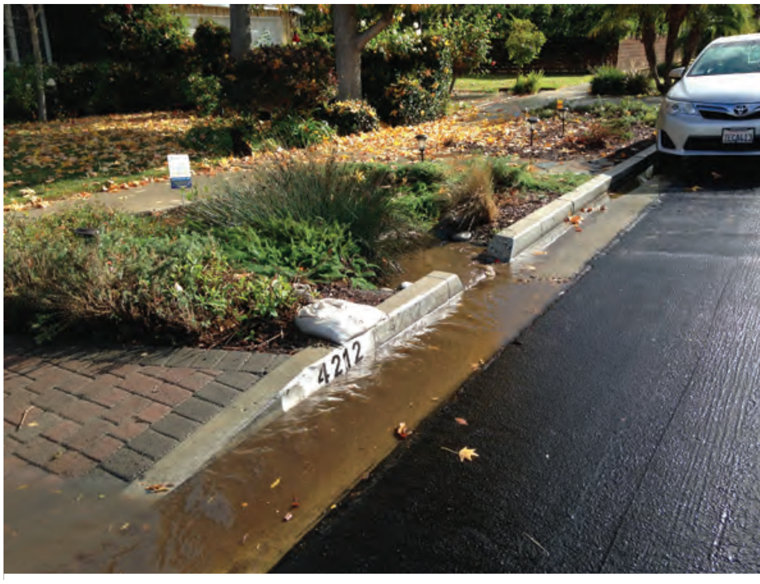
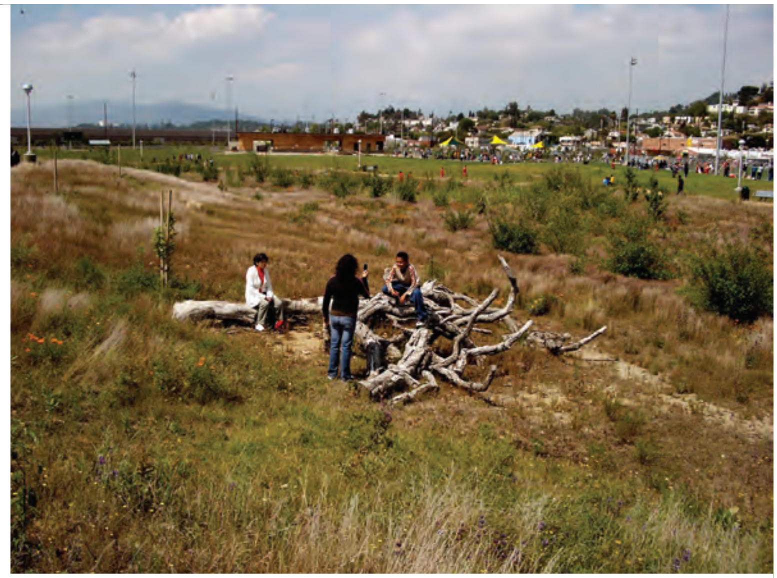
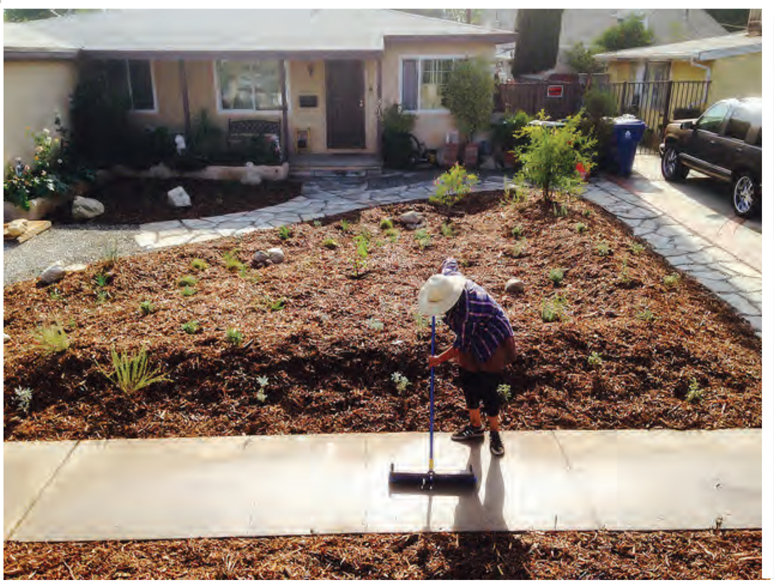
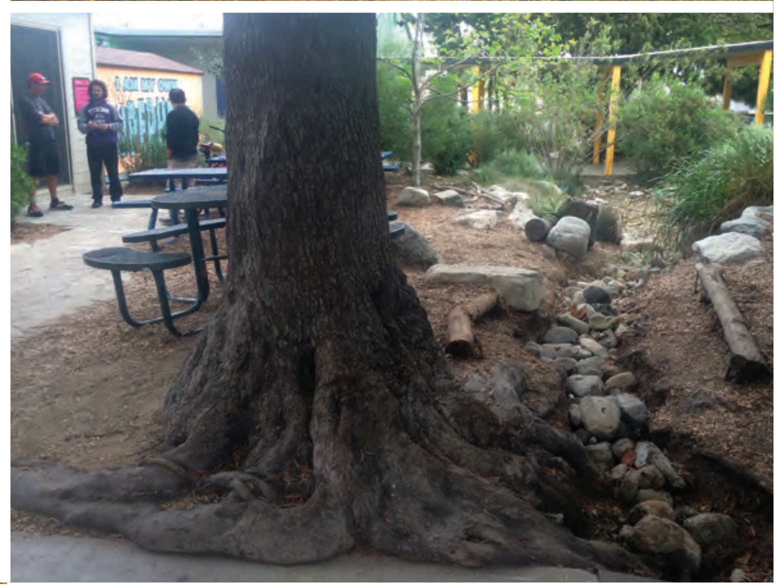
Measuring Benefits of Distributed, Nature-Based Stormwater Projects









