Appendix E:
ARLA's SCWP Benefit-Cost Analysis Tool

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ARLA's Safe Clean Water Program Benefit-Cost Analysis Tool

Manual

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ARLA’s Safe Clean Water Program
Benefit-Cost Analysis Tool
Manual

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Earth Economics acknowledges that we operate on the lands of the Coast Salish peoples, specifically the ancestral homelands of the Puyallup Tribe of Indians, and the 1854 Medicine Creek Treaty.

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This technical document was created for Accelerate Resilience L.A. (ARLA) and Craftwater Engineering Inc. to inform ARLA's Safe Clean Water Program (SCWP) Working Group. This manual describes the methods, data inputs, and assumptions used to monetize SCWP metrics and pilot watershed modelling within the associated Benefit-Cost Analysis Tool. It is recommended that this manual and the accompanying tool be reviewed and updated at least every five years to ensure the results reflect the most up-to-date physical/economic data and methodological advances.

Measuring the Ecosystem Services Benefits of the Safe Clean Water Program

Overview

Investments made in Los Angeles County (hereafter referred to as the County), via the passage of Measure W with funding allocated via the Safe Clean Water Program (SCWP), will yield multiple economic, social, and environmental benefits for communities across the County. To support quantification and valuation of these benefits for ARLA's Safe, Clean Water Program Working Group Project (the "Project"), Earth Economics developed a Microsoft Excel-based benefit-cost analysis tool for Accelerate Resilience L.A. (ARLA), its SCWP Working Group members, Craftwater Engineering, and other stakeholders. Benefit-transfer method (BTM) is the primary means by which the benefit-cost analysis was implemented. BTM can also inform the costs and benefits that would be inputs for other types of analysis, such as full-cost or triple bottom line accounting.

The current version of the tool estimates economic values for up to 16 benefits for a given scenario (depending on scenario inputs) and estimates the net present value of these benefits using a discount rate of 2.5 percent across a 50-year time horizon (the infrastructure lifecycle modeled by Craftwater Engineering). Inputs to the tool are primarily based on metrics generated by the watershed modeling tool, also developed by Craftwater Engineering. This manual provides background on the data inputs, methods, and assumptions for each category of benefits described in the following sections.

It is worth noting that although SCWP projects can provide multiple benefits, the benefit categories included in the tool provide only a partial understanding of the value added by modeled SCWP projects—other market and non-market benefits have not been estimated. Additionally, the tool and this manual only include considerations for the monetization of Measure W investments. More benefit categories should be considered for other County measures, particularly if multi-benefit projects are implemented across agencies.

There are also other benefits that cannot be measured in monetary terms that are important to consider. For example, the ecosystems and ecosystem services of the region carry social and cultural significance for Indigenous Peoples, including the Ventureño, Gabrieleño, and Fernandeño Tribes, as well as the Chumash, Tongva, Kizh, and Taaviam Nations, the original peoples of the area. The cultural values associated with the ways of life, knowledge, beliefs, and practices of Indigenous Peoples are complex and difficult—if not impossible—to measure in monetary terms. Acknowledging the perspectives of multiple stakeholder communities is crucial to achieving inclusive planning and sustainable management systems.

Finally, it is important to recognize that while this manual explains benefit-cost analysis (BCA) variables for SCWP projects, a BCA is but one of many well-established methods to be used in the initial stages of project or policy design. BCA is naturally limited in the information it can provide by what can be quantified in monetary terms. In other words, only costs and benefits that can be measured in dollars will be included in the analysis. BCA alone is not sufficient to inform decision-making and the values it produces represent a starting place, to be evaluated alongside the additional context of what is and is not included, how each value estimate is constructed, as well as a more holistic conversation acknowledging project goals and intent. Given these factors, the CBA tool is best viewed as a vehicle for systematically exploring the strength of assumptions, the range of alternatives, and the relevant trade-offs involved in each decision. BCAs do not replace, but complement, the stakeholder deliberative process characteristic of participatory and representative policymaking. Moving forward, adopting a systems approach to economic valuation for SCWP projects is attractive particularly in the face of the accompanying technical challenges associated with climatic and social uncertainties.

Summary of Benefit Categories Included in the Tool

Table 1. Summary of benefit categories and SCWP metric inputs included in the tool

Benefit Category	**SCWP Metric Inputs**
Water Supply Benefits	
Groundwater recharge	New water captured annually
Stormwater reclamation	New water reclaimed annually
Water Quality Benefits	
Removal of zinc and other pollutants	Average annual pounds of zinc removed
Community Investment Benefits	
Physical activity (health)	New green space added
Physical activity (productivity)	New green space added
Recreation	New green space added
Removal of air pollutants	Change in groundcover
	Change in number of trees
Mitigation of UHI effect on health	Change in canopy*
Building energy cost savings	Change in number of trees
Carbon sequestration	Change in groundcover
	Change in number of trees
Aesthetic value	Change in number of trees
	New green space added
Existence value	Change in canopy*
	New green space added
New total construction jobs supported	Projected planning and construction budget
New total O&M jobs supported	Projected O&M budget
Stimulated economic activity from spending in construction	Projected planning and construction budget
Stimulated economic activity from spending in O&M	Projected O&M budget

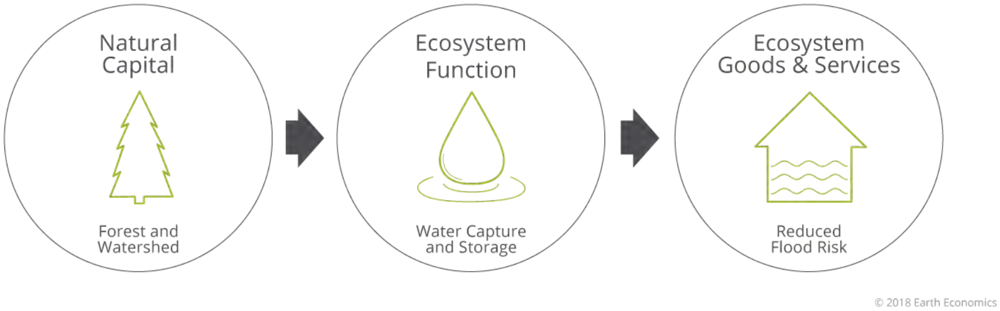
**"Change in number of trees" differs from "change in canopy" as an input because it counts individual trees. "New canopy added" measures the value of acres of tree canopy.*

Explanation of Valuation Modules

Ecosystem Services Valuation Methodology

For more than two decades, Earth Economics has conducted extensive benefit-cost analyses that incorporate the non-market economic value produced by natural capital assets. Natural capital is defined as ecosystems such as wetlands, forests, and pastures, and the plant and animal communities they support. The benefits derived from the ecosystem functions produced by natural capital are known as *ecosystem goods and services* (see Figure 1), such as water supply, carbon sequestration and storage, and flood-risk reduction. Earth Economics uses a framework developed by the United Nations' Millennium Ecosystem Assessment that categorizes 21 ecosystem services into four main categories: provisioning services, regulating services, information services, and supporting services, as described in Table 2.

Figure 1. Model of ecosystem goods and services derived from natural capital



Broadly speaking, ecosystem services describe the benefits people receive from natural capital. Natural capital refers to resources such as water, soils, plants, and animals that provide flows of goods and services that are the basis of all other economic activities. They provide clean water, breathable air, nourishing food, waste treatment, climate stability, and other critical services—for instance, grasses and trees capture, intercept, and store runoff during storms, which reduces flood risk to human life and property.

Over the past half century, economists specializing in the environment and natural resources have developed a broad array of methods to assess the economic contribution of ecosystem goods and services. For certain material goods like fish or timber, this value is expressed as market prices. Many other ecosystem benefits do not have markets associated with them, like clean air or aesthetic appreciation. To estimate the value of these "non-market" benefits, economists apply other techniques such as travel cost analysis, hedonic pricing, and contingent valuation.

Categories of Ecosystem Services

Again, ecosystem services can be grouped into four categories:

- ***Provisioning services*** are those that provide the physical resources that society uses. Soils provide nutrients, which are metabolized into plants. Rivers provide drinking water and fish.

- ***Regulating services*** are benefits resulting from ecosystem balancing functions. Intact ecosystems regulate climate at local and global scales, capture, clean, and transport water, retain and build soils, and improve air quality.
- ***Supporting services*** are provided by the habitats supporting food webs and all life on the planet.
- ***Information services*** are tied to meaningful human interactions with nature. These services include aesthetically and spiritually significant natural places, outdoor recreation, and opportunities for scientific research and education.

