through directly connected pipes and infrastructure, then, according to a study by Roger Bannerman at the Wisconsin Department of Natural Resources, they relate to approximately 54% of the runoff (Hancock, 2010). The magnitude of these findings has led Ann Arbor to create its Green Streets Initiative. The objective is to overhaul the engineering design standards for public streets and encourage street designs that use porous pavement and green infrastructure methods for managing stormwater runoff as the new standard rather than an experimental alternative.

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Ann Arbor will coordinate efforts with the Southeast Michigan Council of Governments (SEMCOG) in its process of creating the *Great Lakes Green Streets Guidebook*, which is funded through the Great Lakes Restoration Initiative. The guidebook will consist of regional and statewide green streets project elements, including locations, sample designs, green infrastructure selection criteria, and cost information. It will also outline a step-by-step process for integrating green infrastructure into new road projects and road maintenance activities. Development of the guidebook is the result of SEMCOG's experience in creating the State of Michigan Low Impact Development manual used by communities across Michigan and the United States.

Bringing Ann Arbor's program to fruition will require close communication among the city's stormwater coordinator, engineering department, and the city technicians that conduct street sweeping, snow removal, and maintenance. Ann Arbor staff has acknowledged the level of effort necessary, but has an equal recognition of the importance and the long-term effects such a program could have on the environment, economics, and total community health.

Chicago's solution. By studying current and past projects, it is clear that long-term benefits to a community are inherently greater when systems are designed to accommodate the natural environment rather than transform it. By decreasing the materials for infrastructure and maintenance, using native vegetation that requires less water, and developing land for "run-on" instead of runoff, energy reduction and environmental improvements can be substantial. For example, if Chicago were to replace half a square mile (0.25% of the city's total area) of pavement with an integrated porous pavement and infiltration basin system, it could prevent 556 million gallons of water from flowing into the tunnel and reservoir system annually, thereby avoiding pumping and treatment for that water. If that same volume was incorporated into the irrigation schematic for urban street trees, planter boxes, or rain gardens, the total annual avoided energy in both water and wastewater treatment could reduce carbon emissions by approximately 2,300 million tons (value-based 2008 rainfall data for the city of Chicago).

Tucson's solution. The 28-home Milagro cohousing development in Tucson is another example of integrated WRM. There are no conventional detention or retention basins at the bottom of the site or any storm drains because there is no runoff. All rooftops drain to the landscape, which is made up of dozens of 18-inch-deep mulched and vegetated infiltration basins or rain gardens from the top of the site all the way to the bottom. A meandering raised footpath separates and drains its runoff into these basins.

By capturing all rainfall and runoff from adjoining hardscapes, and thereby increasing the catchment area of the rain gardens by almost three times, the available rainfall for these gardens has nearly tripled from an annual average of 12 inches to 30 inches, increasing the size of the associated passively cooling shade trees—many of them food-producing. The cumulative storage capacity of these rain gardens exceeds a conventional stormwater system's capacity by 10 times, resulting in a superior flood control strategy that doubles as the foundation of a water-sustainable landscape irrigated only by passively harvested rainwater and recycled onsite wastewater. No potable water is needed for irrigation.

When Milagro was designed, graywater harvesting was illegal in Arizona, so a constructed wetlands was placed at the bottom of the site to treat all the wastewater—graywater and blackwater combined, which after treatment is then pumped and distributed subsurface into the common landscape. With the legalization of graywater harvesting and reuse in the state in 2001, graywater can be directed straight to the landscape via gravity—no pumps, no tanks, and far less pipe. Thus, in times of rain, the sunken, mulched, vegetated basins of the rain gardens rapidly and passively soak up the rain. In times of no rain, the rain gardens can become graywater gardens, rapidly and passively soaking up graywater.

These solutions strengthen our communities, better enabling them to buffer and endure extremes. As they are typically conceived and constructed, communities' infrastructures too rapidly drain water, nutrients, and energy out of the system. This increases flooding, drought, energy consumption, costs, and climate change, while decreasing the natural carrying capacity of the land and community.