The RIVER PROJECT

With funding from

WATER FOUNDATION

June 2018

EXECUTIVE SUMMARY

The Southern California Water Coalition (SCWC) 2018 Whitepaper Update *Stormwater Capture: Enhancing Recharge & Direct Use Through Data Collection* has opened a valuable dialogue into what is known and what is not known about stormwater capture projects implemented across the region over the past decade.

While some have interpreted the paper's data analysis as a finding that large centralized projects are more cost-effective than distributed projects, a closer reading illuminates key factors:

- More monitoring data is needed
- Differentiating between project scales and typologies would provide more clarity on costs and benefits
- Evaluating project co-benefits beyond stormwater volume in additional detail could provide more accurate cost figures to support fiscally sound decision making.

The following is an exploration of implications for Distributed, Nature-Based Projects as a subset of Green Infrastructure. Distributed, Nature-Based projects for water capture, conservation, treatment and reuse are a cost-effective alternative to conventional gray infrastructure. Nature-based projects can be:

- Built cost-competitively with grey and grey/green infrastructure
- Maintained more cost-effectively than conventional grey and grey/green infrastructure long-term (leading to lower life-cycle costs)
- Provide multiple critical benefits offsetting costs and financing to address pressing social, environmental, and economic challenges as compared with grey infrastructure

This paper explores the following factors relevant to this assessment:

- Definitions of Terms
- Need for Data
- Typology
- Scale
- New vs. Retrofit
- Construction Costs
- Operations and Maintenance
- Multiple Benefits

DEFINITIONS OF TERMS

Terminology is significant in describing complex and diverse projects. There are two sets of project classifications that are useful in considering implications for costs and performance, which are referenced in this paper: typology and scale.

- Typology concerns the extent to which a project utilizes human inputs vs non-human inputs, and the different forms of components and operations associated.
- Scale concerns the size and intended distribution for different project types.

