



# Opportunities

## IN DISTRIBUTED WATER INFRASTRUCTURE

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## EXECUTIVE SUMMARY

Though experimentation with distributed water infrastructure has been underway for decades, it has only recently entered mainstream conversation among water leaders. Facing the limits of centralized water infrastructure, as well as the challenges of climate change, resource constraints, site-specific logistical realities, etc., creative minds are looking toward alternative solutions.

This report serves as an introduction to distributed water infrastructure, how it can best be applied, as well as how it is playing out in a variety of scenarios, both urban and rural.

It also reflects on interventions that could be useful in accelerating the adoption of distributed water infrastructure where it makes the most sense, as well as cautionary notes regarding how to avoid unintended consequences.

Constrained cities, those who are outstripping their water availability and/or sewage collection and treatment capacity, are first in line for advanced distributed water infrastructure. These are the early adopters that can provide models and templates for broader application. There is also a role for distributed infrastructure in other scenarios.

In order to accelerate the uptake of these new options, however, we also need a professional ecosystem to support a strategic and socially minded transition.

This report serves as an introduction to distributed water infrastructure, how it can best be applied, as well as how it is playing out in a variety of scenarios, both urban and rural.



## INTRODUCTION

Not all that many years ago, believing in the possibility of distributed water infrastructure was sure to raise eyebrows. Bringing it up in water utility or design-firm circles would almost certainly stop the conversation; at best, the subject would be politely humored, and the conversation would move on to more “sensible” territory. But by 2014, there were visible signs that change was ahead.

That spring two independent but convergent events occurred. In March, The Johnson Foundation at Wingspread convened about two dozen experts from around the United States on the topic of “Optimizing the Structure and Scale of Urban Water Infrastructure: Integrating Distributed Systems”. The purpose of that meeting, and the report it issued<sup>1</sup>, was to identify when and where distributed water infrastructure made sense. Just two months later, the San Francisco Public Utility Commission, with the support of two major water research foundations, convened utility leaders who were interested in the narrower topic of onsite wastewater systems. From that meeting they developed a blueprint for municipalities seeking to develop such a program.<sup>2</sup> San Francisco had been piloting onsite, in-building<sup>3</sup> treatment and was looking to leverage its experiences for larger impact.



**IT’S WORTH TAKING A MOMENT TO EXAMINE WHAT WE MEAN BY THE TERM “WATER”. WE ALL KNOW WHAT WATER IS, BUT WHEN WE SAY “WATER UTILITY” OR “WATER INFRASTRUCTURE” IT’S IMPORTANT TO CLARIFY. TRADITIONALLY, “WATER UTILITY” HAS REFERRED TO A WATER SUPPLY UTILITY OR WHAT SOME PEOPLE CALL A *DRINKING WATER* UTILITY, AND THE TERM “WASTEWATER UTILITY” IS USED WHEN WE MEAN A UTILITY THAT TAKES DIRTY, SEWAGE-LADEN WATER AND CLEANS IT. TODAY, ESPECIALLY IN A WORLD OF WATER-REUSE AND REFRAMING AROUND “ONE WATER”, THE DISTINCTION HAS BLURRED. SO, IN THIS REPORT “WATER” WILL BE A GENERAL TERM THAT INCLUDES ALL TYPES OF WATER UTILITIES, SERVICES, AND INFRASTRUCTURE. WHEN SPEAKING SPECIFICALLY ABOUT SEWAGE COLLECTION OR TREATMENT, IT WILL BE MADE CLEAR, AS IT WILL BE FOR WATER SUPPLY.**

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- 1 The Johnson Foundation at Wingspread, “Optimizing the structure and Scale of Urban Water Infrastructure: Integrating Distributed Systems”, August 2014. [http://www.johnsonfdn.org/sites/default/files/reports\\_publications/CNW-DistributedSystems.pdf](http://www.johnsonfdn.org/sites/default/files/reports_publications/CNW-DistributedSystems.pdf), accessed 30 August 2019.
  - 2 San Francisco Public Utilities Commission, “Blueprint for Onsite Water Systems”, September 2014. <https://sfwater.org/modules/showdocument.aspx?documentid=6057>, accessed 30 August 2019.
  - 3 In the broader water and public health worlds, “onsite” generally refers to septic systems, septic tanks, and leach fields, the traditional way to handle sewage in rural areas. In San Francisco’s case, the term refers to highly innovative technologies that allow for in-building water treatment. This is one of the types of distributed water infrastructure that is garnering a lot of excitement.



# What's Driving The Conversation?

## CHALLENGES WITH CENTRALIZED WATER SYSTEMS

The centralized water infrastructure that developed countries have come to take for granted has served our communities well for the last century. Modern treatment technologies, and the federal laws and state-level health codes behind them, have been largely credited for allowing the dense populations that define modern civilization. Outbreaks of water-borne diseases like typhoid or cholera are largely the subject of historical study rather than present-day worries. We've come a long way, and for that we can thank our water infrastructure and the people who operate it. But yesterday's solutions are increasingly falling short in the face of current challenges.

Some of the present-day hurdles are the result of unintended consequences or challenges in maintaining these large systems, while others are a result of changing needs, particularly those associated with climate change, greenhouse gas emissions, and more stringent expectations for water quality. The challenges or shortcomings can be lumped into two broad categories revolving around size and resilience.

### BIG SYSTEMS COME WITH BIG BURDENS

**Too big to maintain:** Virtually every water utility faces a maintenance and capital backlog that it simply cannot catch up with. Water and wastewater rates are increasing faster than inflation so that repairs and investments can be accelerated, but even so, the bi-annual infrastructure report card issued by the American Society for Civil Engineers most recently gave water infrastructure a "D". As water rates increase, affordability becomes an issue. This is especially true in communities where, due to water conservation (behavioral changes such as fewer toilet flushes), water efficiency (fixtures that use less water), declining populations, or changes in industrial demand, water demand and sewage generation are declining. That means that billable volume is also declining.

**Loss of integrity:** Maintenance backlogs mean that aging pipes are not repaired or replaced fast enough to keep up with the inevitable leaks, cracks, collapses, and (eventually) sinkholes. For sewage collection

systems this has two consequences: groundwater leaks in and in wet weather periods can overwhelm the collection and treatment system leading to sewer overflows that contaminate the community's surface water. For drinking water distribution systems, it means that contaminated groundwater can infiltrate the water supply. Given that sewer and water laterals are generally in the same vicinity, cross-contamination can occur during periods of heavy rain or high water table.<sup>4</sup>

**Financial inflexibility:** Large systems take a long time to plan, a long time to build, are generally debt financed and take decades to pay off. Adding to the capital cost of centralized systems is that virtually every water treatment system must be custom designed by highly specialized engineers. If circumstances change and design needs adjust, it's very hard (and expensive) for a community to adapt their infrastructure. Communities that overestimate their growth, which often happens for those that can least afford the mistake, are still on the hook.<sup>5</sup> This is also a disincentive for water

4 Patrick Drayna et al. "Association between Rainfall and Pediatric Emergency Department Visits for Acute Gastrointestinal Illness" in *Environmental Health Perspectives*, Vol. 118, No. 10, 1 October 2010. <https://ehp.niehs.nih.gov/doi/10.1289/ehp.0901671>. Accessed 30 August 2019.

5 Kirk Ross, "With town of Eureka drowning in sewage bills, state takes control", *The News & Observer*, 8 August 2019. <https://www.newsobserver.com/news/politics-government/article233635952.html>, accessed 30 August 2019.

conservation, as well as volume-based rate structures that can incentivize lower use, because utilities need the rate revenue to pay for the system as it was built.

**Physical inflexibility:** Installing large-diameter pipes beneath city streets is a massive undertaking, both financially and logistically. Once it's done, it's not likely to be tackled again in most engineer's professional careers since pipes have a useful life of 50-100 years. As a city grows, the same collection system must carry larger volumes but eventually there's a limit to what the pipes can carry without leading to backups or overflows. Ironically, there are also problems when a city overbuilds. Oversized sewer pipes can make it mechanically difficult to get the sewage to the central treatment facility without having the solids slow down and settle in the pipes, and begin the decomposition process in the pipes rather than at the treatment plant. When this happens, sulfur dioxide, a natural byproduct of sewage decay, causes unpleasant odors and corrodes metal pipes and pumps.

