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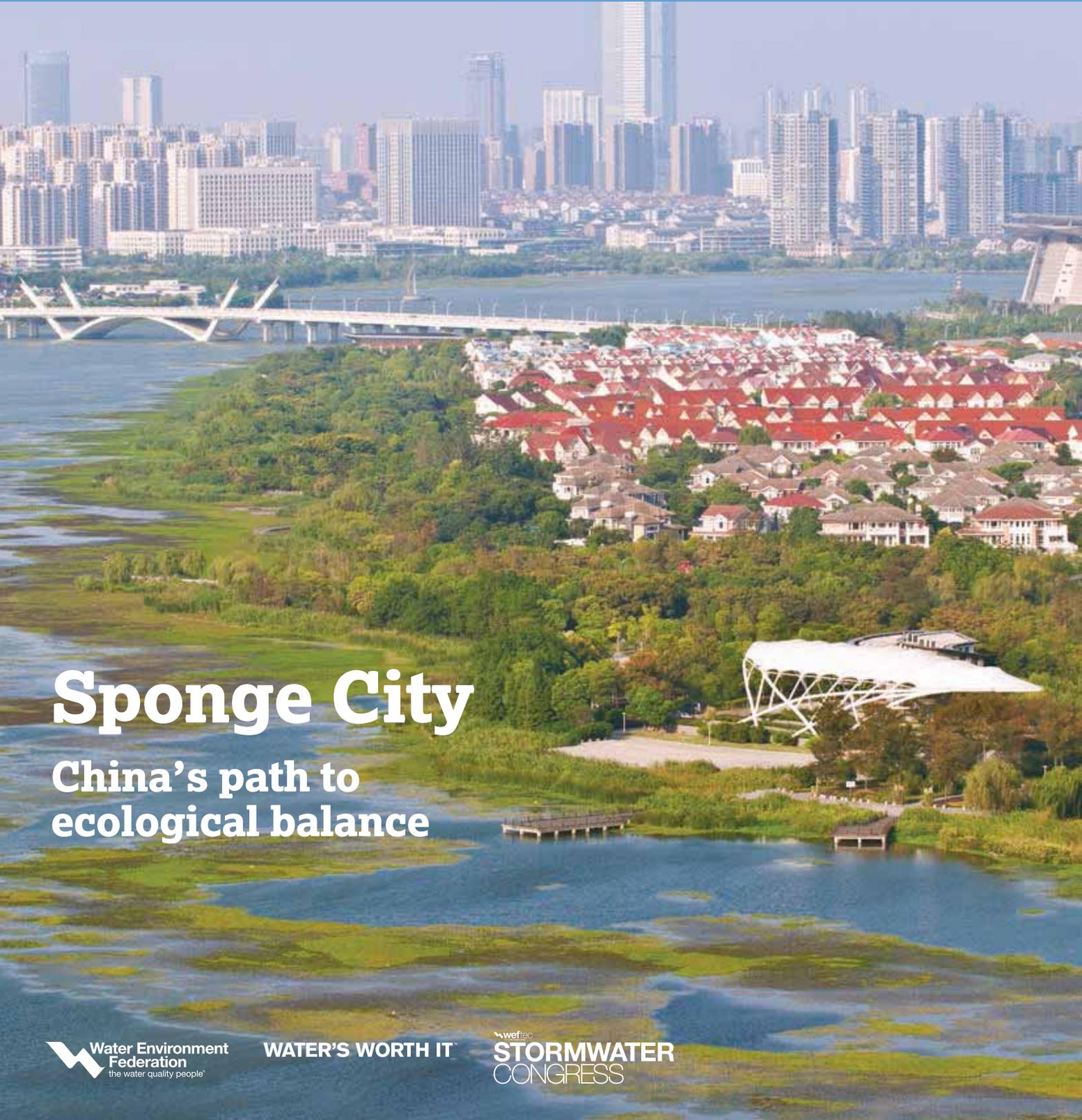
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Sponge City

China's path to ecological balance

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46 Lexington, 40 City Road
London EC1Y 2AN, United Kingdom
Tel: +44 207 251 8778 / Fax: +44 207 336 0377
www.wefworldwater.com

WEF Head Office

601 Wythe Street, Alexandria
VA 22314-1994, USA
www.wef.org

Executive Director WEF

Eileen J. O'Neill, Ph.D.