Table 2. Definition of ecosystem services based on the UN Millennium Ecosystem Assessment

Service	**Economic Benefit to People**
Provisioning	
Energy and Raw Materials	Fuel, fiber, fertilizer, minerals, and energy
Food	Food crops, fish, game, and fruits
Medicinal Resources	Traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Materials for clothing, jewelry, handicraft, worship, and decoration
Water Storage	Long-term reserves of usable water stored in surface waters, aquifers, and soil moisture
Regulating	
Air Quality	Providing clean, breathable air
Biological Control	Providing pest, weed, and disease control
Climate Stability	Stabilizing climate at local and global levels through evapotranspiration, shading, carbon sequestration and storage, and other processes
Disaster Risk Reduction	Mitigating impacts from natural hazards such as floods, hurricanes, fires, and droughts
Pollination and Seed Dispersal	Pollinating wild and domestic plant species via wind, insects, birds, or other animals
Soil Formation	Building soils through decomposition or sediment deposition
Soil Quality	Maintaining soil fertility and the capacity to process organic inputs
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Water Quality	Removing pollutants via soil filtration and metabolization by microbial and vegetative communities
Water Capture, Conveyance, and Supply	Intercepted precipitation, and resulting surface and subsurface water flows
Navigation	Maintaining adequate depth in surface waters to support recreational and commercial vessel traffic
Supporting	
Habitat	Providing diverse shelter and refugia to maintain biological diversity
Information	
Aesthetic Information	Compelling natural views, sounds, and smells
Cultural Value	Meaningful spiritual and historic engagement with nature; sense of place
Science and Education	Natural systems as a focus for the creation and transfer of knowledge
Recreation and Tourism	Enjoying the natural world and outdoor activities

Economic Value of Natural Capital

While the economic value of natural capital is critical to human well-being, decisions impacting the environment have historically overlooked the economic benefits of nature.[1,2] The language of budgets, costs, and returns on investment is just beginning to incorporate such benefits into decision-making, but the effect has already been significant. Because ecosystems are living systems, natural assets are often more resilient and less costly to maintain than built infrastructure. Without natural systems, many benefits that societies receive for free would need to be replaced by built infrastructure, incurring greater construction and maintenance costs, and eventually requiring replacement.[3,4] Acknowledging the economic value of natural capital demonstrates the cost-effectiveness of Nature-Based Solutions, while raising awareness of the long-term connections between people and these natural assets.

1. Benefit Transfer Methodology

To estimate the value provided by ecosystem goods and services, Earth Economics employs benefit transfer methods (BTM), in which the valuation estimates of primary studies of similar services produced by similar ecosystems in similar contexts (e.g., climate, terrain, soils, species) are used to estimate the value of services provided by ecosystems at the new location of interest. BTM is often the only cost-effective option for producing reasonable estimates of the wide range of services provided by ecosystems that have yet to be studied extensively by economists.

The application of BTM begins by identifying critical attributes of a landscape that determine ecological productivity and expected benefits. Primary valuations of ecosystems with similar features are then identified based on their comparability with land-cover types within the study area, as well as important contextual factors, such as climate, elevation, and spatial relationships to urban areas, surface waters, etc. The estimates from the primary studies are then standardized—adjusted to common units and corrected for inflation—to ensure “apples-to-apples” comparisons. In this sense, BTM is similar to a property appraisal, in which recent sale prices of nearby homes that share similar features are used to estimate a home’s value prior to sale. While each approach has limitations, these are rapid and efficient approaches to generating reasonable values to support investment and policy decisions, and as such, have been broadly adopted.

Multiple estimates are often identified for ecosystem services and land-cover types that have been extensively studied. In such instances, Earth Economics reports the range of per-acre value estimates. Unfortunately, some of the ecosystem services produced by land-cover types found in the Project’s study area have not been well-researched; the value of these benefits is not currently estimated by the tool (see below section titled “Other Considered Benefit Categories Not Included in the Tool”).

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[1] Liu, Shuang, Robert Costanza, Stephen Farber and Austin Troy. 2010. “Valuing ecosystem services: theory, practice, and the need for transdisciplinary synthesis.” Annals of the New York Academy of Sciences 1185, 54-78.

[2] National Research Council. 2005. Valuing ecosystem services: toward better environmental decision-making. National Academies Press.

[3] National Research Council. 2011. Sustainability and the US EPA. National Academies Press, Washington, DC. Pg. 101.

[4] US EPA. 2012. The Economic Benefits of Protecting Healthy Watersheds (No. 841- N-12– 004). US Environmental Protection Agency, Washington, DC.

To apply BTM across a broad range of ecosystem service/land-cover combinations, this analysis relied on Earth Economics' extensive database of valuation estimates, the Ecosystem Service Valuation Toolkit (EVT). Studies transcribed into the EVT have passed multiple reviews for quality and rigor, and all estimates have been standardized to support BTM. Earth Economics analysts applied multiple selection criteria to identify primary studies of locations sharing critical features with the study area, including geographic location, climate, and key ecological and demographic characteristics.

2. Areal, Volumetric, and Visit-Based Calculations

Most ecosystem benefits can be standardized as per-acre value provided each year, rescaled to the extent of the relevant land-cover types of the project site. These include water quality, carbon sequestration, and storm protection. Benefits better represented by volume (e.g., water captured, pollutant removal), can be standardized to per-acre-feet, per-year values. Some benefits (especially outdoor recreation) are often calculated based on activity-specific participation rates (e.g., hunting, fishing, wildlife watching) which can then be adjusted for median local incomes and can be improved as more participation data are gathered through visitation counts and surveys.

3. Primary Valuation Methods

In the same way that economists determine the value of real estate as private assets, economists can also determine the contribution of ecosystem goods and services as public assets. For example: although timber is traded in markets, prices rarely reflect other benefits provided by forests, such as water filtration, wildlife habitat, or flood risk reduction. These are known as *non-market benefits*, and their loss can lead to significant costs for nearby communities. Because market prices do not always reflect such costs, economic value must sometimes be assessed indirectly, using a range of valuation techniques. These include:

- **Replacement Cost:** Costs of replacing services provided by functioning ecosystems with built infrastructure (e.g., levees and dams as a replacement for natural floodplain protection). This typically includes construction, operations, and maintenance.
- **Avoided Cost:** Losses that would be incurred if a natural ecosystem were removed or its function were significantly impaired (e.g., increased flooding following elimination of wetlands and riparian buffers).
- **Production Approaches:** Ecosystem services that enhance market outputs (e.g., moderate, predictable rainfall increases crop productivity).
- **Travel Cost:** Where benefiting from natural ecosystems requires travel, the cost to do so implies a minimum level at which such services are valued (e.g., outdoor recreation, tourism).
- **Hedonic Pricing:** Property values vary by proximity to some natural amenities (e.g., homes with water views often sell for higher prices than similar homes without such views).
- **Contingent Valuation:** Survey-derived estimates of how much respondents value a given ecosystem service (e.g., willingness to pay to protect water quality).

The valuation of most ecosystem services is well understood and straightforward. However, for ecosystem services that are difficult to quantify, benefits are often better described qualitatively (e.g., cultural values).

4. Asset Valuation (Discount Rates, Time Horizons)

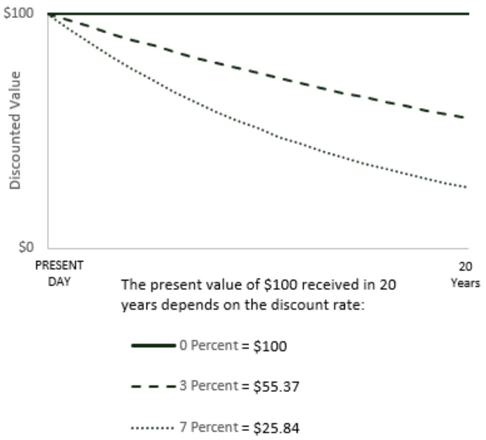
As with durable built capital, it is possible to calculate the asset value of natural capital, as annual flows of ecosystem service benefits will continue, provided the ecosystems providing those benefits are not degraded or depleted. Characterizing the total benefits expected to flow from natural capital over longer time periods helps policymakers plan investments and stewardship activities at appropriate scales. Such asset values are typically calculated as net present value (NPV), in which future benefits are *discounted* to acknowledge preferences or incentives for more immediate benefits over those more distant. Discounting supports comparisons of projects with different life cycles, by presenting future benefits as present-day value.

Discounting adjusts for two factors that influence monetary value over time:

- *Time preference:* People tend to prefer immediate consumption over deferred consumption—receiving a dollar today is better than receiving a dollar in the future.
- *Opportunity costs:* Present-day investments provide greater returns over time than deferring those investments into the future.

While discount rates for built capital are often based on interest rates, experts disagree on the appropriate discount rate for natural capital.[5,6] The choice of discount rate is critical as it heavily influences how benefits occurring over long periods are valued. High discount rates dramatically lower the value of benefits produced over longer time periods—an issue of special concern for natural capital projects that are expected to produce benefits for hundreds of years. For example, a $100 benefit delivered 20 years from the present discounted to 3 percent falls to $55.37 in present-day value; applying a 7 percent rate lowers it to $25.84 (Figure 3). Accordingly, lower discount rates tend to be better at balancing short- and long-term benefits.

Figure 3. A comparison of discount rates' effect on present values



In 2003, the Federal Office of Management and Budget (OMB) recommended two discount rates for regulatory and public investment analyses: three and seven percent.[7] Other federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA) use a discount rate of around three percent

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[5] Arrow, K., Dasgupta, P., Goulder, L., et al. 2004. Are we consuming too much? Journal of Economic Perspectives 18(3): 147–172.

[6] Sterner, T., Persson, U.M. 2008. An even sterner review: Introducing relative prices into the discounting debate. Review of Environmental Economics and Policy 2(1): 61–76.

[7] Office of Management and Budget. 2003. Circular A-4: Regulatory Analysis. Washington, D.C.

for their infrastructure analyses.[8] Some economists have argued that natural capital valuation should apply even lower discount rates.[9] Ultimately, selecting a discount rate is a policy choice. A discount rate of 2.5 percent was applied in this analysis, which is the rate used by both the Bureau of Reclamation and Army Corps of Engineers for water resources projects in 2021.[10,11]

Another important factor when estimating asset value is the time frame of analysis. NPV can be calculated over different periods of analysis, depending on the purpose of the analysis and nature of the project. Because ecosystems are generally self-maintaining and stable over long periods, they are continuously productive, provided they remain unimpaired. Natural capital asset valuations are typically based on time frames of 20 to 100 years, depending on local context and the useful life of built infrastructure alternatives. For this Project's SCWP tool, it is worth noting that many of the benefits provided by natural capital investments will continue to provide value to society well beyond the chosen time horizon of 50 years.