There are can also be problems if the delivery network for potable water is oversized. "Water age" is the term of art used to describe the length of time that water is in the distribution system before it is used by the consumer. This matters because the longer that the water is in the system, the less likely it is that the disinfection received at

the treatment plant is still effective. In large systems, it is hard to find the perfect balance that provides ideal levels of disinfection for all points in the distribution system. As efficiency and conservation take hold, decreased water demand can significantly increase water age bringing with it concerns about Legionnaire's disease.

## COMMUNITY RESILIENCE CHALLENGES

**Energy consumption:** Water is heavy, and moving it requires energy. While gravity can help, there's almost always the need for pumps. The larger the system, the farther the water will need to be pumped (to a water tower, through the distribution or collection system, up a slope, etc.), and the greater the energy demand.

Additionally, the larger diameter pipes needed in a large system require increased energy to produce and maintain. In an era with growing concerns about greenhouse gas emissions, this is a liability.

The federal government is encouraging communities to plan for the very real possibility of a "black sky" event when all external energy sources are cut off for extended periods of time. In all but the most resilient of communities, without external power supplies water supply and sanitation services will be severed. Distributed systems, for the most part, are no different than centralized systems regarding dependence on energy inputs. But smaller systems may be able to recover more quickly or be able to rely on self-generated power.



**SUPERSTORM SANDY IN 2012 PROVED THE RESILIENCE OF DISTRIBUTED SYSTEMS. THE NEW YORK / NEW JERSEY REGION WAS HIT HARD, FLOODING AND KNOCKING OUT MANY OF THE LOW-LYING CENTRALIZED SEWAGE TREATMENT FACILITIES. BUT THE DOZENS OF ONSITE, DISTRIBUTED WASTEWATER RECYCLING SYSTEMS IN THE REGION WERE ALL BACK UP AND RUNNING ON GENERATORS 24 HOURS AFTER THE STORM.**



The Passaic Valley Sewerage Commission's Newark Bay Plant in the wake of Hurricane Sandy.  
Photo Courtesy of Passaic Valley Sewerage Commission

### **Risk of catastrophic failure:**

Centralized wastewater facilities are generally in low-lying areas, which means that they're increasingly prone to flooding. As hurricanes Katrina, Sandy, and Harvey have proven, when a region relies on a handful of facilities for a large portion of its sewage treatment, one catastrophic event can have devastating consequences. It can be months before pumps and biological systems are repaired or replaced, leaving no option but to dump untreated sewage.

Of course, catastrophic failure isn't limited to natural disasters. Water and wastewater facilities are prime national security assets. Knocking out one critical facility can devastate an entire city. As with storms, distributed treatment protects against a large-scale, crippling event.

### **Lowering of the water table:**

In natural settings, the groundwater table is continually restored through rainwater infiltration. But with centralized infrastructure, water is siphoned off upstream for municipal use and distribution, and then collected, treated, and returned to the surface water far downstream. As an unintended consequence, the native hydrology is interrupted. As water tables drop, base flow of rivers diminishes, and in some cases old,

wooden building foundations are compromised to the tune of hundreds of millions of dollars.<sup>6</sup> This situation can be exacerbated when large collection pipes or deep tunnels have cracks. Enormous quantities of groundwater flow into the pipes, accelerating water table declines while increasing the volume of water sent to the treatment facility.

**Expansion is limited** because older facilities were built in open areas, which were then filled in by urban growth. These "in situ" plants need lots of land, of which there may no longer be any adjacent. And the people who live close-in may complain about current or additional odors.

Given these challenges, some are urging communities and system designers to step back from the trend of increasingly large facilities and reexamine the size and scale, as well as the location or placement, of water infrastructure. With today's capabilities of virtual connections and sensors that can monitor and communicate among multiple locations, water service providers can now tap into the highly skilled oversight and operation that large utilities enjoy while also having the nimbleness and resiliency of distributed assets.

Given these challenges, some are urging communities and system designers to step back from the trend of increasingly large facilities and reexamine the size and scale, as well as the location or placement of water infrastructure.



<sup>6</sup> Michael Horne, "The Sadly Shrinking City", Urban Milwaukee, 19 March 2014. <https://urbanmilwaukee.com/2014/03/19/the-sadly-sinking-city/>, Accessed 30 August 2019.



# What Exactly Is “Distributed” Water Infrastructure?

## “DECENTRALIZED” OR “DISTRIBUTED?”

WHEN IT COMES TO WATER INFRASTRUCTURE, THE TERMS ARE USED INTERCHANGEABLY. THOUGH EITHER CAN WORK, MANY HAVE MOVED AWAY FROM *DECENTRALIZED*, FEELING THAT IT CONNOTES BREAKING APART EXISTING CENTRALIZED SYSTEMS WHEN IN FACT THE MOST COMMON CONFIGURATIONS ARE HYBRID, COMBINING THE FLEXIBILITY OF SMALL TECHNOLOGIES WITH THE SCALE AND EFFICIENCY OF LARGE-SCALE CENTRALIZED TREATMENT FACILITIES.



“Distributed” water infrastructure means different things depending on who is being asked. The key attribute is that distributed water treatment facilities are disaggregated from the centralized treatment plant, if there is one, or at least from each other. But size, capacity, interconnectedness and function can vary widely. The experts convened by The Johnson Foundation in 2014 described it as follows:

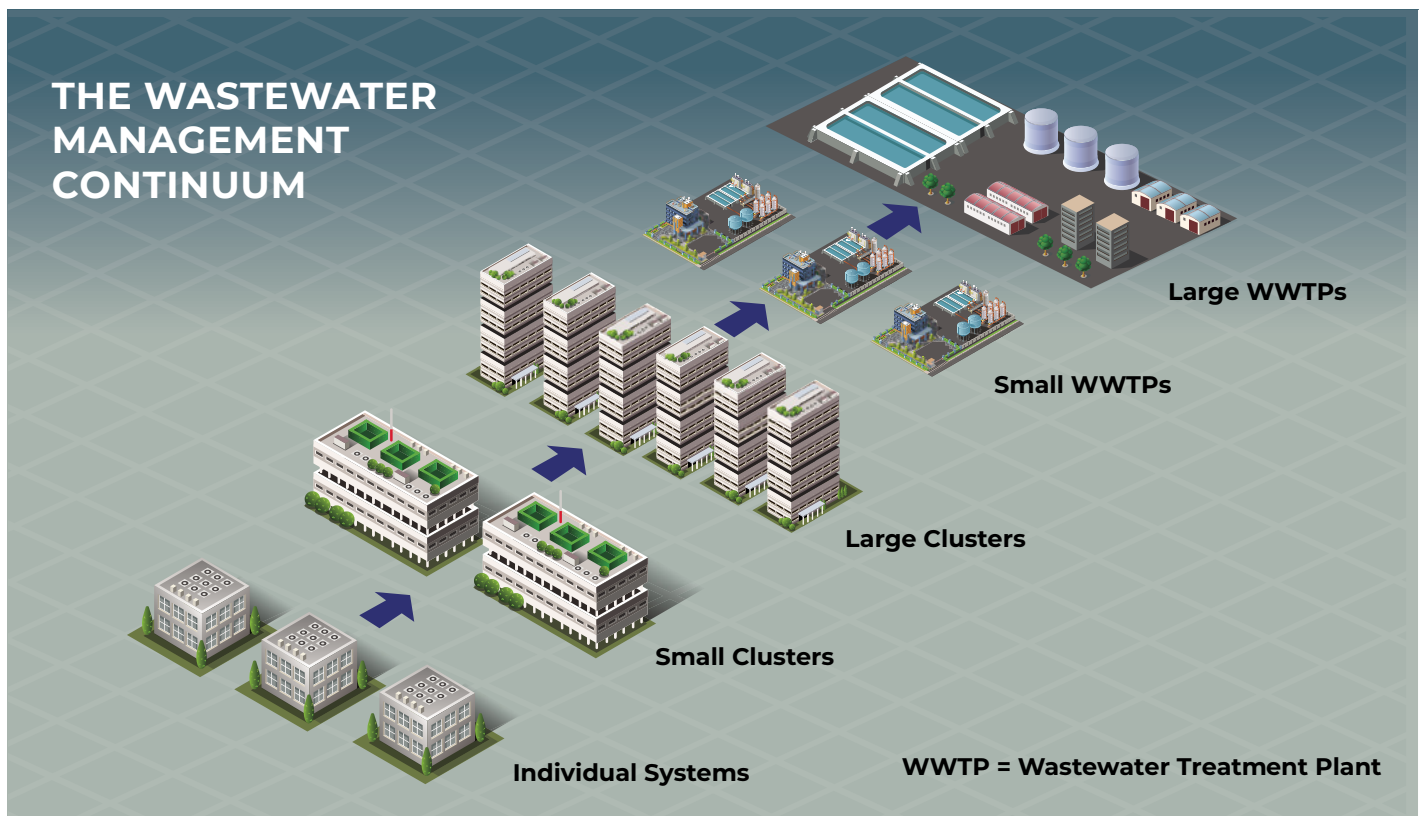
*“In the context of urban water services and systems, the term **distributed** is used to describe dispersed facilities that extend beyond the central infrastructure and are located at or near the point of use. They can service a range of scales, from individual homes to communities; function independently or remain connected to a centralized system; and be located remotely or within city boundaries.”*