Typology

Nature-Based Solutions rely predominantly on soils and vegetation to restore the natural ecosystem processes required to slow, detain, and absorb water, infiltrate water to aquifers, filter pollutants out of water and air, sequester carbon, support biodiversity, provide shade, and aesthetically enrich environments. Examples include: strategically undeveloped mountains and floodplains; wetlands; rain grading/rain gardens; mulch; soil conservation and enhancement; tree and vegetation planting; and parkway basins.

Grey Infrastructure use primarily inert, impermeable materials such as steel and concrete to create conventional infrastructures, piped drainage and water treatment systems that rely on humans to engineer and operate. These make up most of our urban systems including paved streets, dams, drains, flood channels, and dry wells.

Grey/Green Infrastructure are a combination of green and grey infrastructure composed and managed to realize some benefits of green infrastructure within a framework of more conventional development. These are combinations of structures engineered for specific controls, such as green streets, spreading grounds, and planted areas with subsurface water storage capacity.

Size/Scale

Centralized Projects are located on large parcels in key locations in the county, which usually have an average annual capture potential of more than 1,000 acre-feet per year per project and manage stormwater concentrations which are often downstream from the point of runoff generation. Examples include dams, spreading grounds, treatment plants, and areas specifically protected for resource conservation such as the mountains of the upper watersheds, floodplains, and large wetlands.

Neighborhood Projects are located on or impact either large or multiple parcels, which usually have an average annual capture potential of less than 1,000 acre-feet per project. Often these are located on public lands or rights-of-way, which may include parks, streets, greenways, schools, and other significant public infrastructure.

Distributed (Parcel-scale) Projects are simple and replicable enough that they can be spread widely and abundantly. These are public and private landscape-based projects that property owners can reasonably make and manage. Micro interventions such as rain gardens and swales, parkway basins, mulching, soil conservation and enhancement, vegetation and tree planting, permeable paving, and rain tanks may be included as parts of larger projects, or as stand-alone improvements. These are effective source control measures.

	Nature-Based Solutions	Grey/Green Infrastructure	Grey Infrastructure
Distributed	*Rain grading (swales, berms, rain gardens), curb cuts with parkway basins, infiltration trenches, soil amendment, vegetation and tree planting Examples: Water LA Panorama City Retrofits (3.8 AFY for all 22 retrofits)*	*Cisterns, rain tanks, permeable pavement, infiltration trenches, bioswales, green roofs, planter bump-outs, tree wells, most LID Examples: Horace Mann Elementary School, Jeff Seymour Family Center*	*Drywells, small low-flow diversions (LFD)/drainage, some LID Examples: PCH LFD in Pacific Palisades*
Neighborhood	*Wetlands, park grading, stream daylighting/restoration Examples: Rio de Los Angeles State Park, Dominguez Gap Wetlands*	*Green streets, parks with large underground chambers, small engineered treatment wetlands Examples: Watts Green Streets, Bolivar Park (624 AFY), Basset High School Project (266 AFY), Monteith Park Project (80 AFY)*	*Street gutters, storm drains, injection wells, large storage tanks, large low flow diversions/drainage Examples: Agro Drain Sub-Basin Facility at LA World Airport*
Centralized	*Floodplain reclamation, large wetland conservation, mountain and upper watershed conservation Examples: Upper LA River Big Tujunga Restoration (1,000 AFY), Malibu Lagoon*	*Spreading grounds, large engineered treatment wetlands Examples: Tujunga Spreading Grounds (16,000 AFY), Rory M. Shaw Wetlands Park (590 AFY)*	*Dams, Water and waste treatment plants, pipelines, reservoirs Examples: San Dimas Dam, Hyperion Water Reclamation Plant, Santa Monica Urban Runoff Recycling Facility*

Developed in collaboration with Our Water LA partners

Based on these definitions, projects with available monitoring data inventoried in the 2018 SCWC whitepaper are of the grey or grey/green typology, and two of the three distributed projects represented therein would be considered to be neighborhood-scale.

Distinguishing between the neighborhood and distributed scales–as well as between project typologies of grey/green infrastructure and nature-based solutions–would be useful to developing a more robust understanding of the true costs and benefits of various approaches.