Limitations

The benefit transfer method (BTM), while a pragmatic means of estimating the value of ecosystem services, has limitations. Yet, these should not detract from the core understanding that ecosystems produce significant economic value for society. These limitations include:

- All ecosystems are unique; per-acre values derived from another location may not match all factors relevant to the ecosystems under analysis.
- Even within single ecosystems, ecosystem function—and thus, the benefits produced—varies. Scale is an especially significant factor. In most cases, as ecosystem sizes decrease, per-acre value estimates are expected to increase, and vice versa. This is because per-unit benefits are generally inversely related to the overall supply of those benefits.
- The information needed to estimate the value of every ecosystem service produced by all land-cover types within a study site is rarely available. This means that ecosystem services valuations almost always underestimate the full value produced by natural capital.
- Primary studies from which BTM estimates are based usually encompass a variety of time periods, specific locales, and analytical methods. Many researchers report ranges of values, rather than single-point estimates. This study preserves this variance; no studies have been excluded because the estimated values seemed too high or too low. Additionally, only limited sensitivity analyses were performed.
- In response to the study by Costanza et al. (1997) regarding the global valuation of ecosystems, critics objected to the absence of imaginary exchange transactions. Yet including real market

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[8] Dunford, R.W. 2018. The Discount Rate for Assessing Intragenerational Natural Resource Damages. Journal of Natural Resources Policy Research 8(1-2): 89-109.

[9] Weitzman, M. L. 2001. Gamma discounting. American Economic Review 91(1): 260-271.

[10] US Bureau of Reclamation. 2020. Change in Discount Rate for Water Resources Planning. Federal Register. URL www.federalregister.gov/documents/2020/12/11/2020-27294/change-in-discount-rate-for-water-resources-planning.

[11] NRCS. 2021. Rate for Federal Water Projects. Central National Technology Support Center: Rate for Federal Water Projects. www.nrcs.usda.gov/wps/portal/nrcs/detail/national/cntsc/?cid=nrcs143_009685.

> exchanges is not necessary if one recognizes the purpose of valuation at this scale—which is more analogous to national income accounting than to estimating exchange values.[12]

This tool reports in a way that highlights the range and distribution of valuation estimates. While these estimates are not overly precise, they are more useful for decision-making than the alternative of assuming that ecosystem services have zero (or infinite) value. In pragmatic terms, it is better to be approximately right than precisely wrong. The limitations associated with each benefit category included in the tool have been described in the following section.

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[12] Howarth, R., and Farber, S. 2002. Accounting for the Value of Ecosystem Services. Ecological Economics 41(3), 421-429.

Benefit Categories and Valuation Methods Included in the Tool

Water Supply

1. Groundwater Recharge

Description of benefit: The value of added new water supply via groundwater recharge from modeled SCWP projects

SCWP metric inputs (units): New annual water captured due to modeled SCWP activities (acre-feet)

Methods and assumptions: Stormwater infiltration projects, particularly those that expand the footprint of green spaces, help to capture and store water in local aquifers. A replacement cost approach was used to calculate the value of groundwater recharge, which was computed by multiplying the user input "new water captured" metric (in acre-feet per year) by the cost of securing that same volume of water through other sources. A unit value between $634 and $966/acre-foot (USD 2020) was selected, representing the cost of the "next best alternative" water supply, based on the difference between the cost of importing water for groundwater recharge and the cost of pumping and treating groundwater in L.A. (i.e., the avoided cost of obtaining incremental water supplies less the production costs to pump and treat groundwater). These estimates were obtained from the 2018 study by Porse et al.[13]

Formula:

$$\mathrm{VGWR}_{yr} = \mathrm{W}_{yr} \text{ x } (\mathrm{Cost}_{\mathrm{Importing/yr}} - \mathrm{Cost}_{\mathrm{Recharging/yr}})$$

where W_{yr} is new water captured each year by SCWP project components.

2. Stormwater Reclamation

Description of benefit: The alternative cost of importing untreated water

SCWP metric inputs (units): New water reclaimed annually from modeled SCWP projects (acre-feet)

Methods and assumptions: By diverting unused stormwater runoff to reclamation plants, modeled SCWP projects are creating a new, local source of raw (untreated) water. The cost of importing comparable raw water is reflected in the price paid by the MWDOC (Municipal Water District of Orange County) to acquire untreated water from the MWD (Metropolitan Water District of Southern California): $755 per acre-foot (USD 2020).[14]

Formula:

$$\mathrm{VSR}_{yr} = \mathrm{W}_{yr} \text{ x } (\mathrm{Cost}_{\mathrm{Importing/yr}})$$

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[13] Porse, E., Mika, K.B., Litvak, E., Manago, K.F., Hogue, T.S., Gold, M., Pataki, D.E., Pincetl, S., 2018. The economic value of local water supplies in Los Angeles. Nat Sustain 1, 289–297. https://doi.org/10.1038/s41893-018-0068-2

[14] MWDOC. 2021. Water Rates and Charges. Municipal Water District of Orange County. www.mwdoc.com/about-us/about-mwdoc/water-rates-and-charges/

where W_{yr} is new water reclaimed annually thanks to project components of the SCWP.

Water Quality

3. Water Quality: Removal of Zinc and Other Pollutants

Description of benefit: The alternative cost of zinc removal, the limiting pollutant in the Alhambra Wash watershed

SCWP metric inputs (units): Water Quality benefit in dollars per pound of zinc removed per year

Methods and assumptions: A suite of projects that remove zinc from the watershed has value. An appropriate method to express the value of zinc removal is the alternative cost approach. With this approach, the value of the zinc reduction/removal benefit of a project is assumed to be at least as valuable as the next best alternative method for achieving that same amount of removal.

Formula:

$$VWQ_{Yr} = Zn \times (AltCost_{ZnLbRemoval})$$

Where Zn is the average annual pounds of zinc removed by the stormwater management project, and $AltCost_{ZnLbRemoval}$ is the average annual cost in nominal dollars of the least-cost alternative for removing one pound of zinc.

In the Alhambra Wash pilot watershed, zinc is what is known as the limiting pollutant—it requires the most BMP capacity to manage and, if it is effectively managed, other pollutants of concern will also be effectively managed. Therefore, it is appropriate to use zinc as a proxy for Water Quality, because removing zinc from stormwater also removes other pollutants.

While it is clear that society values removing zinc from stormwater, there are no market transactions that measure this value (i.e., you cannot "buy" zinc removal on a market), so other economic methods must be used to determine it. To estimate the value of removing zinc and other pollutants from stormwater (i.e., the Water Quality benefit), this analysis uses the alternative cost method. Technical guidance for the Water Storage Investment Program produced by the California Water Commission defines alternative cost as "the cost of the lowest-cost, feasible alternative to providing a physical benefit provided by a proposed project."[15]

The best source of a least-cost alternative estimate comes from the models developed by Craftwater from the Alhambra Wash pilot watershed. A combination of stormwater project types and BMPs work together to provide better water quality, and the Craftwater models have calculated the optimal arrangement that will deliver the most zinc removal for the lowest cost per unit (i.e., cost-effectiveness).[16] The total cost and total pounds of zinc removal for the optimal arrangement can then be expressed as a ratio—dollars per pound of zinc removed—which is used as a proxy for the Water Quality benefit of alternatives considered for the SCWP.

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[15] California Water Commission, 2016. Technical Reference. Water Storage Investment Program. Available from: https://data.ca.gov/dataset/climate-change-projections-for-water-storage-investment-program-wsip

[16] Project types include rain gardens, infiltration galleries, and storage-to-sewer or -filter.

The Craftwater model, optimized for zinc removal, determined that the most cost-effective solution removed an average of 788 pounds of zinc per year over a 50-year period, at the cost of $125,000,000 (nominal dollars).[17] Dividing these two figures and annualizing results in a Water Quality benefit of $3,173 per pound of zinc removed, per year. While the model focuses on zinc reduction, this estimated benefit represents water quality more broadly, as removing zinc from stormwater also removes other pollutants. These cost estimates were determined using data on local lifecycle costs for stormwater projects that include expenditures for construction, operations and maintenance.

A key assumption used in modeling the least-cost alternative used to derive the Water Quality benefit is that the BMPs selected and modeled represent the totality of project types that could potentially be implemented with SCWP funding. Therefore, there is no alternative that might represent a more cost-effective solution to zinc removal. The model considered all possible structural solutions; non-structural solutions like education and outreach that work effectively in tandem with structural solutions were not considered in the least-cost optimization model. The model is also careful to only use the stormwater management cost component of projects without supplemental amenities such as lighting, new park equipment, pathways and more, so as to create the best possible alternative cost–based Water Quality benefit.

Community Investment Benefits

4. Air Quality: Removal of Air Pollutants

Description of benefit: The value of air quality improvements associated with trees and vegetation in terms of improved human health

SCWP metric inputs (units): New groundcover added (acres); and new trees added (count)

Methods and assumptions: Expanding urban green space can help improve local air quality, as trees, shrubs, and grasses are known to intercept and filter many airborne pollutants. Air quality improvement benefits for grasslands and shrublands were based on Bakshi et al. (2018), which estimated the human health benefits associated with pollution removal. Those authors applied EPA's BenMap-CE and the U.S. Forest Service's i-Tree Eco models to examine human morbidity and mortality associated with ozone, nitrogen oxides, particulates, and sulfur oxides in urban areas across the United States. [18,19,20] The study estimated the avoided costs of adverse health effects (e.g., emergency room visits, hospital admissions, school loss days), by comparing local air pollution metrics with the Leaf Area Index and the extent of grassland and shrubland vegetation to generate annual per-acre benefits of air quality improvements.[21]

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[17] The most cost-effective zinc-removal solution in the Alhambra Wash is 25 percent of funds going towards the development of regional "storage and filtration or diversion to sewer" projects and the remaining 75 percent of funds to distributed "rain garden" projects.