The size and scale of distributed water infrastructure ranges from point-of-use treatment all the way to small “package” plants that can treat the waste for an entire community. As long as the treatment device is smaller than, and disaggregated from, the alternative, it can be considered “distributed”. In the case of stormwater management, permeable pavement, rain gardens, and green roofs are all examples of distributed treatment, whereas a deep tunnel is an example of centralized infrastructure. The classic water supply plant, where water from wells or regional surface water bodies is purified, treated, and pumped through miles of pipes into homes, hospitals, and factories is centralized infrastructure. It could be complemented, or even replaced, by distributed infrastructure, including in-building water reuse technology that captures and treats rainwater, cooling system condensate, foundation water, greywater, or even cleaned sewage effluent. Water-saving practices and technologies are another version of distributed infrastructure in that they free up capacity in the system, often off-setting the need to expand or build new reservoirs or pipelines.

Distributed sewage treatment is where much of the excitement is, particularly in rapidly growing urban areas. Onsite technologies that can treat sewage at the building level, as well as cluster or package systems that can treat small communities or districts within a city, are getting a lot of attention as complements to legacy, centralized systems. Industrial applications, which may or may not be in an urban setting, are also looking at many of the same technologies. At the far end of the distributed wastewater spectrum are toilets which can operate independent of any larger system. Some of these technologies have been around for decades, but with the Bill and Melinda Gates Foundation’s interest in sustainable sanitation, the boundaries of what is possible are rapidly changing. The Foundation’s focus has been in developing countries, many of which have little to no centralized sewage infrastructure. However, the resulting technologies are likely to open new opportunities for the U.S., starting with rural and remote communities.

## DISTRIBUTED VS CENTRALIZED

DISTRIBUTED	CENTRALIZED
<b>WASTEWATER TREATMENT</b> <ul style="list-style-type: none"> <li>In-building wastewater treatment / water re-use for toilets and irrigation.</li> <li>Home-based greywater treatment / water re-use for toilets and irrigation</li> <li>Ecodistrict with localized wastewater treatment, may or may not be tied into centralized collection system.</li> <li>Small community with its own treatment facility</li> <li>Pretreatment, or partial treatment, of specialized waste streams.</li> <li>Waterless, composting toilets</li> <li>Septic systems</li> </ul>	<b>WASTEWATER TREATMENT</b> <ul style="list-style-type: none"> <li>Large wastewater treatment facility and collection system. All treatment occurs at facility.</li> <li>Small community with pipes and pumps to send wastewater to larger facility.</li> </ul>
<b>STORMWATER INFRASTRUCTURE</b> <ul style="list-style-type: none"> <li>Rain garden</li> <li>Rain barrel</li> <li>Cistern</li> <li>Permeable pavement</li> <li>Green roof</li> <li>Bioswale</li> </ul>	<b>STORMWATER INFRASTRUCTURE</b> <ul style="list-style-type: none"> <li>Combined sewer system</li> <li>Deep tunnel</li> </ul>
<b>WATER SUPPLY</b> <ul style="list-style-type: none"> <li>Cistern for outdoor irrigation</li> <li>Cistern with filter and UV purification for indoor use</li> <li>Water reclaimed from in-building wastewater treatment</li> <li>In-building purification devices (e.g. in basement, under sink, on faucet)</li> <li>Private well</li> </ul>	<b>WATER SUPPLY</b> <ul style="list-style-type: none"> <li>Large treatment facility with distribution system. All treatment occurs at the facility.</li> </ul>





## Is Distributed Water Infrastructure A Better Approach?

Whether or not distributed water infrastructure is a better approach depends on who you ask and what problems they are trying to solve. The answer depends on context. Some of the most creative and strategic water utility leaders will, on the one hand, point out the challenges of transitioning to distributed management while at the same time stating that distributed treatment is the future of water. Factors like the cost of water and/or power, whether the existing facilities have expansion space, whether the region is experiencing a water shortfall, and the regulatory and policy context all play a large role in determining whether distributed makes sense. Context will naturally shift over time, so another factor is the extent to which local decision makers have an appetite to plan for future needs with flexibility and resilience in mind.

While distributed infrastructure is not a panacea – there are definite economies of scale that come with centralized services – there are advantages that make it attractive. For example, distributed water treatment can:

- Alleviate demand placed on wastewater collection systems that are (or are projected to be) over-burdened and over-capacity.
- Pre-treat certain contaminants onsite that cannot be handled by a centralized system, such as biopharmaceuticals, or that may do harm to a biological centralized system.
- Save money for satellite communities that would otherwise have to build long pipe-and-pump systems to connect to a centralized treatment or distribution facility. For communities that want to recycle water, this also eliminates the need for a separate “purple pipe” distribution system for the returned, treated water.
- Restore local water tables and stream flows by returning water closer to the point of withdrawal.
- Extend regional water supplies by recycling water onsite for non-potable water for toilet flushing, irrigation, etc.
- Reduce the energy footprint for water movement.
- Provide an opportunity to use heat recovered from wastewater.
- Improve community resiliency to catastrophic events.
- Provide living-wage jobs within local communities or neighborhoods.
- Contribute points toward LEED, EcoDistrict, or other sustainability certifications.
- Increased green spaces, in the case of nature-based infrastructure.
- Protect a utility’s agility to respond to unpredictable future needs.
- Prevent sewer overflows, meet permit requirements.
- Provide local control of water purity.
- Allow the tailoring of water purification and treatment to the needs of local non-potable applications (rather than using potable, fluoridated water where a lower standard would suffice).

## DISTRIBUTED WATER INFRASTRUCTURE IN ACTION

While there is a lot of talk about distributed water infrastructure, there is no one-size-fits-all solution. Nor is it unquestionably the best option in all situations, at least not in the near term. It's important to understand the particular needs of a community or building in order to know which (if any) distributed solutions will make sense. To illustrate the point, let's look at some scenarios and how distributed water infrastructure could play a role.

### CONSTRAINED CITIES

If necessity is the mother of invention, then it is no surprise that resource-constrained cities, driven by necessity, are actively inventing new ways to tackle their water challenges. These tend to be thriving, growing cities with high property values and a citizenry that values sustainability. These cities are often faced with an overtaxed water supply, tapped out sewer capacity, or both, and are looking for alternatives. Traditionally, the solution to these constraints has been to enlarge and expand by constructing larger diameter pipes, deeper wells, new reservoirs, and expanded capacity at the central sewage treatment facility. But eventually cities hit their limit with these highly disruptive and capital-intensive approaches and begin searching for more sustainable approaches.

Cities that rise to the top of the list in this category include Austin TX, New

York City NY, San Francisco CA, and Portland OR. In these vibrant cities, entrepreneurial developers and water innovators are driving the demand or are responding to municipal incentives designed to entice the private sector to help the community meet its water

needs. Some cities are driven to act primarily by a need to stretch their water supply, while others are focused primarily on reducing flow through their sewage collection and treatment system. Generally the two needs overlap at least somewhat.

#### EXAMPLE

##### New York City, NY

Facing an overtaxed sewer system in the late 1990's, New York City (NYC) had two options: increase the size of their collection pipes, a massively expensive and disruptive process, or reduce their sewage volume. Searching for ways to pursue the latter, they offered incentives to developers who could help by reducing the volume through water conservation and/or onsite water re-use.