NEED FOR DATA

The 2018 SCWC whitepaper was driven in part by a recognition of the need for more results-based decision making in the region, and was designed to compile and evaluate the available monitoring data. Most projects locally and globally are developed and evaluated based on modelling parameters, rather than actual observed results from monitoring. The whitepaper highlighted a universal imperative to advance consistent monitoring across all scales and typologies—that can accurately measure performance and inform data-driven, results-based decision making.

A comprehensive search for complete monitoring data on stormwater capture projects resulted in an inventory of 32 projects from 6 different agencies. Of these, twenty-five (25) were classified as centralized retrofit/rehabilitation projects, four (4) as centralized new, and three (3) were classified as distributed new projects (SCWC 2018). Monitoring data were not provided from projects completed with the City of Los Angeles' Prop O funds nor those implemented under their LID ordinance. However, a major finding of the SCWC white paper is that such data has not yet been developed and made available. Making monitoring data available from Prop O projects—many of which were neighborhood-scale and new centralized projects—would have added significant value to the analysis. Monitoring data on distributed projects must also be developed. More data is necessary to more equally represent and evaluate actual results across typologies and scales.

A consistent data sheet covering a similar period was completed for each project. However, the source data—coming from different agencies and with different project goals—was produced and compiled by different measures. Certain factors were estimated or assumed as necessary. A major limitation is the infeasibility of breaking down the impacts of individual projects out of budgets and infrastructure only tracked more broadly. For a centralized retrofit, the impacts from a specific project alone may be substantially different than the total impacts of both pre- and post-construction infrastructure. Source data limitations could be addressed in future by targeted measuring of installations for select factors, including tracking of labor hours specific to individual installations. Pre-construction data collection could also provide comparison to evaluate the specific impacts of improvements to existing projects.

The 2018 SCWC inventory found that actual volumes of water captured over the evaluation period were generally less than originally modeled and assumed for the primarily centralized projects. Of note, the evaluation period included the drought from 2012-2016. Conversely, evaluation of pre- and post-construction monitoring of distributed nature-based installations in New York City found performance exceeded modeled expectations (NYC Department of Environmental Protection 2014) during a drier period than the pre-evaluation. Together these examples highlight the benefit of actual measures. Methods, assumptions, actual climate, soil conditions, and other factors can impact modeling findings and produce divergent results.

Making decisions based on such assumptions can continue to yield divergent results. Accurate representation is essential for optimal efficiency of investments. Key actions to address data needs include:

- Advancing funding allocations for consistent monitoring in select representative current and future projects
- Establishing consistent monitoring measures for different project types, which project developers and owners could then apply

Performance in Related Literature
In recent decades, major US cities have been making significant investments in distributed, nature-based projects: these include Portland, OR; Seattle, WA; Philadelphia, PA; New York, NY; Chicago, IL; Detroit, MI; and Tucson, AZ. The US EPA promotes the cost-effectiveness of green infrastructure, including distributed project types and highlights the need to evaluate comprehensive factors to accurately represent performance (2017). However, despite extensive project installations, relevant data for apples-to-apples comparisons is limited.

Monitoring data collected by the Portland Bureau of Environmental Services (2013) for distributed, nature-based projects is promising. Despite assumptions that urban soils would have highly variable soil infiltration rates, the results have been consistent with an initial infiltration rate of 5.0 inches per hour, and minimum rate approaching 1.5 inches per hour over prolonged steady inundation. Recent NRCS soil data indicates infiltration rates are likely to exceed those rates across large areas of the Los Angeles basin.

In flow tests for the 25-year storm (1.89" in 6 hours), peak flow reductions were reduced from 62% to 100%, with an average reduction of 90%. At one facility monitored continuously, annual runoff over an eight-year period has been reduced by 84%. Water quality design storm results range from 61% to 100% retention, with most facilities achieving 100% (Portland Bureau of Environmental Services 2013). Projects are strategically installed with planned roadway improvements, leveraging other departmental expenditures to minimize costs (EPA 2007).