[18] US EPA. 2021. Environmental Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE). www.epa.gov/benmap

[19] US Forest Service. 2020. i-Tree Eco. URL: www.itreetools.org/tools/i-tree-eco/i-tree-eco-overview

[20] Bakshi, B. R., Ziv, G., Hirabayashi, S., Gopalakrishnan, V. 2018. Air Quality and Human Health Impacts of Grasslands and Shrublands in the United States. Atmospheric Environment 182: 193-199.

[21] See p. 195 in Bakshi et al., 2018.

Based on this Project's SCWP projections of expanded shrub and grassland cover in Los Angeles County, it is possible to approximate the annual added air quality benefits.

Formula:

$$VAQ_{acre/yr} = APR_{acre/yr} \text{ x } Cost_{Health/yr}$$

where $APR_{acre/yr}$ is annual air pollutant removal per acre of grassland or shrubland and $Cost_{Health/yr}$ is the annual cost of illness from air quality-related diseases.

To derive a per-tree air quality value for tree cover, a 2016 study of the value provided by urban trees was used.[22] In this study, i-Tree Streets (since replaced by i-Tree Eco) was used to estimate the average offset costs for the O_3, NO_2, PM_{10}, SO_2, and VOCs intercepted by street trees in 50 California cities. Across the Southern California Coast, urban trees were estimated to provide $24.85 million (2020 USD) in air quality improvements each year. For a regional inventory of over 2.7 million trees, the value translates into roughly $9.40 (USD 2020) per tree.

Because mature trees can be expected to provide greater air quality improvements than saplings, the benefits provided of new tree plantings will gradually increase over time. Accordingly, the air quality value formula per tree per year has been adjusted by a growth factor representing tree development stages. This growth function was taken from a 2002 study that predicted annual benefits per-tree in Modesto, which was seen as appropriate to transfer to L.A. County.[23,24]

Note: adjustments by tree development stage were also used in calculations of the estimated energy cost savings and carbon sequestration.

Formula:

$$VAQ_{tree/yr} = \%Dev(\text{year since planting}) \text{ x } APR_{tree/yr} \text{ x } Cost_{Offsets/yr}$$

where %Dev is a function of the time passed since a tree is planted and it reaches full maturity, $APR_{tree/yr}$ is annual air pollutant removal per tree and $Cost_{Offset/yr}$ is the average annual cost of pollution offset transactions in California.[25]

5. Physical Activity: Public Health

Description of benefit: Avoided health costs due to physical activity enabled by green space added within Los Angeles County

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[22] McPherson, E.G., van Doorn, N., de Goede, J., 2016. Structure, function and value of street trees in California, USA. Urban Forestry and Urban Greening 17, 104–115. https://doi.org/10.1016/j.ufug.2016.03.013

[23] Note that this approach does not account for tree health or vigor.

[24] McPherson, E. G., and Simpson, J. R. 2002. A comparison of municipal forest benefits and costs in Modesto and Santa Monica, California, USA. Urban Forestry and Urban Greening, 1(2), 61-74.

[25] California requires air quality management districts that do not attain ambient air quality standards to adopt emission reduction programs. These programs allow polluters to reduce their own emissions to target levels or purchase offsets from polluters who have already cut their emissions.

SCWP metric inputs (units): New green space added (acres)

Methods and assumptions: Adding green space—especially to areas with few parks—can encourage physical activity that leads to public health benefits. Physical activity has been shown to reduce morbidity and mortality from heart disease, diabetes, etc. While specific effects are difficult to estimate for a single project, it is important to acknowledge that improved access to recreational opportunities can help to improve public health overall. A 2016 RAND study of neighborhood park use in Los Angeles—and the associated physical activity and health impacts—was used to generate a range of estimates based on local demographics, physical activity levels, and avoided medical costs. [26,27,28,29]

Formula:

$$\text{VPA-H}_{\text{acre/yr}} = \text{Vis}_{\text{acre/yr}} \times \text{Cost}_{\text{Health/yr}}$$

where $\text{Vis}_{\text{acre/yr}}$ is the number of annual adult park visitors that engage in active physical activity and $\text{Cost}_{\text{Health/yr}}$ is the annual additional healthcare costs of physical inactivity in L.A. County.

Note: additional equity considerations can be incorporated using lessons and geospatial information from the 2016 Parks Needs Assessment, which produced a comprehensive inventory of the County's parks, open spaces, and natural areas.[30] Considering factors such as park acres per 1,000 people, the number of residents within a half-mile distance of each park, park amenities, and park condition, the Assessment determined that 32 percent of the County's residents lived in "Very High Need" areas. The assessment also generated a general profile of urban park visitors in Los Angeles County, 41 percent of whom were between 24 and 54 years old. Both younger and older age groups comprised a surprisingly small share of overall visitors. Finally, the Assessment also reported race, ethnicity, and other socioeconomic data on park visitors, which could inform SCWP project design regarding diversity, equity, and inclusion considerations.

6. Physical Activity: Productivity

Description of benefit: Avoided productivity losses associated with physical activity enabled by green space added within Los Angeles County

SCWP metric inputs (units): New green space added (acres)

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[26] RAND. 2016. City of Los Angeles Neighborhood Parks: Research Findings and Policy Implications (2003-2015).

[27] CDC. 2014. State Indicator Report on Physical Activity. Centers for Disease Control and Prevention, Atlanta, GA.

[28] Chenoweth, D., and Leutzinger, J. 2006. The economic cost of physical inactivity and excess weight in American adults. Journal of Physical Activity and Health, 3(2), 148-163.

[29] Cohen, D., McKenzie, T., Sehgal, A., Williamson, S., Golinelli, D., Lurie, N. 2011. Contribution of Public Parks to Physical Activity. American Public Health Association.

[30] LACDPR. 2016. Los Angeles Countywide Comprehensive Parks and Recreation Needs Assessment. L.A. County Department of Parks and Recreation.
https://cola-carto.carto.com/viz/6564c91a-59a2-11e6-a4cb-0e3ebc282e83/embed_map

Methods and assumptions: Adding green space—especially to areas with very few parks—can encourage outdoor physical activity, which has been shown to improve worker productivity.[31] Using visitation data from the 2016 RAND study and productivity impact estimates from Chenoweth et al. (2006), the avoided productivity losses associated with physical activity in expanded green spaces within L.A. County was estimated.[32,33]

Formula:

$$\text{VPA-P}_{acre/yr} = \text{Vis}_{acre/yr} \times \text{Cost}_{Prod/yr}$$

where $\text{Vis}_{acre/yr}$ is the per-acre estimate of adults who engage in physical activity in L.A. parks each year, and $\text{Cost}_{Prod/yr}$ is the annual lost productivity associated with physical inactivity in L.A. County.

7. Recreation

Description of benefit: The value of newly accessible green spaces for recreation

SCWP metric inputs (units): New green space added (acres)

Methods and assumptions: Recreational benefits have been based on consumer surplus—that is, the value of outdoor recreation to park visitors (reported as willingness-to-pay) beyond any costs incurred to visit those parks (e.g., transportation). Consumer surplus per day was based on a conservative estimate of $3.22 (USD 2020) reported by Hansen et al. 1990.[32] Visitation to neighborhood parks was based on the 2016 RAND study, which estimated 14–22 thousand adult visitors per acre, per year to City of Los Angeles Neighborhood Parks. Multiplying consumer surplus by visitation results in a range of $44–$71 thousand USD 2020 per acre, per year.

Formula:

$$\text{VRec}_{CS/yr} = \text{GS}_{yr} \times \text{RecCS}_{acre/yr}$$

where GS_{yr} is acres of additional green space added each year by the SCWP, and $\text{RecCS}_{acre/yr}$ is the consumer surplus of urban outdoor recreation in per-acre, per-year terms.

8. Mitigation of Urban Heat Island Effect: Public Health

Description of benefit: Avoided health impacts due to the ability of tree canopy to reduce urban heat.

SCWP metric inputs (units): New tree canopy added (acres).

Methods and assumptions: The urban heat island (UHI) effect refers to the tendency for urban areas to retain heat more than nearby rural areas. Multiple factors are known to contribute to the UHI effect, including impervious surfaces (e.g., concrete, asphalt, rooftops), building structures and configurations

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[31] Bolin, K. 2018. Physical inactivity: productivity losses and healthcare costs 2002 and 2016 in Sweden. BMJ Open Sport and Exercise Medicine, 4(1), e000451.

[32] Hansen, W.J., A.S. Mills, J.R. Stoll, R.L. Freeman and C.D. Hankamer. 1990. A case study application of the contingent valuation method for estimating urban recreation use and benefits. National Economic Development Procedures Manual - Recreation, Volume III. IWR Report 90-R-11. Fort Belvoir, VA: US Army Corps of Engineers.

that restrict air circulation and the release of infrared radiation, and relatively low proportions of green space capable of providing evaporative cooling and shade.