SLOWING THE FIRE

Climate change is neither a future phenomenon nor a recent condition; the sparks that began anthropogenic climate changes were lit more than a century ago. Rather, it is our modern scientific understanding of nature that has allowed us to realize and quantify the effects of our actions on the climate more accurately. WRM can be tied to climate change in three ways: alterations of the natural ecosystem, increased reliance on engineered infrastructure, and a reliance on imported resources rather than local ones. A prime example of this issue can be found in Los Angeles, Calif.

Because Los Angeles has so much excess pavement, rainwater from a 100-year storm would rush off those sealed surfaces, flooding the Los Angeles River and spreading into neighboring cities instead of seeping into the ground. Because all of this stormwater is essentially wasted, Los Angeles must import a large amount of water by piping it across the mountains, which requires vast amounts of energy and displaces water from one area to another. Because of Los Angeles's modern systems, local resources are driven out, thereby increasing the necessity to import others. This water quandary also translates into major energy demands. Although all areas of the United States supply and use energy for treating water, California has been tracking its use the closest. Why? Because Southern California has some of the highest demands nationally but the lowest local supply. As a result, there is heightened interest in tracking energy and economic budgets for water. In Southern California, the energy intensity of the water supply system is four times greater than the national average. The Los Angeles water system uses an average of 7,770 kW/million gallons to supply water to nearly 16 million people living in and around the city, further adding to climate change emissions (Wilkinson, 2007).

MAKING THE SEEDS OF SOLUTIONS GROW

"Plant the rain before you plant the trees, because without water they will not grow." This was the primary lesson taught by an African water harvester who taught himself how to sustainably harvest and enhance local resources to turn eroding, flood-producing wastelands into relatively spongelike, flood-averting oases.

Similar rain and tree plantings are occurring throughout Tucson and elsewhere in the Southwest, stimulated by changes in laws legalizing stormwater-harvesting street curb cuts and earthworks. Tucson has also mandated that all new commercial landscapes need to provide at least 50% of their irrigation needs with harvested rainwater, which can be done with inexpensive passive earthworks. Thus parking lots, as with streets, are becoming another onsite source of runoff transformed into "run on" or "sink in." In new home landscapes, it is also becoming easier to use graywater because all new homes in Tucson must install graywater-harvesting stubouts, which are sections of pipe in the wall and floor through which homeowners can easily direct the graywater to the landscape if wanted.

In the same way, Ann Arbor passed a new residential stormwater ordinance that took effect Mar. 1, 2010 (City of Ann Arbor, 2011), which mandates that all residents adding impervious surface area (e.g., home additions, patios, driveways) of 200 square feet or greater are required to offset their stormwater effects by adding green infrastructure treatments such as rain barrels, rain gardens, or porous pavement. The features must be sized to contain the first 0.5 inches of rain that falls onto the newly constructed space. This type of stormwater code is a first in Michigan in that it is targeted at individual houses, thereby addressing the largest contributers to impervious surface area.

Numerous nonprofit organizations in Michigan and Arizona are teaming up with government agencies to promote and implement sustainable WRM programs and practices such as water harvesting, LID, and green infrastructure on private property, public parks, rights of way, schools, and around public buildings. Many of these groups have helped sponsor informative guides such as SEMCOG's *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers* and the Watershed Management Group's 30-page guide to green infrastructure in the southwestern United States. Even though for many communities these are nascent concepts with few pilot projects, they are educating people about how to better manage our water resources. Turning these pilot projects into standard practice, however, will take retooling of local government codes; increasing education among the technical community in how to design, install, and maintain these systems; and encouraging this paradigm shift. In many locations, volunteers do the bulk of the work. Professionals may take on the implementation, but residents neighboring the projects often provide the majority of the maintenance. This shows that if we plant the policies that make LID possible, a new form of WRM will follow, and with it community involvement will grow.

LID strategies in the midwestern and southwestern United States may have different primary drivers—flood control, water conservation, stormwater quality, reduction of combined sewer system overflows—but they achieve the same results: simple, effective, visible, and thus replicable strategies all slowing, spreading, and cycling more of the water flow. Simultaneously, this process is infiltrating the once-impervious minds of those who see the results. People are reconnecting with the hydrologic cycle. They see directly how their efforts and actions can enhance or deplete that cycle, allowing the community to make informed decisions based on what it observes and knows.

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