Group Publisher Jack Benson
jbenson@wefpublishinguk.com

Editor-in-Chief Pamela Wolfe
pwolfe@wefpublishinguk.com

Executive Editor Seth Brown
sbrown@wef.org

Associate Editor Kristina Twigg
ktwigg@wef.org

Publisher Nic Christy
nchristy@wefpublishinguk.com

Subscription Enquiries

Portland Services
Tel: +44 (0) 1206 796351
sales@portland-services.com

Global Advertising Representatives

Asia and Europe excluding Italy
Stephen (Sid) James
Tel: +44 0207 993 4605 / Cell: +44 7956 640454
sjames@wef.org

Italy

Fabio Potesta
Mediapoint & Communications SRL
Corte Lambruschini, Corso Buenos Aires, 8
5 piano - interno 7/6, 16129 Genova, Italy
Tel: +39 010 5704948 / Fax: +39 010 5530088
info@mediapointsrli.it

Israel

Zvi Segal Direct Media – Marketing Services
24 Hayovel Street, Raanana 43401
(PO Box 306, Raanana 43103) Israel
Tel: +972 9 748 1806 / Fax: +972 9 741 3284
segdir@inter.net.il

North Eastern U.S. and Canada

Dave Mathews and Vickie Bobo
308 Tribble Gap Road, Suite 6, Cumming, GA
30040, USA
Toll Free: +1 866 756 7811
Tel: +1 678 947 9950 / Fax: +1 678 947 9244
dmathews@wef.org
vbobo@wef.org

Western U.S. and Canada

Tom Brun and Janice Jenkins
Arnold Palmer Regional Airport
148 Aviation Lane, Suite 307, Latrobe,
PA 15650
Tel: +1 724 539 2404 / Fax: +1 724 539 2406
tbrun@wef.org
Janice Jenkins direct +1 724 929 3550
jjenkins@wef.org

South East US and Latin America

Cari McBride
601 Wythe St., Alexandria, VA 22314, USA
Office phone: +1 703 535 5266
Mobile: +1 703 626 7449 / Fax: +1 703 229 6499
cmcbride@wef.org

Other information

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Cover image Wetland city landscape in China.
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Stream daylighting – A viable CSO mitigation strategy

Drawing on a large case study in the US city of Cincinnati, Ohio **Robert Hawley** of Sustainable Streams, LLC; **John Lyons** of Strand Associates; **Gary Wolnitzek** of Human Nature, Inc.; and **MaryLynn Lodor** of the Metropolitan Sewer District of Greater Cincinnati report on how stream daylighting can reduce combined sewer overflows and revitalize communities.

In the 1800s and early 1900s, massive public works investments in sanitation and drainage across the United States improved public health by systematically routing both stormwater and wastewater away from homes and public spaces. Combined with the incorporation of filtration and chlorination technologies in potable water systems, these investments are credited with achieving the largest declines in US mortality rates compared to any other century. A National Bureau of Economic Research working paper published in 2004 suggests a 23-to-1 return on investment.

Because conveyance networks were designed to flow by gravity, they typically followed natural drainage patterns. In many cases, this resulted in routing stormwater and wastewater into a combined sewer system, and often coincided with the burial of small creeks and streams. In valleys with streams that were too large to be economically buried, the sewer network generally ran parallel to the stream network.

During dry weather conditions, wastewater would flow by gravity through the sewer network to a treatment plant. Most of these combined sewer systems, however, were designed with overflow points where mixed wastewater and stormwater were intentionally routed to sections of the remaining surface stream network during rain events. This would further dilute and convey sewage downstream.

Today, such combined sewer overflows (CSOs) are considered counter to Clean Water Act goals. However, it is important to remember that the combined sewer system approach was considered the standard of the time and contributed to tremendous improvements in urban sanitation across dozens of major US cities.