UHI effects during heat waves have been associated with both morbidity and mortality impacts, especially among the most vulnerable: children, the elderly, and low-income populations with less access to air conditioning.[33] Those living on limited and fixed incomes are also more likely to live in neighborhoods with higher rates of ambient air pollution, which may interact with higher temperatures in harmful and even deadly ways.[34] A recent CDC study of heat-related deaths in the U.S. between 2004 and 2018 found those aged 65 and above were most vulnerable.[35] Non-Hispanic American Indians and Alaska Natives had the highest rate of heat-related deaths, followed by non-Hispanic Black people. Arizona, California, and Texas accounted for 37 percent of all heat-related deaths, despite accounting for just 23 percent of the national population of these groups.

Estimating the value of the mitigation of morbidity and mortality by each additional acre of tree canopy follows an avoided cost approach, in which the value of the current tree cover is used to estimate losses which may have been occurred in the absence of the existing tree canopy, based on the 2020 TreePeople inventory.[36] This entailed first identifying the ability of tree canopy to mitigate urban heat reported by McDonald et al. (2020), and the effects of elevated heat on morbidity and mortality as reported by Sinha et al. (2021). [37,38] Note that heat-related morbidity rates were based on renal and respiratory illness—the primary drivers of elevated heat morbidity—for those 65 and older, following Gronlund et al. (2014), but the mortality calculation reflects all age groups, due to the less-granular data provided by the CDC and Medina-Ramon and Schwartz (2007). [39,40]

Once the (indirect) relationships between tree canopy and morbidity and mortality had been characterized, the impacts were translated into monetary estimates. Heat-related hospitalization costs reported by Knowlton et al. (2011) provided a basis for estimating avoided morbidity (cost of illness)

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[33] Witze, A. 2021. Racism is magnifying the deadly impact of rising city heat. Nature 595, 349–351. https://doi.org/10.1038/d41586-021-01881-4

[34] Kioumourtzoglou MA, Schwartz J, James P, Dominici F, Zanobetti A. 2016. PM2.5 and mortality in 207 US cities: Modification by temperature and city characteristics. Epidemiology 27: 221-227.

[35] Vaidyanathan, A. 2020. Heat-Related Deaths—United States, 2004–2018. Morbidity and Mortality Weekly Report, 69: 24, 729–734. https://doi.org/10.15585/mmwr.mm6924a1

[36] TreePeople. 2020. Los Angeles County Tree Canopy Map Viewer. www.treepeople.org/los-angeles-county-tree-canopy-map-viewer/

[37] McDonald, R. I., Kroeger, T., Zhang, P., and Hamel, P. 2020. The value of US urban tree cover for reducing heat-related health impacts and electricity consumption. Ecosystems, 23(1), 137-150.

[38] Sinha, P., Coville, R.C., Hirabayashi, S., Lim, B., Endreny, T.A., Nowak, D.J., 2021. Modeling lives saved from extreme heat by urban tree cover. Ecological Modelling 449, 109553. https://doi.org/10.1016/j.ecolmodel.2021.109553

[39] Gronlund, C. J., Zanobetti, A., Schwartz, J. D., Wellenius, G. A., and O'Neill, M. S. 2014. Heat, heat waves, and hospital admissions among the elderly in the United States, 1992–2006. Environmental Health Perspectives, 122(11), 1187-1192.

[40] Medina-Ramon, M., & Schwartz, J. (2007). Temperature, temperature extremes, and mortality: a study of acclimatisation and effect modification in 50 US cities. Occupational and environmental medicine, 64(12), 827-833.

benefits. Heat-related deaths were assessed as the value of statistical life (VSL), a common approach to assess and compare large-scale impacts.[41,42]

The value per acre of tree canopy was estimated to range between $128.50 and $818.35 (USD 2020), based on the VSL, L.A. County hospitalization data, and literature estimates of hospitalization costs during heat waves in California. For the County as a whole, the current tree cover reduces mortality and morbidity costs by $600 million to $4.2 billion dollars each year.

A detailed description of the studies and methods used in this estimation have been reported in a supplementary technical report by Earth Economics that can be accessed upon request.

Table 4. L.A. County heat mitigation benefits of current tree canopy, persons per acre, per year

	Low	High
Avoided mortality	7	42
Avoided hospitalizations for acute kidney failure, population over 65	391	2,462
Avoided hospitalizations for obstructive pulmonary disease, population over 65	47	458

Again, mature trees can be expected to provide greater UHI effect mitigation benefits relative to new plantings. As with air quality estimates, these benefits have been adjusted by McPherson and Simpson's (2002) growth factor reflecting the age of trees planted for modeled SCWP projects.

Formula:

$$\text{VMitigUHI}_{yr} = \%\text{Dev(year since planting)} \times \text{Canopy}_{acres} \times \text{AvoidedCost}_{acre/yr}$$

where %Dev is a function of the time passed since a tree is planted and it reaches full maturity, Canopy_{acres} is the acres of new canopy cover, and $\text{AvoidedCost}_{acre/yr}$ is the estimated annual heat-induced health costs mitigated by an acre of tree canopy each year.

9. Temperature Regulation: Building Energy Cost Savings

Description of benefit: The reduced cost of cooling buildings associated with the heat mitigating effects of new trees planted for modeled SCWP projects

SCWP metric inputs (units): New trees added (count)

Methods and assumptions: Trees reduce the intensity of urban heat extremes through evaporative cooling and shade, thereby lowering demand for electricity to power air conditioning systems. As overall urban power demand continues to grow relative to power production, anything that reduces electricity consumption is likely to increase in value.[41]

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[41] Knowlton, K., Rotkin-Ellman, M., Geballe, L., Max, W., and Solomon, G. M. 2011. Six climate change–related events in the United States accounted for about $14 billion in lost lives and health costs. Health Affairs, 30(11), 2167-2176.

[42] US EPA. 2010. Valuing Mortality Risk Reductions for Environmental Policy: A White Paper (Reports and Assessments No. EE-0563). US Environmental Protection Agency.

The 2016 study by McPherson et al. estimated benefits provided by urban trees in terms of reduced demand for air conditioning, controlling for tree species and maturity, with shading effects based on aerial photographs.[28] Across the Southern California Coast, annual electricity savings from air conditioning reductions totaled 101 GWh/year (approximately 36.5 KWh per tree), for a total savings of $17.22 million per year (USD 2020). Most of this effect is attributed to reductions in peak summertime air temperatures, though around 25 percent of that value is derived from the direct shading of buildings. These savings are especially important to recognize as Los Angeles County pursues solutions to mitigate climate change.

As with other ecosystem services, trees become more effective at reducing energy costs as they mature. Accordingly, the cost savings formula per tree per year has been adjusted by a growth factor representing tree age, taken from McPherson and Simpson's 2002 study.

Formula:

$$VES_{tree/yr} = \%Dev(\text{year since planting}) \times Cost_{AC/yr}$$

where %Dev is a function of the time passed since a tree is planted and it reaches full maturity, and $Cost_{AC/yr}$ is the average annual cost of electrical power used for air conditioning.

10. Climate Regulation: Carbon Sequestration

Description of benefit: The value of standing biomass (e.g., trees, shrubs, grasses) to sequester and store atmospheric carbon

SCWP metric inputs (units): New groundcover added (acres); and new trees added (count)

Methods and assumptions: Trees and grasses grow by metabolizing atmospheric carbon as biomass. The value of sequestering a ton of carbon in terrestrial sinks has been estimated based on the avoided long-term damage a ton of carbon dioxide (CO_2) emissions in a given year would impose on future generations.[43] This is known as the Social Cost of Carbon (SCC).

To differentiate trees from other forms of green space, two methods were used to estimate the value of carbon sequestration from modeled SCWP projects. Sequestration rates for California grasslands and shrublands were derived from multiple sources (see Table 7), as well as rates per tree reported in local tree canopy inventories.[44] These rates were multiplied by the Social Cost of Carbon to arrive at a value estimate.[45]

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[43] US EPA, 2017. The Social Cost of Carbon: Estimating the Benefits of Reducing Greenhouse Gas Emissions. https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon.

[44] Los Angeles Parks. 2021. TreeKeeper Softwater. https://laparksca.treekeepersoftware.com/

[45] Interagency Working Group on Social Cost of Carbon. 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf?source=email

Like other benefits, carbon sequestration increases with tree age and size. Following McPherson and Simpson (2002), information on tree maturity in the SCWP context can be used to estimate annual carbon sequestration on a per-tree basis.

Formula:

$$VCS_{acre/yr} = \%Dev(\text{year since planting}) \times SC_{acre/yr} \times SCC$$

where %Dev is a function of the time passed since projects were first planted, $SC_{acre/yr}$ is carbon sequestered per acre of grasses and shrubs each year, and SCC is the social cost per ton of carbon.

$$VCS_{tree/yr} = \%Dev(\text{year since planting}) \times SC_{tree/yr} \times SCC$$

where %Dev is a function of the time passed since a tree is planted and it reaches full maturity, $SC_{tree/yr}$ is the carbon sequestered by one tree each year, and SCC is the social cost per ton of carbon.

11. Existence Value

Description of benefit: The non-use value of open space in urban contexts

SCWP metric inputs (units): New green space added (acres); and new tree canopy added (acres)

Methods and assumptions: Existence value describes the wellbeing gained from knowing that a particular natural feature or location exists, regardless of any practical utility for the persons valuing its persistence—as such, it is a passive, non-use benefit. The Exxon Valdez oil spill settlement established the legal validity of existence value, as well as a means of assessing its value in monetary terms. Estimating existence values relies on contingent valuation, survey-based methods that elicit willingness to pay to ensure that specific natural capital or environmental services persist.