For comparison with the Portland 25-year 6-hour storm, the average 95th percentile 24-hour storm event across most of the LA Basin is approximately 2". Most storm events that occur in Los Angeles could be contained at this scale and level of performance, as well as a significant volume of first flush and peak flow from larger storms.

New York has over 4,000 projects on public and private land, approximately 90% distributed right-of-way bioswales, and New York City (NYC) Department of Environmental Protection (2014) monitoring concluded similar results. Monitoring data demonstrated that green stormwater projects reduced more stormwater from reaching sewers than expected (modeled), and significantly more than the pre-project period. Monitoring before and after construction included three study areas where an average of 24 projects up to 20' x 6' in size were installed, averaging infiltration rates between 1 and 6 inches/hour. On average they each captured 14.3% of total runoff from an average drainage area of 22.03 acres, with one study area capturing greater than 89% of all storms monitored (majority of storms less than 1" with peak rainfall 1.27 inches per hour) through only 18 installations (NYC Department of Environmental Protection 2014).

TYPOLOGY

The vast majority of urban areas are made up of grey infrastructure, including the dams, roads, walkways, gutters, channels, pipes, pumps and water treatment facilities that provide essential functions. However, this infrastructure relies exclusively on human inputs to operate and maintain. Manufacturing and installing increasingly sophisticated components out of labor and carbon-intensive materials; using energy to convey water by pipes and pumps; transferring sediment and debris by vehicle; these projects require ongoing operations and maintenance over time.

Over the past 15 years, we have begun to pilot and implement a variety of green infrastructure projects in the region, testing ways to incorporate various natural elements into the armature of familiar grey infrastructures. The degree to which natural process play a role in these projects has varied, but many still consider the green part of green infrastructure to be a costly and decorative appendage rather than an essentially functional feature. Therefore, the material inputs utilized and the operation and maintenance practices adopted are often not dissimilar to grey infrastructure.

Integrating green infrastructure—specifically nature-based projects—can reduce those inputs and diversify vital benefits by leveraging naturally-occurring systems, processes, and biological organisms. Natural systems are inherently regenerative. They do a lot of work in the processes of growing and sustaining life: cycling air, water, and nutrients—including carbon and volatile compounds; opening up soil; and continually creating materials that nourish, shade, cleanse, and enrich the world around us. When we make space for diverse life and these processes, we allow nature to do the work that humans would otherwise need to expend resources to accomplish.

As we continue to develop our understanding of natural systems, we see a growing emphasis on distributed and nature-based projects: from the Intergovernmental Panel on Climate Change (IPCC), US EPA, and Rockefeller Foundation's 100 Resilient Cities Challenge down to the California Water Quality Control Boards, Natural Resources Agency, and local communities.

Portland, Philadelphia, and New York have famously made triple bottom-line assessments on alternative solutions to separate their combined sewer overflow (CSO) systems. They among others have concluded that making significant investments in distributed, nature-based projects such as rain grading and right-of-way swales is the most cost-effective course of action (City of Portland Bureau of Environmental Services 2013, City of Philadelphia Water Department Office of Watersheds 2011, Entrix 2010, Stratus Consulting 2009, NYC Department of Environmental Protection 2017, 2016, 2014, 2010).

SIZE/SCALE

Centralized projects are critical in ensuring a sustainable future, from the San Gabriel Mountains—originally conserved for water resources and providing a majority of our local water—to the many dams and spreading grounds that help to manage water flows and infiltrate for local water supply, and the treatment plants managing urban wastewater. However, new thinking on what constitutes centralized projects is needed. While we have recently come to accept that available land for traditional centralized projects is limited, the potential for regional nature-based projects to address current imperatives merits consideration. These include conservation of upper watershed mountain and foothill areas, as well as floodplain reclamation, and stream and river restoration.

Neighborhood projects can be designed to manage flows at the sub-drainage level, and can work with existing municipal land uses (roads, park space) to reduce pressure on existing infrastructure and/or offset the impacts of impervious surface areas while providing a range of co-benefits.