Rising to this challenge, Albanese Development Corporation partnered with Natural Systems Utilities (then operating as Applied Water Management) to develop onsite water re-use and rainwater harvest systems for the first of its redevelopment projects in Battery Park City, 92 acres prioritized by NYC for redevelopment. The 27-story Solaire luxury apartment building opened in August 2003 as the first "green" residential high-rise building in the U.S. and earned the United States Green Building Council (USGBC) LEED rating of Gold. All of the building's wastewater (approximately 25,000 gallons per day) is treated with hollow fiber micro-filtration membranes, ultraviolet light disinfection, and biological nitrogen removal to comply with New York's direct reuse standards. The reclaimed water is used for toilet flushing, landscape irrigation, laundry and cooling tower make-up water. Since Solaire, water recycling systems have been incorporated into five additional Battery Park City redevelopment projects along with other buildings in midtown Manhattan and elsewhere in NYC.

Two factors are critical to the ongoing success of these NYC projects. In addition to the city's initial encouragement of onsite water re-use, one of the keys to its success is the longevity of Natural Systems Utilities, the company that designed and continues to operate the treatment systems. Without Natural Systems Utilities there to operate and maintain the systems, building owners would have a hard time finding maintenance services for these specialized installations. The other supporting factor is a strong economy and high property values that provide the financial underpinnings for the buildings' maintenance.

## EXAMPLE

### Austin, TX

Austin, faced with a growing population and a constrained water supply, recently passed its “Water Forward” plan, which includes what is probably the most aggressive water harvesting plan in the U.S. By 2040 the city wants to be capturing and treating 100 million gallons per year<sup>7</sup> through onsite resources. Though onsite sewage treatment will provide some of that capacity, the focus is on capturing and re-using rainwater, cooling system condensate, and similar low-cost, easy-to-purify sources of water. Codes, ordinances, and oversight have not necessarily caught up to the plan or to localized enthusiasm. According to Sharlene Leurig, CEO of Texas Water Trade and chair of the Water Forward Commission, there’s a strong need for an investor-owned utility with deep experience in onsite water management to manage what is now a *laissez-faire* environment.<sup>8</sup>

Developers are responding to the opportunity and are actively seeking partnerships with the handful of private utilities that are experienced with onsite, urban water treatment. For the city’s new municipal building, slated to open in 2021, the developer is partnering with Sustainable Water to install and operate its “WaterHub”, a proprietary wastewater reclamation and reuse system. The Austin project will recycle 5000 gallons per day to be used for toilets and landscape irrigation, though they have much larger operations (up to 1 million gallons per day) in operation elsewhere.

Any community willing to experiment with the newest water infrastructure innovations recognizes that there are potential risks that the new system might fail, but in these communities the risk is mitigated by the resources on hand. There are likely to be highly skilled, knowledgeable technical experts within the professional network of water utilities, municipal employees, consulting firms, and academic institutions that are part of any thriving city. Additionally, there are likely to be financial resources to help a community recover from any unexpected turn of events.

These cities are particularly attractive sites for neighborhood-scale water infrastructure, where the benefits of distributed infrastructure can still reap some of the advantages of scale. Clusters of 10,000 up to 20,000 people, or the industrial equivalent, are often where energy recovery matched with wastewater treatment and water recovery is economically viable. Because a full neighborhood-scale redevelopment is rarely under the control of one owner or one builder, the planning and permitting process is inevitably more complex and generally needs a motivated community organization or city planning department to help it past the hurdles. This is a place where private investment and / or targeted NGO support can make the necessary difference. In addition to location-specific partners, Ecodistricts is a US-based organization working with cities around the world to achieve Ecodistrict® certification which includes distributed water management.

## REFLECTIONS

Constrained cities are without a doubt the places where distributed water infrastructure makes the most sense and can solve the most problems for the most people. It is thus not surprising that this is also where the most innovation has taken place over the past two decades. Distributed water infrastructure can alleviate pain points around water supply and capacity for sewage collection and treatment, as well as provide resilience in the face of catastrophic events. And because expansion of the existing

central treatment facilities and their distribution or collection systems is so expensive (i.e. due to high cost of land for plant expansion, and high cost of economic disruption when replacing pipes, and/or high cost of moving water out to greenfield development), constrained cities are the places where the dollars and cents are most likely to align with environmental goals. Furthermore, these are often communities which place high value on sustainability and residents who are willing to pay for it.

<sup>7</sup> City of Austin TX, “Water Forward, Austin’s Integrated Water Resource Plan”. 2018. [http://austintexas.gov/sites/default/files/files/Water/WaterForward/Water\\_Forum\\_Plan\\_Report\\_-\\_A\\_Water\\_Plan\\_for\\_the\\_Next\\_100\\_Years.pdf](http://austintexas.gov/sites/default/files/files/Water/WaterForward/Water_Forum_Plan_Report_-_A_Water_Plan_for_the_Next_100_Years.pdf). Accessed 30 October 2019.

<sup>8</sup> Personal conversation with Sharlene Leurig, Chief Executive Officer, Texas Water Trade, 25 January 2019.

Constrained cities are also ripe for water harvest and reuse on a large scale. Austin, TX has the policy framework aligned with a rapid expansion on this front, focusing on harvesting rainwater, cooling system condensate, and foundation drainage water. Furthermore, the cost of water and sewer services is high enough to justify investment in these independent water systems. There are firms that are confident that Austin presents design-build-operate opportunities that can provide cash-positive scenarios from the first day of operation with a 15- to 20-year payback. In these cases, investment capital is the rate-limiting step, and so they are seeking patient investors who share their interest in sustainable water.

That said, there are a few precautions that even the most resilient of communities should consider as they approach the policy and permitting mandates that create the foundation for adopting and incorporating these types of distributed water infrastructure. These include:

**Build for redundancy.** If possible, retain the connection of the distributed water infrastructure to the city's primary water distribution and sewage collection systems. This provides for alternate capacity if needs exceed expectations or if the system fails or needs to be taken off-line for repair.

**Mitigate risk with financial tools.** This could take the form of insurance, liquid capital requirements, or other assurances that the infrastructure owner has the financial resources to recover from equipment failure or a wholesale need to replace.

**Ensure that maintenance schedules are adhered to** and that replacement parts are on hand or readily available.

**Ensure a sufficient pool of qualified operators.** Operating distributed water infrastructure is a specialized skill set that not all water operators have. Communities can work with water and public works professional associations to ensure that a skilled workforce is available.

## REDUCED-POPULATION CITIES

Cities faced with the double-blow of declining population and declining per-capita water use<sup>9</sup> are especially challenged to sustain the revenue needed to maintain, much less improve, their water infrastructure. This is especially true because cities don't shrink inward like a deflating balloon, abandoning the parts most distant from the city center and compressing people and businesses in toward the center. Urban decline is not that tidy.

Distributed water could be viewed as a less burdensome way to right-size a declining-population city's water infrastructure. However, making the transition without further undermining the already fragile public utility's revenue is uncharted territory. If a city with a patchwork of active homes interspersed with long stretches of no demand were designing its water infrastructure from scratch, distributed systems would probably make a lot of sense. But in the context of a legacy system, the impact is less predictable and hence the application of distributed water infrastructure in these cases needs more examination before recommendations can be made. There are organizations exploring options in Detroit and elsewhere, but the jury is still out as to whether or not the concepts can move forward to successful applications.

## REFLECTIONS

Cities with declining populations and declining water demand are where distributed water infrastructure is the most confounding. Yes, distributed water infrastructure could solve important problems. Urban flooding and sewer overflows could benefit from rainwater harvest. Distributed treatment and water recovery could alleviate the problems of flow stagnation in oversized pipes, and could potentially provide a city with an

<sup>9</sup> The USGS (U.S. Geological Survey) assesses the nation's water consumption every five years. Their studies have shown that over the last decade or more, water supply utilities are experiencing lower demand overall. When coupled with population growth this can be traced to a steady decrease in per-capita water use dating back to the early 1990's. <https://pubs.er.usgs.gov/publication/cir1441>

avenue for abandoning oversized and aging infrastructure, hence downsizing the required capital investment. However, these are also the cities that have the least financial resiliency and thus are least able to take risks.