Enclosure of surface channels into more hydraulically efficient subsurface pipes is a practice that still occurs today as development expands to suburban and exurban areas. A 2009 study in the *Journal of the North American Benthological Society* published by US Environmental Protection Agency (EPA) researchers and colleagues suggests that urban areas typically have approximately 50 to 90 percent less headwater stream length than would be expected in forested drainages. For example, an analysis of Cincinnati, Ohio's stream networks suggests that only about 25 percent of the nearly 500 kilometers of estimated historic streams channels remain on the surface today.

Reversing the trend

Rather than being viewed as a nuisance, urban waterways and associated green spaces are increasingly considered socioeconomic and environmental resources. Beyond their conventional role of providing flood control services, urban streams offer numerous

ecosystem, cultural, and economic-development opportunities. Indeed, there are an increasing number of successful US urban redevelopment projects that revolve around prominent water features – from Yonkers, New York to San Antonio, Texas. Additionally, when compared to closed-pipe systems, streams provide immensely more habitat and water quality benefits. For example, EPA research published in a 2014 *Biogeochemistry* journal shows that urban streams tend to be about 20 to 30 times more effective at processing nitrate than their buried counterparts.

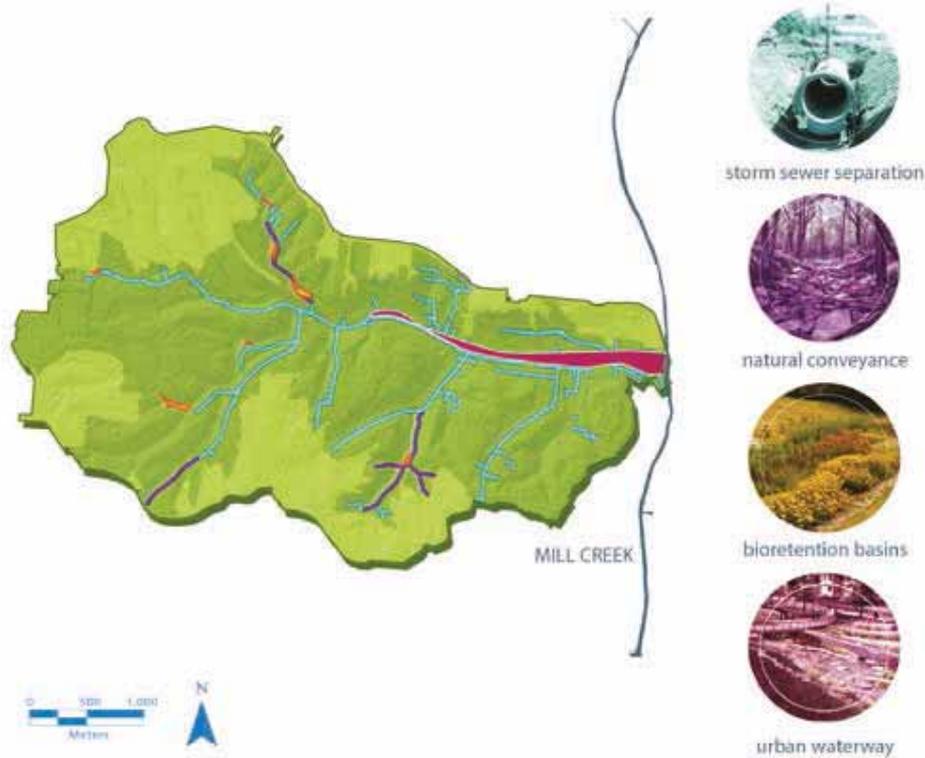
The wide appeal of high-quality urban waterways has led several municipalities to evaluate the concept of bringing these buried resources back to the surface. This process – referred to by some as stream daylighting – has been vetted as a particularly advantageous strategy for mitigating CSOs. Not only can it be more cost-effective than conventional gray approaches to CSO mitigation, it can also serve as a catalyst to urban renewal.

Such indirect benefits can be doubly advantageous for municipal sewer districts because the net effect of urban redevelopment is an expanded customer base. And compared to suburban sprawl – which requires new infrastructure but tends to have relatively low customer density – urban renewal enables sewer utilities to create greater revenue from areas where infrastructure is already in place.