Distributed projects manage rainwater at the source. These smaller projects are quicker to install as compared with larger centralized projects (The River Project 2018, City of Philadelphia Water Department 2013, 2011, 2009, Roseen 2011). Additionally, the cost of operations and maintenance is taken up by property owners, and the failure of any one micro project will not destabilize an entire system. Distributed-scale projects not only capitalize on efficient use of space, but are necessary to realize regional targets (Black & Veatch et. al. 2016, CH2M et al. 2016, US Bureau of Land

Management and LA County Flood Control District 2016, Geosyntec 2015). For residential retrofits, an adoption rate of 1% of homes a year is assumed necessary to meet regional targets, or approximately 16,000 homes a year.

Based on recent assessments in regional plans–even if all centralized and neighborhood project opportunities were maximized, we would still fall short of regional goals for local water supply, management, and quality. **Implementations at different scales creatively adapted to diverse conditions are key, from the regional out to distributed parcel-based interventions.**

NEW VS RETROFIT

Retrofits to existing infrastructure may use less material and typically involve less disturbance, materials, and work to complete than new projects.

One of the major conclusions of the 2018 SCWC white paper is that retrofit projects are generally more cost-effective than new projects. While capture from pre-construction infrastructure components could not be meaningfully differentiated from retrofits due to limitations of source data collection, even allowing for this limitation the centralized retrofit projects demonstrated a high cost-efficiency ratio by a wide margin.

Similarly, distributed, nature-based retrofits demonstrate significant potential to be both cost-effective and high impact. In evaluating water management projects in California, The Pacific Institute (Cooley and Phurisamban 2016) concluded that landscape conversions were by far the most cost-efficient. Costs were estimated as low as *negative* (-)$4,500 AFY factoring for offsets such as reduced labor, fertilizer, and pesticide use. The Water LA pilot for residential retrofits corroborated these findings with 22 home retrofits capturing an estimated 3.8 acre feet in an average rain year, at an average labor and materials cost of $5,200/home (The River Project 2018), not factoring for the additional offsets. Such simple landform grading for stormwater capture is now a requisite to qualify for LADWP's turf removal rebates, amplifying the impact of landscape conversions without increasing their cost.

New thinking on what constitutes retrofits can help focus thinking on opportunity sites. For instance, existing park space can become a space for stormwater management through the use of simple landform grading. At the same time, adjusting the scope of new projects to include neighborhood and distributed scale nature-based projects can provide significant benefits without significant additional cost. This may be due to the limited extent of additional materials and labor necessary for their creation.

CONSTRUCTION COST

Efficient design and implementation are essential for any project to be cost-effective. Every project has different goals and targets to fulfil, which may involve many different factors. Grey, grey/green, or nature-based typologies at centralized, neighborhood, or distributed scales may be most appropriate for different goals. Accurately evaluating relevant factors is key to reflect impacts and true cost for benefits.

For comparison the following considers costs by water volume captured alone.

The Pacific Institute (Cooley and Phurisamban 2016) has defined small, centralized stormwater projects as those with an annual yield of 280 to 1,500 AFY, ranging from $590 to $1,300 AFY with a median cost of $1,200. Higher-cost projects require more infrastructure for conveyance to recharge areas. Large stormwater projects are defined as those with an annual yield of 6,500 to 8,000 acre-feet, ranging from $230 to $260 AFY with a median cost of $250 AFY.

- By these measures, many centralized projects inventoried for the SCWC 2018 whitepaper (ranging from 3–2,569 AFY) do not qualify as even small, and none qualify as large.
- The Tujunga Spreading Grounds Enhancement Project is estimated to deliver nearly 12,200 AFY (DWP 2016) at $27 million, an example of what would be considered a large and most cost-effective project. At an estimated project life of 30 years and not factoring for ongoing operations, the estimated cost per AF is approximately $74 per acre foot. Few opportunities for projects of this scale considered most cost-effective exist in Southern California.