The Exxon Valdez study estimated a lower bound of $2.8 billion (1990 USD) for the loss of ecosystems following the spill.[46] While existence value estimates often tend to be high, they have been approved for use in Natural Resource Damage Assessment (NRDA) methodology.[47]

The existence value of projects modeled for ARLA's SCWP Working Group Project was based on a 2020 global meta-analysis of contingent valuation studies on urban open space.[48] The statistical model from that study was applied to Los Angeles County—a method known as function transfer. By adjusting for the scale, population density, local income, and green space types proposed for Los Angeles County, it is possible to generate more accurate estimates of the existence value of open space within the County. The per acre estimates from the meta-analysis are $2,557 for new tree canopy and $3,377 for added

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[46] Carson, R.T., Mitchell, R.C., Hanemann, M., Kopp, R.J., Presser, S., Ruud, P.A. 2003. Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez Oil Spill. Environmental and Resource Economics 25: 257-286.

[47] Unsworth, R.E., Petersen, T.B., 1995. A Manual for Conducting Natural Resource Damage Assessment: the role of economics.

[48] Bockarjova, M., Botzen, W. J. W., and Koetse, M. J. 2020. Economic valuation of green and blue nature in cities: A meta-analysis. Ecological Economics, 169, 1-13.

green space. It is generally accepted that function transfer is more effective than transferring individual estimates.[49]

Note that this model focuses solely on per-acre and per-tree existence values, but not the importance of urban green spaces as wildlife habitat, nor landscape-scale configurations of green space. To the extent that SCWP projects enhance connectivity between other urban green spaces, it may also improve habitat quality, suggesting that this estimate may be a lower bound of total existence value. The equations of the original meta-analysis can be found in the source study.

12.Aesthetic Value (Hedonic Value)

Description of benefit: The value of improved appearance to Los Angeles County's neighborhoods associated with green infrastructure elements of modeled SCWP projects

SCWP metric inputs (units): New green space added (acres); and new trees added (count)

Methods and assumptions: Urban green spaces and parks often provide attractive views for nearby residents. To differentiate between new tree planting and more general green space, two methods were applied to estimate aesthetic benefits.

For new tree plantings, a lower estimate of added visual beauty per tree was provided by the 2016 McPherson study of the structure, function, and value of street trees in California. There are 2.7 million trees in the Southern California Coast that contribute \$278.6 million in aesthetic beauty each year, around \$101 per tree (USD 2020). The higher estimate of \$126.8 per tree, per year was provided by a 2019 TreeKeeper inventory for the City of Los Angeles.[50] Both estimates were derived from a function transfer model, and fall within the range of aesthetic values reported for California cities.[29] Moreover, the model addresses supply effects, in which the marginal value per-acre declines as the total extent of tree canopy increases. However, such effects only become apparent with relatively higher canopy extents.

Again, as trees mature, their aesthetic benefit increases. Accordingly, the valuation formula has been adjusted by the growth factor reported by McPherson and Simpson (2002).

Formula:

$$\text{VAes}_{\text{Trees/yr}} = \text{\%Dev(year since planting)} \times \text{Trees}_{\text{count}} \times \text{Aes}_{\text{tree/yr}}$$

where %Dev is a function of the time passed since a tree is planted and it reaches full maturity, $\text{Trees}_{\text{count}}$ is the number of trees planted, and $\text{Aes}_{\text{tree/yr}}$ is the estimated annual aesthetic value per mature tree.

The aesthetic value of new green space added by modeled SCWP project components was based on a 2020 global meta-analysis of contingent valuation studies on urban open space.[51] Applying function transfer (see the section on Existence Transfer, above), the original statistical model was adjusted for the

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[49] Brander, L.M., Koetse, M.J. 2011. The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. Journal of Environmental Management 92: 2763-2773.

[50] All values in the TreeKeeper model are current with 2020 USD.

[51] Bockarjova, M., Botzen, W. J. W., and Koetse, M. J. 2020. Economic valuation of green and blue nature in cities: A meta-analysis. Ecological Economics, 169, 1-13.

scale, population density, local income, and green space types using data from L.A. County Offices and the US Census. This produced an estimate of $3,225 per acre of open space each year (USD 2020).

Formula:

$$VAes_{GS/yr} = GS_{yr} \times Aes_{acre/yr}$$

where GS_{yr} is acres of new green space added annually by the modeled SCWP projects and $Aes_{acre/yr}$ is the annual per acre aesthetic value of green space.

It is important to note that as local aesthetics are improved by expanding urban green space, it can increase demand for real estate—and thus prices, including rents—in nearby neighborhoods.[52] Reducing displacement risks for those with limited and fixed incomes requires an understanding of the local drivers of displacement, and ensuring that new projects include anti-displacement programs. This will ensure that all residents can enjoy the benefits of additional green space in their neighborhoods.

Community Investment Benefits: Total Economic Contribution

Infrastructure spending in L.A. County supports both local and regional economic activity. The magnitude of these effects are modeled using input-output (I-O) analysis, which simulates spending across industries tied to specific activities. Project spending for planning, construction, operations, and maintenance generates additional local and regional economic activity, as firms purchase goods and services to maintain their businesses, pay employees (who then spend money on rent, food, and other expenses). This is known as the "multiplier effect," which can vary by project type.

Here, estimates of the total economic activity directly and indirectly associated with modeled SCWP project spending were taken from a 2011 I-O analysis by Burns and Flaming that examined the impacts of stormwater, recycled water, groundwater management and remediation, water conservation, and graywater systems projects in Los Angeles County.[53]

Project categories defined by this study are as follows:

1. *Stormwater*: detention, storage, treatment, recharge, use, and ecosystem restoration
2. *Recycled Water*: collection, detention, treatment, storage, and distribution
3. *Groundwater Management / Remediation*: treatment equipment, de-salting plants, and recharge facilities
4. *Water Conservation*: meter installations / sub-metering, indoor appliance/fixture retrofits, irrigation, landscape conversions, and education campaigns
5. *Graywater Systems*: indoor installation and retrofits, installation, filtration tank storage, treatment, and outdoor drip irrigation

A summary of this analysis (as applied to modeled SCWP project types) is presented in Table 5, below. Estimates included in the tool represent the low and high bounds for total economic output and jobs for

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[52] Curran, W., and Hamilton, T. 2012. Just Green Enough: Contesting Environmental Gentrification in Greenpoint, Brooklyn. Local Environment. 17(9), 1027–42.

[53] Burns, P. and Flaming, D. 2011. Water Use Efficiency and Jobs. Economic Roundtable Research Report, 2011. https://ssrn.com/abstract=2772795

both the planning and construction phase and the Operations and Maintenance (O&M) phase, and are consistent with the broader literature.

Table 5. Total economic contribution (USD 2020) and jobs supported per $1 million in spending, Burns and Flaming (2011)

	Stormwater	Recycled Water	Groundwater Management	Water Conservation	Graywater
Planning and Construction (initial)					
Total economic output	$1,992,674	$1,956,156	$1,965,899	$2,094,898	$1,910,962
Multiplier$_{Constr}$	*1.9927*	*1.9562*	*1.9659*	***2.0949***	***1.9110***
Total jobs	13.1	12.6	12.8	16.6	14.9
Employment Multiplier$_{Constr}$	*0.00001310*	***0.00001260***	*0.00001280*	***0.00001660***	*0.00001490*
O&M (annual)					
Total economic output	$1,989,059	$1,864,379	$2,002,640	*	*
Multiplier$_{o\&m}$	*1.9891*	***1.8644***	***2.0026***	*	*
Total jobs	13.8	10.0	13.9	*	*
Employment Multiplier$_{o\&m}$	*0.00001380*	***0.00001000***	***0.00001390***	*	*

The fields highlighted in green represent minimum and maximum per-dollar multipliers across all project types for both planning and construction and O&M phases. These multipliers are used in the equations below to calculate total economic contribution and total jobs supported by SCWP project spending; this broad range was chosen to capture the total range of all possible SCWP project types, which could conceivably fit into all five project categories.

13. Contribution from Spending on Planning and Construction Activities

Description of benefit: The total economic activity spurred by spending on planning and construction activities for modeled SCWP projects

SCWP metric inputs (units): SCWP projected planning and construction budgets in this Project (USD 2020)

Methods and assumptions: To estimate the total economic contribution generated from modeled SCWP investments in this Project, selected multipliers were applied to project planning and construction budgets.

Formula:

$$\text{TEC}_{\text{Constr}} = \text{Multiplier}_{\text{Constr}} \text{ x } \text{Budget}_{\text{Constr}}$$

where Multiplier$_{\text{Constr}}$ is the two planning and construction spending multipliers (highlighted in green, Table 5) from Burns and Flaming (2011) and Budget$_{\text{Constr}}$ is the initial expenditure on planning and construction of modeled SCWP projects. Using both planning and construction multipliers produces a range of estimated total economic output rather than a single estimate.

This approach assumes that construction is completed within one year. It is also limited to the economy of Los Angeles County and cannot account for future shifts in prices and structural changes in the linkages between local industries.

14. Contribution from Spending on O&M Activities

Description of benefit: The total economic activity spurred by spending on Operations and Maintenance (O&M) of modeled SCWP projects

SCWP metric inputs (units): SCWP projected annual O&M project budgets in this Project (USD 2020)

Methods and assumptions: As with the contribution analysis of planning and construction spending, selected multipliers were applied to annual project O&M budgets

Formula:

$$\text{TEC}_{o\&m} = \text{Multiplier}_{o\&m} \text{ x } \text{Budget}_{o\&m/yr}$$

where $\text{Multiplier}_{o\&m}$ is the two O&M spending multipliers (highlighted in green, Table 5) from Burns and Flaming (2011), and $\text{Budget}_{o\&m/yr}$ is the annual O&M budget for modeled SCWP projects. Using both O&M spending multipliers produces a range of estimated total economic output rather than a single estimate.