It's natural to want struggling communities to be able to benefit from the most innovative technology available, but innovations often don't work out as planned. This can have devastating reverberations for a community that is already brittle from underinvestment. The experimentation would be especially devastating if it undermined revenue for the existing community-owned utility without concomitantly offsetting operating and capital expenses.

A city and its water and sewer utilities may also be impacted if independent providers of water services were to enter their "market". San Francisco, a dynamic and growing city, welcomes entrepreneurial partners into their water-services ecosystem.<sup>10</sup> There is more than enough work for everyone. However in a city with declining water and sewer demand, and the resulting revenue base decline, the loss of customers would likely be a further blow, and would put an additional burden on the remaining customer base.

If services decline, water and sewer rates increase, and onsite water technology is more easily available, individual building

owners could opt out of the city system. This could accelerate what some refer to as the "death spiral" of the urban water utility. To avoid ever getting into this situation, it is recommended that cities with declining population (or even those with steady population but declining water use) routinely incorporate distributed water infrastructure in options for long-term planning. Distributed water infrastructure can and should be one of the tools available to declining cities, but it will be to the benefit of the community as a whole for the water utilities or appropriate municipal planning authority to lead the conversation about which technologies will best serve their constituents in the decades ahead.



## WHAT COLOR IS DISTRIBUTED STORMWATER INFRASTRUCTURE?

PRACTITIONERS REFER TO STORMWATER INFRASTRUCTURE AS EITHER "GREY" OR "GREEN". GREEN REFERS TO DISTRIBUTED INFRASTRUCTURE THAT INCORPORATES LIVING PLANTS. EXAMPLES INCLUDE GREEN ROOFS, RAIN GARDENS, AND BIOSWALES. "GREY" DISTRIBUTED STORMWATER INFRASTRUCTURE INCLUDES CISTERNS, PERMEABLE PAVEMENT, AND RAIN BARRELS, AS WELL AS CONTROLS, SENSORS, AND PUMPS (IF THERE ARE ANY). BECAUSE "GREY" IS ALSO USED TO DESCRIBE TRADITIONAL CENTRALIZED SYSTEMS, MANY PEOPLE LUMP ALL DISTRIBUTED STORMWATER UNDER THE GREEN LABEL.



## WHO DOES THE WORK?

DISTRIBUTED STORMWATER INFRASTRUCTURE CAN BE EITHER

"PASSIVE" OR "ACTIVE." PASSIVE SYSTEMS DO THE WORK ON THEIR OWN, COLLECTING STORMWATER AND THEN ALLOWING IT TO SOAK INTO THE GROUND, EVAPORATE, OR DRAIN NATURALLY. EXAMPLES INCLUDE RAIN GARDENS AND PERMEABLE PAVEMENT. ACTIVE SYSTEMS, WHICH ARE PRIMARILY GREY, DO NOT OPERATE WITHOUT ADDITIONAL HELP TO DRAIN THE ACCUMULATED WATER AT THE APPROPRIATE TIME. OF COURSE, NO INFRASTRUCTURE IS ENTIRELY PASSIVE. EVEN RAIN GARDENS NEED ROUTINE UPKEEP TO MAINTAIN THEIR PERFORMANCE.

10 Conversation with Paula Kehoe, Director of Water Resources, San Francisco Public Utilities Commission, 29 April 2019.

## COMBINED-SEWER CITIES

“Combined sewers” are systems where stormwater is collected into the same pipes as wastewater. Combined sewers were considered state-of-the-art a century ago, but today are generally considered an albatross<sup>11</sup> especially because most of the 772 cities that have them are also experiencing more intense rainfall events. The challenge for a combined sewer system, which collects rainwater to be treated along with sewage, is that it can easily be overwhelmed during heavy rains, resulting in expulsions of a sewage-rainwater soup into local rivers, streams, and lakes. Because the Clean Water Act prohibits most sewer overflows, wastewater utilities often become subject to consent decrees which dictate a timeline for sharply reducing their overflows. Conventional solutions include often very expensive deep tunnels and other centralized stormwater storage.

Facing the prospect of raising fees to pay for these unpopular projects, cities may be open to alternative ways to capture and repurpose stormwater if it can offset more expensive options. Distributed stormwater infrastructure, in the form of bioswales, cisterns, permeable pavement, green roofs, rain gardens and other structures that capture rainwater or facilitate infiltration are forms of distributed infrastructure that most of these cities are exploring.

### EXAMPLE

#### Milwaukee, WI

Milwaukee, Wisconsin is one of nearly 800 communities in the U.S. with a combined sewer system. As part of its mandate to reduce the number and volume of sewer overflows impacting Lake Michigan, Milwaukee Metropolitan Sewerage District’s (MMSD) discharge permit requires that it add 250,000 gallons of green infiltration and storage per year<sup>12</sup>, most of which is being accomplished through partnerships with private and public landowners as well as NGOs. To help MMSD achieve its storage requirements, ReFlo<sup>13</sup>, an NGO focused on rainwater harvest, has stitched together support from a variety of sources to build large-scale cisterns that can supply water for Milwaukee’s vibrant urban agriculture sector. ReFlo’s projects are providing distributed water to commercial farmers and community gardens alike. One high-profile example is Alice’s Garden, a large community garden adjacent to a school in a predominantly African American section of Milwaukee. Supported by MMSD, two local foundations, and more than two dozen community groups, ReFlo installed a bioswale and 20,000 gallon underground cistern along with a solar-powered pump and purification system to provide water to the gardeners.



Photo Courtesy of Alice’s Garden

In addition to stormwater benefits, the system offsets the annual water costs for Alice’s Garden and provides some degree of resilience, given that the gardens now have two water sources (cisterns, as well as the traditional public supply). Though not specifically cited, there is likely to also be increased plant health and productivity since treated city water, with its chlorine residuals and fluoride, is not ideal for plant growth.<sup>14</sup> In this case, the potential benefits of off-setting municipal water demand have not been central to the project because the city’s water department has excess supply.

Efforts to repurpose rainwater for beneficial use have been underway in Milwaukee since the early 2000’s. However, state regulations on water re-use add a burden that only the most determined applicants are willing to tackle. The state, concerned about *Legionella* outbreaks, can be inconsistent in its interpretation of the codes and makes it nearly impossible to repurpose rainwater for indoor use unless the plumbing systems are entirely separated. Modernization of the state plumbing code, or delegation of authority to the City of Milwaukee, would reduce the administrative start-up costs for rainwater harvest projects.<sup>15</sup>

11 Mary Anna Evans, “Flushing the Toilet Has Never Been Riskier”, 17 Sept. 2015, The Atlantic. <https://www.theatlantic.com/technology/archive/2015/09/americas-sewage-crisis-public-health/405541/>, accessed 30 August 2019.

12 <http://archive.jsonline.com/news/milwaukee/mmsd-ordered-to-provide-green-infrastructure-for-storm-water-0e8a0kk-186242082.html>, accessed 23 August 2019.

13 <https://reflo2o.com/>

14 <https://www.mercurynews.com/2017/02/13/for-plants-rain-has-benefits-that-tap-water-simply-cant-deliver-9/> accessed 23 August 2019.

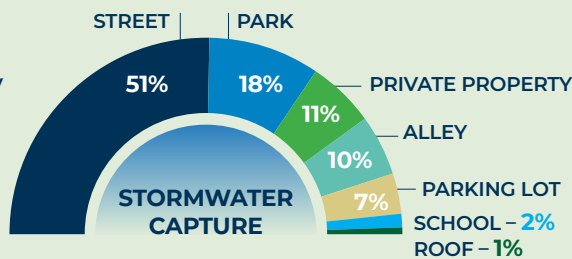
15 Personal conversation with Justin Hegarty, Executive Director, ReFlo. 20 August 2019.

## EXAMPLE

### Lancaster PA

In 2018 the US EPA issued a consent decree for the City of Lancaster, laying out a 20-year horizon for the elimination of combined sewer overflows. The city issued and began its first green infrastructure plan in 2011 and began levying a stormwater fee in 2014, but more work was needed. In the hopes of containing costs, the city is prioritizing distributed stormwater infrastructure. The updated plan enumerates more than 200 projects targeted for public property as well as another 125 projects that could be installed on private property if owners consent. Private parking lots, which make up 27% of the city's impervious surface, are a high priority target for infiltration projects.<sup>16</sup>

Here's how much each category of green infrastructure currently contributes to keeping stormwater out of Lancaster's combined sewer system.