The proposed Lick Run corridor with the urban waterway, mixed-use trails, native vegetation, and open spaces.
Renderings by Human Nature

THE WIDE APPEAL OF HIGH-QUALITY URBAN WATERWAYS HAS LED SEVERAL MUNICIPALITIES TO EVALUATE THE CONCEPT OF BRINGING THESE BURIED RESOURCES BACK TO THE SURFACE.



Community enhancement and revenue savings

A case study of the Lick Run sewershed in Cincinnati, Ohio, United States highlights some of the additional benefits of using stream daylighting as a CSO-mitigation strategy. The Lick Run sewershed drains to the Metropolitan Sewer District of Greater Cincinnati's (MSDGC's) largest-volume CSO. In a typical year, the outfall is estimated to discharge approximately two billion liters of combined sanitary and stormwater flows to Mill Creek, just upstream of its confluence with the Ohio River. The proposed gray solution to mitigate CSOs in this sewershed was the installation of a two-kilometer-long, nine-meter-diameter tunnel that would be buried more than 60 meters deep. The tunnel would store combined sewage during storm events and gradually pump the mixed stormwater and wastewater to the water reclamation facility. From there, it would undergo the conventional wastewater treatment.

Because monitoring shows that wet-weather flows are approximately two orders of magnitude greater than dry-weather flows, a large majority of combined flows pumped and treated would be stormwater. As a part of a 2006 EPA-approved consent decree to comply with the Clean Water Act, this gray approach became the default solution for the sewershed, with an estimated capital cost of more than US\$400 million.

As an alternative to making such a large infrastructure investment that would be buried 60 meters below ground and have little, if any, benefit to the declining neighborhood above, MSDCG evaluated a green alternative. The district examined whether it could create greater cumulative benefits to the community it serves at lower cost. The green alternative

involved the strategic interception and removal of stormwater from the combined sewer system. This solution would route surface runoff to a separate drainage network incorporating a combination of conventional pipe segments and green practices, such as bioswales and bioretention basins. The newly installed storm sewer system also would include several opportunities to uncover previously buried streams and reconstruct them as open channels. The centerpiece of the green alternative became the recreation of 1.5 kilometers of the historic Lick Run channel in Cincinnati's urban corridor.

Collectively, the green approach would save an estimated \$170 million relative to the tunnel alternative, while achieving comparable levels of CSO mitigation at Lower Mill Creek – making the project acceptable to state and federal regulators.

EPA has since approved the green approach, and portions of the plan are already constructed with others nearing construction and final design. Yet, making the green alternative for the Lick Run neighborhood a reality involved more than sound engineering and regulatory support. It also involved extensive stakeholder engagement, property acquisition and remediation of contaminated soils, utility coordination, transportation improvements, and more than 60 public meetings.

Maximizing the triple bottom line

Three well-attended public workshops during the master-planning phase showed that local stakeholders preferred the green alternative at a rate of 9 to 1 over the tunnel alternative. Stakeholders favored a solution that both provided a level of flood control and facilitated redevelopment of the urban corridor. Additionally, stakeholders showed a strong



preference for a controlled natural aesthetic in the Lick Run channel. This more controlled aesthetic was consistent with their goals of promoting urban renewal as well as mixed-use redevelopment, trails, open spaces, and more neighborhood-friendly traffic patterns.

To meet desired flood control performance, a hybrid design incorporated a separate box conduit to convey high flows ranging from greater than bankfull to approximately the 10-year storm. The hybrid approach also enabled the restored channel to mitigate the effects of the urban flow regime by converting otherwise erosive flows into hydraulics more representative of flows experienced in a natural watershed. Reduced surface channel velocities also resulted in safer conditions for the urban corridor and associated green spaces.

In addition to the Lick Run corridor, the green solution included the reconstruction of several buried channels at locations farther upstream in the watershed. One of these locations involved about 900 meters of stream daylighting in Glenway Woods Nature Preserve, which has a forested ravine setting within the city limits of Cincinnati. For approximately the last 100 years, stormwater runoff from within the 12-hectare forest was routed into the combined sewer system where it was either treated or contributed to CSOs.