Community Investment Benefits: Jobs

Infrastructure investments are among the most efficient strategies to create new jobs providing family-supporting wages to workers with little formal education. Programs fostering on-the-job training can work their way out of poverty—an achievement in line with one of the goals in Measure H as well as Measure W (passed by L.A. County voters in 2017 and 2018, respectively).

In addition to estimating contributions to local economies from project spending, I-O analyses can also estimate employment throughout a project lifecycle. Burns and Flaming's estimates of the jobs created by water efficiency projects were applied here. However, there are several caveats to these results. First, I-O approaches are better suited for modeling large-scale contributions, which may not accurately describe all SCWP projects. Second, it is not possible to differentiate between "green" jobs and other positions.[54] The biggest challenge in estimating job creation benefits is whether new jobs are actually created, or the project simply results in shifts of the current labor force. Positions filled by those who are simply changing jobs cannot be reliably identified.

15. New Planning and Construction Jobs

Description of benefit: The total planning and construction jobs created by modeled SCWP projects

SCWP metric inputs (units): SCWP projected planning and construction budget in this Project (USD 2020)

Methods and assumptions: To estimate the total economic contribution generated from modeled SCWP investments, selected multipliers were applied to project planning and construction budgets

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[54] See page 47, Table 5.2 in Burns and Flaming (2011) for the list of industry sectors that are supported by stormwater project spending.

Formula:

$$\text{Jobs}_{\text{Constr}} = \text{EmploymentMultiplier}_{\text{Constr}} \text{ x } \text{Budget}_{\text{Constr}}$$

where $\text{EmploymentMultiplier}_{\text{Constr}}$ is the two planning and construction employment multipliers (highlighted in green, Table 5) from Burns and Flaming (2011), and $\text{Budget}_{\text{Constr}}$ is the initial expenditure on planning and construction of modeled SCWP projects. Using both employment multipliers produces a range of estimated total economic output rather than a single estimate.

16. New Operations and Maintenance Jobs

Description of benefit: The total Operations and Maintenance jobs created by modeled SCWP projects

SCWP metric inputs (units): SCWP projected O&M budget in this Project (USD 2020)

Methods and assumptions: As with planning and construction, selected multipliers were applied to annual project O&M budgets

Formula:

$$\text{Jobs}_{\text{o\&m}} = \text{EmploymentMultiplier}_{\text{o\&m}} \text{ x } \text{Budget}_{\text{o\&m/yr}}$$

where $\text{EmploymentMultiplier}_{\text{o\&m}}$ is the two O&M employment multipliers (highlighted in green, Table 5) from Burns and Flaming (2011), and $\text{Budget}_{\text{o\&m/yr}}$ is the annual O&M budget for modeled SCWP projects. Using both employment multipliers produces a range of estimated total economic output rather than a single estimate.

Summary of Benefit Categories

Table 6. Summary of benefit category inputs for the tool (2020 USD)

Benefit Specific	Method	Input	Physical Unit	Low	High	Caveat
Aesthetic value	Benefit transfer	New Trees Added	Tree	$101	$120	Based on assumptions of the i-Tree tool and McPherson et al (2016).
Aesthetic value	Meta-Analysis	New Green Space Added	Acre	$3,225	$3,225	Meta-analysis. Ecosystem services are not perfectly transferable across sites.
Removal of air pollutants (Air Quality)	Avoided cost	New Groundcover	Acre	$46	$46	Based on a national-level study.
Removal of air pollutants (Air Quality)	Avoided cost	New Trees Added	Tree	$9	$9	
Carbon sequestration (Climate Stability)	Avoided cost	New Groundcover	Acre	$57	$96	Carbon sequestration rates can be strongly influenced by management practices.
Carbon sequestration (Climate Stability)	Avoided cost	New Trees Added	Tree	$18	$18	Baseline sequestration rates are based on street trees in Modesto, CA, as reported by McPherson and Simpson (2002).
Existence value	Meta-Analysis	New Canopy	Acre	$2,557	$2,557	Meta-analysis. Ecosystem services are not perfectly transferable across sites.
Existence value	Meta-Analysis	New Green Space Added	Acre	$3,377	$3,377	
New total planning and construction jobs added	Input-output analysis	Projected planning and construction budget	Jobs/$1 million	12.6	16.6	Static I-O analysis of economic impacts of water use efficiency projects using the 2009 social accounting matrix for L.A. County. Numbers for stormwater and recycled water projects were selected. Assumes construction finishes in one year.
New total O&M jobs added	Input-output analysis	Projected annual O&M budget	Jobs/$1 million	10	13.9	
Economic contribution of spending in planning and construction	Input-output analysis	Projected planning and construction budget	Economic contribution per $1 million spending in stormwater and recycled water projects	$1,910,962	$2,094,898	
Economic contribution of spending in O&M	Input-output analysis	Projected annual O&M budget	Economic contribution per $1 million spending	$1,864,379	$2,002,640	

			in stormwater and recycled water projects			
Physical activity (public health)	Avoided cost	New Green Space Added	Acre	$9,719	$15,878	Visitor data from a study of neighborhood parks in the City of Los Angeles. L.A. County Department of Parks and Recreation does not have its own estimates.
Physical activity (productivity)	Avoided cost	New Green Space Added	Acre	$7,137	$11,659	
Recreation (Consumer surplus)	Consumer surplus	New Green Space Added	Acre	$43,699	$71,389	
Mitigation of UHI effect on health (Public health)	Avoided cost	New Canopy	Acre	$128	$815	Based on national and regional impacts. Does not account for local temperatures.
Water Quality	Alternative Cost	Pounds of zinc removed per year	Pounds	$3,173	$3,173	Least-cost alternative developed by Craftwater models. Includes all combinations of structural solutions, but does not consider the impact of non-structural stormwater management approaches.
Groundwater recharge (Water Supply)	Alternative cost	New Water Captured Annually	Acre-foot	$634	$966	Assumes that all "new water captured" will recharge an aquifer that is used for water supply in L.A. County
Stormwater reclamation (Water Supply)	Alternative cost	New Water Captured Annually	Acre-foot	$755	$755	

Valuation Studies

Table 7. Studies informing economic analysis of benefits

Aesthetic
McPherson, E. G., van Doorn, N., & de Goede, J. 2016. Structure, function and value of street trees in California, USA. *Urban Forestry & Urban Greening*, 17, 104-115.
McPherson, E. G., & Simpson, J. R. 2002. A comparison of municipal forest benefits and costs in Modesto and Santa Monica, California, USA. *Urban Forestry & Urban Greening*, 1(2), 61-74.
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Bakshi, B. R., Ziv, G., Hirabayashi, S., Gopalakrishnan, V. 2018. Air Quality and Human Health Impacts of Grasslands and Shrublands in the United States. *Atmospheric Environment* 182: 193-199.
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Carbon Sequestration
DeLonge, M.S., Ryals, R., Silver, W. 2013. A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands. *Ecosystems* 16: 962-979.
Duarte, C.M., Middelburg, J.J., Caraco, N. 2005. Major role of marine vegetation on the oceanic carbon cycle. *Biogeosciences* 2: 1-8.
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Lu, X., Kicklighter, D., Melillo, J., Reilly, J., Xu, L., 2014. Land carbon sequestration within the conterminous United States: Regional- and state-level analyses
Milesi, C., Elvidge, C.D., Dietz, J.B., Tuttle, B.T., Nemani, R.R., Running, S.W. 2005. A strategy for mapping and modeling the ecological effects of US lawns. Proceedings of the ISPRS Joint Conference.
Petrie, M. D., Collins, S. L., Swann, A. M., Ford, P. L., & Litvak, M. E. 2015. Grassland to shrubland state transitions enhance carbon sequestration in the northern Chihuahuan Desert. *Global Change Biology*, 21(3), 1226-1235.
Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. USDA Forest Service Northeastern Research Station, General technical report NE-343.
Building Energy Savings
McDonald, R. I., Kroeger, T., Zhang, P., & Hamel, P. 2020. The value of US urban tree cover for reducing heat-related health impacts and electricity consumption. *Ecosystems*, *23*(1), 137-150.
McPherson, E. G., & Simpson, J. R. 2002. A comparison of municipal forest benefits and costs in Modesto and Santa Monica, California, USA. *Urban Forestry & Urban Greening*, 1(2), 61-74.
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McPherson, E. G., & Simpson, J. R. 2003. Potential energy savings in buildings by an urban tree planting programme in California. *Urban Forestry & Urban Greening*, *2*(2), 73-86.
Existence Value
Brander, L.M., Koetse, M.J. 2011. The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. *Journal of Environmental Management* 92: 2763-2773.

Bockarjova, M., Botzen, W. J. W., & Koetse, M. J. 2020. Economic valuation of green and blue nature in cities: A meta-analysis. *Ecological Economics*, 169, 1-13. [106480].

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Imhoff, M. L., Zhang, P., Wolfe, R. E., & Bounoua, L. 2010. Remote sensing of the urban heat island effect across biomes in the continental USA. *Remote Sensing of the Environment*, *114*(3), 504-513.