Source: "Green It! Lancaster" Plan, City of Lancaster

themselves by reducing the overall infrastructure investment needed, we are still early in the technology adoption curve. Some communities assume that the monitoring and management systems, which themselves could be considered a "distributed technology", are too expensive or too complex for consideration. Steps that can accelerate the understanding and uptake of these technologies, especially for smaller communities, would go a long way toward diverting investment in deep tunnels and other centralized stormwater management. To this end, the Water Environment Federation hosts the Stormwater Testing and Evaluation for Products and Practices (aka "STEPP") Program, a collaborative effort leading the way to establish standards, protocols and consistent terminology for this rapidly growing area.<sup>17</sup>

## REFLECTIONS

For active stormwater storage to be effective, it must be emptied between rain events. It's hard for utilities to ensure that cisterns, rain barrels, and even distributed storage basins are emptied between rain events, especially if they are privately owned and operated. Without that assurance, it's difficult to get them permitted and accepted as part of a utility's mandated stormwater compliance, even by the most progressive of regulatory agencies. Fortunately,

a handful of companies are gaining traction with proprietary technologies that allow for real-time sensing and control which, when integrated with weather forecasts, can ensure that water is released in advance of the next storm. There are companies with monitoring and management platforms designed to manage individual cisterns, and others that are designed to coordinate water management across a system of stormwater storage ponds and detention basins. Though these systems can generally pay for

Passive green stormwater can also be an effective tool for reducing urban stormwater challenges, though the small volume of water stored in each installation makes managing a whole community's stormwater load challenging.

## SMALL TOWNS AND COMMUNITIES

Small-scale water services come in a variety of shapes and sizes, but are generally small treatment facilities that could be sized to accommodate anywhere from 100 people to a

<sup>16</sup> [https://lanasteronline.com/news/local/green-projects-key-in-lancaster-s-huge-task-of-meeting/article\\_39c485f0-2bfc-11e9-9ebf-4bed8f512861.html](https://lanasteronline.com/news/local/green-projects-key-in-lancaster-s-huge-task-of-meeting/article_39c485f0-2bfc-11e9-9ebf-4bed8f512861.html)

<sup>17</sup> WEF. "Stormwater Testing and Evaluation of Products and Practices (STEPP) Consortium and Work Team Meeting Summary. July 2018. <https://wefstormwaterinstitute.org/programs/stepp/>. Accessed 17 September 2019.

few thousand. A large number of communities across the country are at or below median income, often well below median, and many are struggling to meet social and infrastructure demands on a wide variety of fronts. Maintaining the water and wastewater services often falls to someone who is juggling multiple other responsibilities and may not have time or resources to keep up with growing technological knowledge needed to operate water and wastewater systems and comply with increasing regulations.

What happens all too often in these communities is that routine maintenance slips, expensive equipment deteriorates faster than it should, and suddenly the community is facing expensive replacements. There could also be water quality violations, which put additional pressure on the community to find new fixes to their predicament. At this point, communities face one of two general categories of options. One option is to repair or upgrade what they have. This tends to be the less expensive option, but all too often even the new or upgraded technology is more than they can maintain. Without resources for thorough options research communities may also receive poor advice, leaving them footing the bill for a system that wasn't designed for their needs. The typical second option is to extend

pipes to a nearby community that has excess capacity and allow them to take over management of the system. This can be highly advantageous for the larger community, giving them an opportunity to spread their fixed costs over a larger number of customers. But there is a risk that it is expensive for the smaller, "satellite" community. It also has environmental downsides, including increased energy burden and disruption to local hydrologic regimes.

In addition to these two options, a third alternative is to regionalize or consolidate the management across multiple communities while maintaining distinct plants with no physical connection. Regionalization can come in many forms. It could be a state-authorized entity such as Hampton Roads Sanitation District (see below), or a private company which operates and/or owns and operates multiple utilities. One especially intriguing option is a non-profit such as EJ Water,<sup>18</sup> which specializes in the management of small community's water systems without the burden of needing to generate financial returns for investors. With the advent of remote monitoring technologies, we are likely to see creative new configurations for consolidation, bringing the technical expertise and specialization to small communities that so desperately need it.

Small-scale water services come in a variety of shapes and sizes but are generally small treatment facilities that could be sized to accommodate anywhere from 100 people to a few thousand.

18 EJ Water is a 30-year old water cooperative serving 12 counties in central Illinois. <https://www.ejwatercoop.com/>. Accessed 29 October 2019.

## EXAMPLE

### Surry County, VA

Hampton Roads Sewerage District (HRSD) is a large regional sewer authority serving a cluster of cities near the mouth of the Chesapeake Bay. Created in 1940 by the Commonwealth of Virginia in response to rapid population growth and the correlated growth in sewage dumping, the district has essentially been “distributed” since its inception. Rather than collect all the region’s sewage into one central treatment facility, it has always operated multiple mid-size facilities. It has also gained a nationally renowned reputation for attracting top talent and innovative management. Perhaps it is not surprising, then, that as smaller communities scattered in the rural counties around Hampton Roads have encountered challenges with their sanitation services, they’ve turned to HRSD for help.

Recently HRSD inherited Surry County’s two treatment plants, one of which was in poor condition. The initial thought was to pipe the county’s sewage into one of HRSD’s other large facilities that had available capacity. As they explored that possibility and were faced with the expense of getting the pipeline through archaeologically sensitive Jamestown, that plan was abandoned. HRSD is instead upgrading the better of the two Surry plants, abandoning the other, and will operate one “distributed” or satellite treatment system for the community. Surry County officials will sleep well, knowing that their wastewater operations and billing are in the hands of an experienced, professional public utility. At the same time, they were able to avoid the capital expense and environmental disruption of connecting to the more distant central facility.

## REFLECTIONS

Small communities and cities often lack the resources and/or opportunity to evaluate the long-term pros and cons of local-scale treatment vs. connecting to a larger community. Instead, they often end up relying on private water companies or adjacent communities who stand to benefit financially depending on what path is taken. Consultants who specialize in distributed technology that could help these communities save both capital and operating expense often

report that there are significant cultural barriers and distrust regarding distributed or innovative water infrastructure. Regulatory agencies as well as consulting engineers, perhaps still stinging from disappointing experiences from the 1970’s and 1980’s, are reluctant to change course from tried-and-true methodologies even when they are significantly more expensive than alternatives and offer no water quality advantages. Small communities need access to neutral, trusted advisors who can provide them

with options and be their advocate as they navigate their choices.

There also does not seem to be a professional network where small systems engineers, technology providers, operators, and community representatives can come together to learn from each other. If there is enough interest, there may also be synergies around common procurement paths, master service agreements, and establishing pools of professional operators who can take care of both the on-site needs and the remote monitoring technologies. Groups like the Water Research Foundation, the Water Environment Federation, WaterNow, and possibly RCAP have experience and expertise with these issues, and with appropriately aimed support there may be an opportunity to address these challenges in a systematic way.

## RURAL ONSITE TREATMENT

Roughly 60 million Americans are served by onsite septic systems. Along with new development, approximately one-third of which relies on septic systems, distributed treatment is a growing reality for much of the country.<sup>19</sup> In many situations conventional septic systems work quite well, especially where rigorous state oversight ensures that they are monitored and maintained appropriately. But not every community is well-suited for conventional septic.

In areas with high water tables and/or soils that do not drain well, sewage from

19 U.S. Environmental Protection Agency, <https://www.epa.gov/septic/septic-systems-overview>, accessed 29 August 2019.

homes and small businesses moves too slowly through the soil and can result in sewage backing up into the dwelling or bubbling up to the soil surface, either of which is an unpleasant outcome. In areas with extremely sandy soils the opposite problem can occur. Sewage moves too quickly in these situations and can contaminate nearby aquifers or sensitive surface waters. Surface waters may be able to assimilate the pollutants if the area is sparsely populated, but if housing density exceeds the area's carrying capacity, surface waters will suffer from excess nitrogen loads and potential bacterial contamination.

Communities facing the limit of septic system capacity, or which should never have had them permitted in the first place, are presented with difficult options. Depending on the proximity of a town or community treatment system, they may be forced to connect to a centralized sewer system, an option which can easily cost tens of thousands of dollars. Even more daunting, they may be faced with having to create their own community treatment system. But in many cases, community treatment (i.e. small-scale "centralized" treatment) is simply not an option because homes are too far apart, laying pipes would be too disruptive, or there are other extenuating circumstances.