For the daylighted stream segments in



distinct planting zones and habitat niches created by the cross-section design. It also met the stakeholder goal of a controlled natural aesthetic with open native meadows and riparian zones. The zones covered a gradient ranging from a low bench inundated during nearly every storm, to a high bench submerged about 10 to 40 times per year, to a floodway that would see flow on average only every 10 to 25 years. Plantings in each of these zones included distinct communities of native species that were appropriate for the respective inundation frequencies.

Progress with daylighting

In sum, both the urban corridor and nature preserve stream designs provide water quality benefits and reconstructed aquatic habitat that was buried for some 100 years and would have stayed buried indefinitely had MSDGC moved forward with the tunnel solution. The EPA-approved Lick Run alternative meets the obligations of MSDGC's consent decree for about \$170 million less than the tunnel alternative, provides additional community benefits, and serves as a model of a holistic watershed solution. Further, by tailoring the stream designs to stakeholder input, the projects were not only more appropriate for their respective settings but also more likely to succeed due to broader community support.

Authors' Note

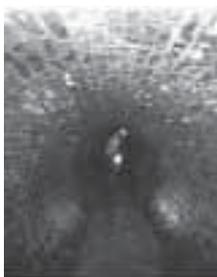
Robert Hawley is the principal scientist at US-based Sustainable Streams, a licensed professional engineer with a dozen years of experience on stream science and restoration, and has more than 70 total publications. He serves as a member of the Water Environment Federation's Stormwater Committee, an affiliate of the Civil and Environmental Engineering Department at Colorado State University, and a part-time instructor for the University of Kentucky's Civil Engineering Department.

John Lyons, director of operations at the Cincinnati, Ohio office of Strand Associates, is a licensed professional engineer with 28 years of private sector, regulatory, and municipal experience. He is a recognized leader in the use of sustainable alternatives for stormwater management to reduce CSOs, alleviate flooding, and provide opportunities for community enhancement.

Gary R. Wolnitzek, a licensed landscape architect of 30 years, is owner and principal of Human Nature, Inc., a Cincinnati-based consulting firm specializing in the planning and design of public open spaces and green infrastructure. He has extensive training in the preservation and restoration of natural systems as well as managing stormwater with natural systems.

MaryLynn Lodor, deputy director of the Metropolitan Sewer District of Greater Cincinnati in the US state of Ohio, holds a Master's of Science from Rensselaer Polytechnic Institute in Environmental Management and Policy and has over 20 years of experience in water and wastewater utilities. She serves on the board of local watershed organizations and is a member of the National Association of Clean Water Agencies' Stormwater Committee.

The rendering shows an aerial view of urban waterway features and open space areas along the Lick Run corridor for the US city of Cincinnati, Ohio's Lick Run Watershed. Renderings by Human Nature



the nature preserve, stakeholders preferred a more natural channel aesthetic than that of the urban corridor. Cross-section designs were intentionally irregular, with a mix of native creek rock that ranged in size from gravels to boulders with an abundant incorporation of large logs and root wads. In the nature preserve, about 600 meters of existing ephemeral tributaries were in good condition and could be preserved through the project rather than being redesigned. As such, work in those reaches primarily focused on invasive species removal and revegetation.

Both the urban corridor and nature preserve stream designs included appropriate habitat forms for their geomorphic setting, such as step-pools in steeper reaches and pool-riffles in flatter zones. Stone placement improved stability and mimicked the natural shape and character of the native limestone creek rock found in the region's streams. Regional curves published in the journal *Geomorphology* that included adjustments for watershed urbanization guided cross-section size.

All of the daylighted channels incorporated native vegetation across the riparian zones and floodplains. The planting plan for the nature preserve was consistent with the natural restoration aesthetic that included an irregular forest pattern. By contrast, the planting plan for the urban corridor followed

Above: A comparison between a natural stream and a buried stream enclosed in a brick combined sewer from the 1800s. Left photo by Robert Hawley, right photo from the Lick Run Master Plan, 2012

Above left: Illustrated map of the Lick Run Watershed in Cincinnati, Ohio, United States. Dark green shading indicates areas of Lick Run Watershed with strategic storm sewer separation. The blue lines show construction of a separate storm sewer network. Purple lines indicate open channels. Orange polygons represent bioretention basins. Magenta coloration shows the Lick Run urban waterway. Illustration by Human Nature