SCWC 2018 finds the median costs for new centralized projects are $6,900 per acre-foot, and retrofit projects are $600 per acre-foot including operations and maintenance costs (typically estimated at 3%). With the exception of the Virginia Avenue Park Library Rainwater Harvesting Project that collects and treats water on-site for bathroom flushing, the other two projects defined as Distributed in this study would be defined as Neighborhood scale in the above definitions, including underground chambers, paving, utilities, etc. The median cost of these projects was $25,000 per acre-foot including operations and maintenance costs. Of particular note, these last projects also had many targets outside the goal of cost-efficient water supply delivery.

The Pacific Institute 2016 definition for Landscape Conversion most closely aligns with distributed, nature-based projects. The landscape conversions involve minor excavations and planting, as the new LADWP turf rebate which also now requires minor additions of stormwater capture improvements including grading for stormwater capture to qualify for the full rebate amount. At the low end “costs ranged from -$4,500 to -$2,600 per acre-foot (i.e., negative costs) because the reduction in maintenance costs outweighs the investment cost of the conversion. At $5 per square foot, the higher end of the landscape conversion cost, the cost of conserved water would be $580 to $1,400 per acre-foot.”

The River Project’s Water LA 2018 Report also demonstrates distributed, nature-based retrofit projects falling in this range. Without subtracting costs for mowing, blowing, fertilizers, pesticides, irrigation, etc. the average home retrofit cost an estimated $1,013/AF over a 30-year expected project life, and the average parkway basin alone cost $470/AF.

Concerning new project installations, the City of Portland installs swales with planned roadway improvements, so the only additional costs associated with the stormwater project are the costs of a steel curb insert to allow stormwater to enter project areas and the additional soil excavation. These additional costs are more than offset by the $2,400 to $4,000 cost that would have been required to relocate existing catch basins (EPA 2007).

OPERATIONS AND MAINTENANCE

There is a need to track operations and maintenance for individual projects to accurately evaluate costs over time. Most projects evaluated by the 2018 Southern California Water Coalition whitepaper applied an assumed 3% of capital costs to align with the Metropolitan Water District of Southern California 2015

Integrated Water Resources Plan (IRP) Update. Most existing operations budgets cover broader assets than individual projects, and may not be accurately broken down to determine actual costs. Tracking of individual projects costs over time would be invaluable to drive results-based decision-making.

At the assumed 3% of capital costs, the Water LA distributed, nature-based retrofit projects would cost $156/year in maintenance (The River Project 2018). SCWC 2018 includes operations and maintenance costs for centralized projects ranging from $5,000 to $464,000/year, with a median cost of $35,100.

Operations and maintenance of nature-based projects are above ground, making access simple for simple tasks such as trimming, mulching, and debris removal. Of key significance, vegetation, invertebrates, microbiota, etc. cycle nutrients and maintain soil porosity without ongoing human inputs. Accordingly, the cost-effectiveness of such projects improves over time when compared to more traditional grey and grey/green infrastructure. A tree planted today will provide more benefit in the next 15 years than it will provide in the first year. With appropriate maintenance, projects can strengthen over time rather than wearing down, leading to lower life-cycle costs (Roseen 2011). Green infrastructure tends to need more frequent O&M than traditional grey infrastructure, but it is less intense and expensive as projects grow more resilient as they age. Additionally, replacing existing turf with more appropriate native/drought-tolerant landscapes as a way reduce water waste/enhance local water supplies (native gardens use 83% less water than traditional grass), can offer additional cost savings (such native landscaping generates 56% less green waste and require 68% less maintenance than the traditional gardens) (City of Santa Monica 2013).

Additionally, property owners can provide the necessary O&M, just as they now care for their landscapes. Investments to build capacity and buy-in are needed to accelerate adoption of these new practices, but as garden/garden has shown (City of Santa Monica 2013), the inputs and time required to properly manage climate-resilient landscapes are different but less burdensome—in both time and materials—than the current paradigm. Eliminating the need for pesticides, fertilizers, and gas-powered machinery creates added benefits for water and air quality goals.