Though it has not yet reached broad social acceptability, another option is specialized toilets that use little

to no water and can allow homes and businesses to remain off-grid even when septic is not a viable or permissible option. In the 1960's Swedish engineer Rikard Lindstrom pioneered the first composting toilet that could be incorporated into homes and businesses. His company, Clivus Multrum, has been operating in North America since 1973 and has expanded into greywater treatment as well as toilets that use a pressurized "foam flush".<sup>20</sup> Clivus Multrum's products are routinely incorporated into national, state, and regional parks which are often in remote places that are not compatible with conventional septic systems or simply don't have sufficient water supply to support conventional toilets. Their products are also found in homes and commercial buildings that are equally constrained or that are simply aiming to reduce their environmental footprint.

There are a wide variety of other off-grid toilets that can offer alternatives to property owners needing to steer clear of septic systems but who want to, or need to, address sanitation without connecting to a distant treatment plant or using potable water. In addition to other brands of composting toilets, there are versions that accelerate the composting or disintegration through aeration, temperature control, or incineration. Others siphon off the urine, which can slow aerobic decomposition to be handled separately.<sup>21</sup>

Communities facing the limit of septic system capacity are presented with difficult options. Depending on the proximity of a town or community treatment system, they may be forced to connect to a centralized sewer system, an option which can easily cost tens of thousands of dollars.

20 Clivus Multrum website, [www.clivusmultrum.com](http://www.clivusmultrum.com), accessed 22 August 2019.

21 For an easy-to-read overview of waterless toilets, see this entry by How Stuff Works: <https://science.howstuffworks.com/environmental/green-tech/sustainable/waterless-toilet.htm>, accessed 29 August 2019.

**EXAMPLE****Lowndes County, AL**

Lowndes County, Alabama is in the heart of the “Black Belt”, a region of the deep south that was known for its cotton plantations and large populations of enslaved people in the first half of the nineteenth century. The region remains predominantly African American, many of the residents being descendants of the enslaved individuals who worked the fields more than 150 years ago. The soils are well-suited for growing cotton and other demanding crops, but poorly suited for septic systems. The region remains among the poorest, most distressed regions of the United States.<sup>22</sup>

Most of the rural homes, many of which are mobile homes, have septic systems. However, because of the incompatibility of the soils, the septic systems often fail and overflow. A new septic system, which probably wouldn't work for long anyway, would cost between \$15,000 and \$20,000, which is one year's income for most of the region's households. Faced with no other options, some residents are forced to illegally “straight pipe” their sewage, i.e. run their sewage through a pipe straight into a nearby ditch or creek.<sup>23</sup>

One alternative is to connect these homes to a centralized sewage treatment facility, but even if there is a nearby option, the cost is generally prohibitive. Groups like the Alabama Center for Rural Enterprise Community Development Corporation (ACRE) are working with engineers and policy makers to try to find onsite, waterless or low-water options for sanitation, but the solutions are still distant. Though composting toilets might provide systems that would work, significant social barriers prevent their adoption.

This problem is not unique to Lowndes County. It has long been known to be a challenge in the developing world, and with the work of Alabama activists we are starting to realize that there is some version of this challenge in virtually every state in America. The Bill and Melinda Gates Foundation identified sustainable sanitation as one of the world's grand challenges and has been incentivizing exploration and innovation that will hopefully lead to a socially acceptable, easy-to-maintain waterless toilet that could be used in Lowndes County and elsewhere.

**REFLECTIONS**

The challenges seen in Lowndes County are repeated in one version or another throughout the country wherever the rural poor call home. Appalachia, the Black Belt, colonias along the Texas-Mexico border, Alaskan Native communities and everywhere in between have their version of failing septic systems. More financially solid communities are not immune to septic failure and contamination of nearby waters, but they tend to have options not available to the rural poor and Native communities. Cape Cod, Massachusetts, for instance, has been struggling for years to find a solution to the nitrates polluting their waters from septic systems because of the region's sandy soils.

The fundamentals of low-water or waterless toilets have been explored and tinkered with for decades, but the systems that are available today are generally acceptable only to the rare homeowner who is comfortable handling night soil, a euphemism for composted human sewage. Incinerating toilets are an option, but they are expensive to purchase and operate, require high-energy inputs, and can require up to 30 minutes to process feces between uses.

Finding culturally appropriate, sustainable solutions is an active area of research by a small cadre of academics. Much of the focus is on solutions that are appropriate for developing countries, but what

22 [https://en.wikipedia.org/wiki/Black\\_Belt\\_%28U.S.\\_region%29](https://en.wikipedia.org/wiki/Black_Belt_%28U.S._region%29), accessed 29 August 2019.

23 Michael Harriot, “Lowndes County, Ala: The Place that God Forgot”, The Root, 27 April 2018, <https://www.theroot.com/lowndes-county-ala-the-place-god-forgot-1825483659>, accessed 29 April 2019.

some have called “the dirty little secret” is that this is a tremendous problem in the U.S. as well. More support is needed for under-resourced community groups such as Alabama’s ACRE. These are groups who are trying to understand the extent of the problem and work with sympathetic experts to find solutions that are sustainable in all senses of the word: environmentally, economically, and operationally. Finding a national organization that could serve as a convener for community groups and hub for solutions would be a significant contribution and step forward, with care being given that any such organization be acceptable to those on the front line of this challenge.

## RURAL WATER PURIFICATION

Residents of rural America generally depend on their own wells to supply their water. Unfortunately, all too often these wells become contaminated with agricultural pollutants ranging from nitrate fertilizers, disease vectors seeping in from livestock manure or nearby septic systems, and / or agricultural chemicals used as insecticides or herbicides. At times groundwater is also subject to legacy pollutants from nearby military bases, fire-fighting activities, industrial or mining operations, coal ash pits, or any of a number of other possible sources of contamination. When this

happens, homeowners generally are presented with three options: dig a new, deeper well, connect to a neighboring community’s water supply, or purchase bottled or vended water for cooking and drinking needs. The first two options are not always logistically

feasible and are always expensive. The latter may not be expensive in the short run but is inconvenient and cumulatively expensive as the years add up. Alternative options which deserve more examination are rainwater harvest and onsite water purification.<sup>24</sup>

### EXAMPLE

#### Machaca, TX

Though there aren’t hard statistics to back up such a claim, Texas is probably leading the nation in rainwater harvest for potable use in businesses, residences, and livestock. One such example is the Do/Peters-Do residence in Machaca Texas outside of Austin. Faced with poor quality groundwater, the owners of this home invested in rainwater harvest as their primary source of potable water.<sup>25</sup> Though most states still have significant health-code barriers to permitting these systems, the basic concept is quite simple. A home collects rainwater from its roof and stores the water in a large cistern. In Texas these cisterns are often above-ground galvanized tanks, though large molded plastic tanks placed either above or below ground are equally feasible alternatives. As water is needed, it is pumped into the home, purified first through a sand filter and then with ultraviolet light just before use. Prices vary, of course, but are generally less expensive than digging a new well or connecting to a municipal supply. Because the water does not need to be pumped up from hundreds of feet below the ground’s surface, the electrical costs to operate are likely to be less. Homes with asphalt shingle roofs would not be suitable for potable water harvest, at least not without additional purification steps. But for many homes, businesses, and livestock operations in regions of the country with at least moderate rainfall, rainwater harvest is a logical and affordable water supply option. The primary barrier is state policy and code rather than technology or price.



Texas Water Development Board 2018 Rain Catcher Award. Photo provided by the Do/Peters-Do Residence.

<sup>24</sup> Atmospheric water generation is a third alternative. It is a highly energy-intensive process, and not generally compatible with other sustainability goals. There is at least one company which has paired the water capture with photovoltaic panels but the units are expensive and produce relatively small volumes of water. Thus, the technology is not yet ripe for most uses.

<sup>25</sup> Texas Water Development Board website, <http://www.twdb.texas.gov/innovativewater/rainwater/raincatcher/2018/DoPeters.asp>. Accessed 29 August 2019.