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Physical Activity: Health

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State Indicator Report on Physical Activity. 2014. Retrieved from: www.cdc.gov/physicalactivity/downloads/pa_state_indicator_report_2014

Chenoweth, D., & Leutzinger, J. 2006. The economic cost of physical inactivity and excess weight in American adults. *Journal of Physical Activity and Health*, 3(2), 148-163.

Cohen, D., McKenzie, T., Sehgal, A., Williamson, S., Golinelli, D., Lurie, N. 2011. Contribution of Public Parks to Physical Activity. American Public Health Association.

Ferguson P., Xiangyi J., Leenhouts K., Woo, H. 2014. The Los Angeles Parks Foundation: A Study of the 50 Parks Initiative. Sol Price School of Public Policy, University of Southern California.

Physical Activity: Productivity

Bolin, K. 2018. Physical inactivity: productivity losses and healthcare costs 2002 and 2016 in Sweden. *BMJ Open Sport & Exercise Medicine*, 4(1), e000451.

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Recreation

RAND. 2016. City of Los Angeles Neighborhood Parks: Research Findings and Policy Implications (2003-2015)

Hansen, W.J., A.S. Mills, J.R. Stoll, R.L. Freeman and C.D. Hankamer. 1990. A case study application of the contingent valuation method for estimating urban recreation use and benefits. National Economic Development Procedures Manual - Recreation, Volume III. IWR Report 90-R-11. Fort Belvoir, VA: US Army Corps of Engineers.

Market Benefits: Jobs and Economic Contribution

Burns, P. and Flaming, D. 2011. Water Use Efficiency and Jobs. Economic Roundtable Research Report, 2011. https://ssrn.com/abstract=2772795

Water Quality

Refer to Craftwater Model

Water Supply

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Other Water Quality Valuation Methods Considered but Not Included

Measuring Water Quality Benefits via Stormwater Retention Capacity

Stormwater is a growing problem for the County, driven by urban expansion and a growing population. Impervious surfaces (e.g., streets, rooftops, parking lots) collect pollutants; when rains fall on these surfaces, that contamination is transported to the nearest storm drain and water body. Capturing stormwater also means capturing the many pollutants it transports; vegetated green infrastructure—such as rain gardens, street trees, and bioswales—help to slow, capture, and filter stormwater runoff.

The broader literature estimates gallons of stormwater retained per acre of green infrastructure, and it is possible to estimate the economic value of those gallons. These estimates are sourced from different watersheds, and focus on different BMPs. Ultimately, this valuation approach was rejected because it did not directly address water quality, and did not offer the same level of specificity as the watershed models.

Measuring Water Quality Benefits via Nitrogen and Phosphorus Removal Capacity

Excessive nutrients are also a leading cause of water quality impairments nationwide. While nitrogen and phosphorus occur naturally in surface waters, excess quantities can lead to algal blooms and lower dissolved oxygen levels, and can produce toxins harmful to humans and other organisms.[55] These nutrients are found in human and animal waste as well as in artificial fertilizers, soaps, detergents, and other industrial and municipal waste.[56,57] Nutrients can be directly discharged into surface water streams or as runoff to streams bound to sediment when erosion occurs. All sections of the Los Angeles River have been classified as impaired under CWA Section 303 for nutrients and algae.[58]

This analysis considered using the cost of nitrogen and phosphorus removal at water treatment facilities and the health costs associated with excess nitrogen in the aquatic environment to create a range of estimated benefits of removing nutrients that would be achieved by the modeled SCWP projects. Ultimately, this approach was rejected because nitrogen and phosphorus are but one of many pollutants of concern in the watershed, and isolating one or both of these values to the exclusion of others only captures a fraction of the value of water quality as a whole. Additionally, the Craftwater model was not specifically calibrated to measure nitrogen and phosphorus reductions—instead focusing on zinc—and so mapping nutrient removal benefits onto the model would have relied on assumptions that would have produced relatively imprecise results.

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[56] Jiang, F., Beck, M.B., Cummings, R.G., Rowles, K., Russell, D., 2004. Estimation of Costs of Phosphorus Removal in Wastewater Treatment Facilities: Construction De Novo. Water Policy Working Paper #2004-010.

[57] US EPA Office of Science and Technology, 2003. Strategy for Water Quality Standards and Criteria (No. EPA-823-R-03-010). US Environmental Protection Agency.

[58] California EPA Los Angeles Regional Water Quality Control Board. 2021. L.A. River Watershed Impaired Waters www.waterboards.ca.gov/rwqcb4/water_issues/programs/regional_program/Water_Quality_and_Watersheds/ws_losangeles.shtml

Water Quality: Avoided Cost of Violations

Contaminated surface waters negatively impact both humans and environmental systems. Failure to comply with national and state environmental standards has direct costs to taxpayers, through fines and other penalties. In 2008, Los Angeles County was sued for over 500 violations of the Clean Water Act related to polluted stormwater discharge.[59] In principle, fines, penalties, and litigation settlements can be used to approximate the cost to bring water quality into compliance with environmental standards—an avoided cost approach. Digging into the data revealed several concerns. In practice, some fines leveled for violations are never actually paid, and when they are, many are negotiated down—if a fine is never paid, it cannot be an avoided cost. Also, other alleged violations are not settled by payments, but rather additional investments in projects that protect water quality—this approach would not account for the value of the non-punitive investments. Finally, fines are not based on unit measures of water quality impairment, and so do not precisely speak to water quality. Ultimately, lacking a consistent and transparent indicator of avoided legal costs actually paid, this approach to assessing Water Quality benefits was not pursued.

Water Quality: Bacteria Reduction

Blooms of disease-causing bacteria can increase water treatment costs and impact swimming, fishing, and boating, and expose swimmers and surfers to infections. A 2017 study reported that kayakers on the L.A. River can encounter E. coli bacteria levels 100 times federal limits. Public health and safety agencies in Los Angeles County recommend swimmers avoid surface waters for at least three days following rain.[60] The benefits of reducing disease-causing bacteria through modeled SCWP projects in L.A. County could not be included, due to a lack of supporting research.

Reducing the amount of any pollutant means economic benefits that can be realized in the form of lower costs of treatment, compliance, and reduced impacts on public health and the environment. However, it is unclear how often recreational users are encountering bacteria-laden stormwater, how often they get sick in response to increased levels of bacteria in that stormwater, and what those costs of illness are. The valuation literature does not identify increased public health benefits per unit of bacteria reduced; no data exist to accurately measure the positive impact of marginal stormwater quality improvements, and such an effort would only capture a fragment of the total value of water quality.

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[59] Arnold, B.F., Schiff, K.C., Ercumen, A., Benjamin-Chung, J., Steele, J.A., Griffith, J.F., Steinberg, S.J., Smith, P., McGee, C.D., Wilson, R., Nelsen, C., Weisberg, S.B., Colford, J.M., 2017. Acute Illness Among Surfers After Exposure to Seawater in Dry- and Wet-Weather Conditions. Am J Epidemiol 186, 866–875. https://doi.org/10.1093/aje/kwx019

[60] Guerin, E., 2017. They didn't know the LA River was full of E. coli—but public officials did. Southern California Public Radio. URL: https://archive.kpcc.org/news/2017/09/20/75770/la-river-who-s-minding-health-risks-to-boaters

Benefit Categories for Future Consideration

Based on existing Earth Economics tools and data and similar valuation reports, future benefit categories of consideration could include education, enhanced property value, tourism, and community cohesion.[61, 62,63]

Understanding of the benefits of SCWP projects and similar improvements for water management in L.A. County demands further research on at least two fronts: (1) engineering research on the types of water capture and management projects that can help address the challenges facing L.A. County; and (2) enhancing knowledge of the avoided harms and generated benefits of available public investment options, particularly for areas of historic disinvestment. Filling in these knowledge gaps can help provide critical context for decision-making at all levels. As this manual shows regarding the second type of information gap, a holistic and robust benefit-cost analysis of L.A. County water improvements is limited by the current technologies, data inputs, and assumptions. From the public health benefits of water quality improvements to the avoided cost of closures due to water quality impairments, there are important benefit categories not currently included due to data limitations. Further, local research could supply better data and support more robust methods for the valuation of metrics currently included in this manual and tool. Public input, particularly from communities facing greater environmental harms, should be the first step in informing directions for future research.

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[61] Pourat, N., Martinez, A. E., Haley, L. A., and Chen, X. 2018. Parks After Dark Evaluation Brief. Policy Brief (UCLA Center for Health Policy Research), (4), 1-12.

[62] Trust for Public Land. 2017. The Economic Benefits of the Public Park and Recreation System in the City of Los Angeles, California. www.tpl.org/econbenefits-losangeles

[63] *Community cohesion* is a loosely defined term that reflects aspects of neighborhood identity, safety, and trust. The literature connecting green infrastructure and community cohesion aspects is site-specific. To support valuation of this benefit, additional data from Los Angeles County is needed. However, local experiments suggest that this benefit could be substantial. In 2010, the Los Angeles Department of Parks and Recreation began the "Parks After Dark" (PAD) program, extending park operating hours on summer weekends in unincorporated areas of the County. The PAD program offers free activities and resources for people of all ages. It began as part of the County's Gang Violence Reduction Initiative, and has since expanded to 33 parks. A 2017 evaluation reported a 76 percent reduction in crimes across all PAD communities. In addition, there has been a substantial increase in physical activity by park visitors and lowered risk of chronic disease. Greater social cohesion and community wellbeing have also been observed. A 2018 survey reported that 90 percent of participants said PAD makes it easier to spend quality time with their families, and 91 percent indicated PAD helps them to know their neighbors. Also, 89 percent said they knew people they could contact in a crisis (Pourat et al. 2018).