Conversely, grey and grey/green infrastructure projects typically require manual or mechanic operation, cleaning, and below-ground repairs that can be costly due to lack of access, excavation, and reconstruction (Roseen 2011). The cost of upgrading grey infrastructure can be astronomical, especially if maintenance is deferred over time. For example, the Clearwater Project upgrades being proposed by the Sanitation Districts of Los Angeles County (to replace existing sewage infrastructure leading from Carson to the coast) is estimated at $700 million. Similarly, the proposed California Water Fix (recently approved for funding by MWD) is estimated to cost between $17-26 Billion, with $50 million a year for operations and maintenance. Moreover, experience teaches us that large-scale projects tend to severely underestimate construction costs. More decentralized, greener infrastructure is a way to hedge again needing massive capital investments as old infrastructure ages and degrades.

Multiple Benefits

According to the US EPA (2017), the two most common approaches for cost analysis fail to address broader differences in performance, assessing only:

- initial construction costs
- life cycle costs, including planning, design, installation, operation and maintenance, and replacement.

Nature-based projects provide manifold benefits. Quantifying these benefits demonstrates they realize significant return for investments collectively over time. The City of Philadelphia found that the value of green infrastructure for stormwater management ranged from $1.94 to 4.47 billion over a 40-year period, as compared with $0.06 to $0.14 billion for grey infrastructure alternatives alone (Stratus 2009). Factors included water quality improvements as well as recreation, aesthetics for land value, urban cooling, wetland creation, jobs, energy efficiency, air-related health impacts, and traffic impacts. In Portland a 3.5 to 5 percent increase in home values was also observed with green streets and swales (Entrix 2010).

In Los Angeles, the urban environment is built-out with limited space for improvements, and the region faces many challenges from climate change and drought to chronic physical and mental health that can be positively impacted by environmental improvements. Efficiency is increasingly vital for every investment and every square foot. **Distributed and neighborhood-scale nature-based projects are critical to clean, absorb, and infiltrate water effectively, while also:**

- improving air quality, sequestering carbon, and providing urban cooling by replacing concrete and other impermeable surfaces with healthy soils, vegetated groundcover, shrubs, and trees
- mitigating local flood risk by offsetting peak flow and reducing erosion
- increasing longevity and integrity of water quality investments through reduced wear on systems
- making opportunities for habitat and improving species diversity
- reducing green waste when replacing existing turf and mulching vegetation on-site, lessening disposal and transportation costs
- making opportunities for recreation with associated amenities
- improving aesthetics, further increasingly quality of life and economic potential through increased land value and commercial interest
- making communities more climate resilient by increasing green space and reducing energy associated with pumping and treatment of water
- supporting a green economy, providing a wide variety of design, construction and ongoing maintenance jobs throughout the LA region
- reducing traffic impacts of alternatively larger infrastructure projects

Soil and vegetation may be among the most essential assets to address climate change. Developing research continues to highlight additional benefits of soil and vegetation to impact air quality and carbon sequestration. Diverse vegetation structures including trees, shrubs, and groundcovers can reduce localized concentrations of nitrogen dioxide by as much as 40% and particulate matter by as much as 60% (Pugh et. al. 2012). Trees are also well-established for absorbing carbon, and globally soil alone stores more than three times the total carbon in the atmosphere (Rattan 2007, Batjes 1996). Wetlands are most effective—primarily freshwater wetlands—holding up to 30% of soil carbon in 8% of the land area (Nahlik and Fennessy 2016). 0.35 tons carbon/hectare/year (.007 lbs/square foot) can be sequestered by reforestation alone (Minasny et. al. 2017, Morris et. al. 2017)

Increasing soil organic matter (SOM) can also increase its available water-holding capacity (Hudson 1994). Healthy soil can increase water infiltration and hold up to 20 times its weight in water (California Department of Food and Agriculture 2018), significant factors in minimizing flood impacts.

Distributed, nature-based projects are not only cost-effective additions and alternatives for grey and grey/green infrastructure, but essential companions in a project portfolio for a sustainable, livable, climate-resilient Los Angeles.

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