## EXAMPLE

### Salinas Valley, CA

The Salinas Valley is widely known in water circles for its water challenges. Modest rainfall and high agricultural water demand result not only in significant competition for precious water supplies but also diminished quality of both surface and ground water. As is so often the case, many of the residents of the region, which are predominantly Latin-American agricultural workers, have to spend their limited financial resources securing bottled or vended water. Researchers at the University of California at Los Angeles are piloting small-scale water purification units that use membrane technology to purify nonpotable water from agricultural drainage ditches, generally high in salts and agricultural chemicals, to potable standards. These pilot systems are sized to supply water for approximately 100 households. Equally importantly, the systems that they are designing can be monitored remotely via computers and smart phones so that skilled technicians need not be on site and can manage multiple installations simultaneously. They are also exploring models that use solar power, allowing them to operate off-grid, and in hard-to-reach areas.<sup>26, 27</sup>

## REFLECTIONS

If there is low-hanging fruit in the distributed water world, making use of new water supplies is it. The technology for harvesting rainwater and purifying it to the level sufficient for indoor, potable use is readily available if not yet familiar territory. Simple actions like creating easy-to-understand training manuals for installers, creating a market for rainwater harvest kits that bundle the cistern and purification units along with installation and operational instructions, creating videos to help homeowners understand the simple maintenance needs, etc. could help create the glide path for more rapid uptake. With appropriate support, organizations such as Texas Water Trade, the American Rainwater Catchment Systems Association, RCAP, US Green Building Council, or Green Plumbers could readily fill this niche.

The more challenging task is to modernize plumbing and health codes to make them more amenable to onsite water reuse, including rainwater harvest. This is a highly technical, state-by-state endeavor that would benefit from a coordinated national approach. The National Blue Ribbon Commission for Onsite Non-Potable Water Systems has been working on model health codes for non-potable water systems, particularly those that recycle greywater and blackwater, and has recently become affiliated with WaterReuse, a national organization focused on promoting water reuse.

WaterReuse or the Blue Ribbon Commission itself would be excellent vehicles for tackling this challenge.

While rainwater harvest for indoor use is relatively straightforward from a technology vantage, purifying contaminated water in a distributed manner remains an active area of applied research. Recommendations in this arena include doing a more thorough assessment of the technologies entering the pilot phase and selecting one or two for targeted investment to help accelerate commercialization.

## INDUSTRIAL PRE-TREATMENT NEEDS

Industrial pre-treatment or off-grid, independent treatment of wastewater generated from specialized industrial facilities is well-suited for distributed infrastructure. Municipal wastewater facilities often require that industrial generators either treat their waste entirely on their own, or partially treat it before sending it to the municipal system. This may be because the industry uses specialized chemicals that cannot be adequately or affordably treated at the municipal plant, or because there is high carbon content in the effluent that could potentially overwhelm the municipal plant, especially if volumes fluctuate unpredictably. This latter example is especially true for food and beverage processors, including the increasingly popular microbreweries. Fortunately, there is a lot of interest and innovation in

26 UCLA Samueli Newsroom, "Clean Water for All", 19 March 2019. <https://samueli.ucla.edu/clean-water/>, accessed 30 August 2019.

27 Justin Jacques, "Po(r)table reuse: Mobile, automated treatment facilities bring low-footprint, high-recovery treatment of impaired water resources to rural California." March 2018. WE&T. pp. 25-27.

the marketplace aimed at addressing onsite, distributed treatment to address industrial needs, driven in part by desire to avoid crippling surcharges from wastewater utilities.

#### EXAMPLE

##### **Magic Hat Brewery, South Burlington VT**

Nearly a decade ago, Magic Hat Brewery was paying \$200,000/year to its sewer utility for wastewater treatment. The brewery knew that its spent hops, yeast, and grains had value if they could be anaerobically digested to produce methane rather than sent to the wastewater facilities. They were able to partner with PurposeEnergy through a power-purchase agreement to remove 99% of the organic load from their wastewater while also generating more than a third of the brewery's electric needs. PurposeEnergy provided all of the capital for the project (provided by equity investors), and continues to own, operate, and maintain the pretreatment operation as well as the energy equipment. Magic Hat no longer needs to worry about its wastewater and unexpected surcharges, overall sewage costs declined, and they can feel good about the green energy being generated.<sup>28</sup>

#### REFLECTIONS

Distributed treatment of industrial effluent, especially from breweries, methane plants, food processors, and other carbon-rich sources is an exciting opportunity both from an investment and an environmental perspective. Care must be taken, however, that the pursuit of these opportunities does not undermine public wastewater and water supply utilities. If the water is re-used onsite, this may result in raising rates for other customers. The management of industrial applications has significant attention from the investment marketplace, as well as the municipal wastewater sector, and does not appear to need socially minded investment to catalyze its adoption at present. Investors interested in pursuing this further are referred to the recent report "Impact Investment Strategies in Water: Distributed Wastewater Treatment and Water Reuse".<sup>29</sup>

Industrial pre-treatment or off-grid, independent treatment of wastewater generated from specialized industrial facilities is well-suited for distributed infrastructure.

28 "Digest This: Profiting from Brewing Byproducts", presentation by Todd Hasselbeck, April 2015. <http://www.purposeenergy.com/>, accessed 16 September 2019.

29 CREO, "Impact Investment Strategies in Water: Distributed Wastewater Treatment and Water Reuse", 2019. [https://www.slideshare.net/slideshow/embed\\_code/key/cJAp7cXXQszEBf](https://www.slideshare.net/slideshow/embed_code/key/cJAp7cXXQszEBf). Accessed 17 September. 2019.



## Closing Thoughts

Distributed water infrastructure is here to stay. It's not likely to completely replace centralized water distribution and treatment systems in our lifetimes, but it has an important and growing role in providing flexible, restorative, and affordable options to complement and begin replacing what we have today. Much like distributed electrical generation, there are growing pains in learning how to adopt our regulatory, financing, operational, and physical structures to meet the new paradigm. But meet it we will.

Distributed stormwater adaptations, both green and grey, are furthest along in community acceptance and adoption, motivated in large part by the astronomical costs – both financial and social – of centralized approaches to stormwater management. The commonly heard phrase is that “we can’t build our way out” of stormwater challenges, but what is really meant is that communities can’t afford the old approaches to a growing problem. We can and must build our way out, but we will do so with smaller-scaled, flexible grey assets and grow our way out using vegetation to do its traditional job of slowing and capturing rainwater. The sector is still accelerating, but is showing early signs of maturity with the development of standards, training and certification programs, and regulatory changes.

Other aspects of distributed water are still in their infancy. Early technologies and concepts are gaining traction, and investors have their ears cocked for promising leads. However, at times it seems like we’re still in the Brownian motion phase. Distributed water and wastewater do not yet have an overall strategy, cohesion, or social coordination.

Growing, thriving cities are the incubators for leading-edge innovations in distributed water supply and wastewater treatment. As they take on the risk of early adoption, their experiments and ability to pay for the privilege of being first movers will reassure and lower the costs for others. In order to accelerate the uptake of these new options, however, we need a professional ecosystem to support a strategic and socially minded transition.

The National Blue Ribbon Commission for Onsite Non-Potable Water Systems, now housed within the WasteReuse Association, has been an important player in guiding cities and states as they create the policy frameworks to support key applications of distributed water. We need to add to that by creating a home for innovative practitioners of all sorts who are trying to find their way in this new, more resilient approach to water, and a vehicle for impartial guidance for those who need more resilient water approaches the most but can least afford it. And importantly we also need to ensure that the exciting changes ahead are available for all, and that all have a voice in shaping what will work best for them and their communities.

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Her prior work includes leading The Johnson Foundation's environment program from 2008-2014, convening hundreds of leaders to address national water sustainability and resiliency under the umbrella of "Charting New Waters". Earlier she held leadership roles with Milwaukee Riverkeeper®, The Nature Conservancy and NatureServe, and also held positions as an energy conservation specialist and a biology / mathematics teacher. She earned her Ph.D. from Duke University, her M.B.A. from the University of Wisconsin-Milwaukee, and her bachelor's degree in environmental sciences from the University of Virginia. Lynn also serves as president-elect for the Water Environment Federation, is past chair of River Network's board, and is a member emerita (past chair) of the University of Wisconsin-Madison's Nelson Institute Board of Visitors. She recently completed three years as a non-resident senior fellow with the Brookings Institution. Lynn is based in Minneapolis, MN.

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