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Opportunities to Integrate Environmental Protection in Multi-objective Projects

Office of Research and Development
National Risk Management Research Laboratory, Ada, Oklahoma 74820

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Executive Summary

Nonpoint source pollution is an ongoing challenge for environmental agencies who seek to protect waters of the United States. The objective of water quality protection is increasingly needed to be incorporated in landscape projects throughout a watershed. Urban stream and waterfront redevelopment projects present opportunities to achieve integrated environmental, economic, and social benefits in urban waters. This report explores opportunities to incorporate environmental protection objectives into multi-objective landscape projects to create sustainable urban waters.

Based on available project performance information and representativeness of different site contexts, 15 stream restoration and waterfront redevelopment projects were selected and synthesized in this study. These projects include 14 U.S. projects (in 10 states) and one international project (in South Korea). Project information was retrieved from case study reports, project summaries, and journal articles, from sources including the websites of Landscape Architecture Foundation, American Society of Landscape Architects (ASLA), design firms, project partnerships, and local government. The projects in this study provided a variety of landscape performance benefits including: 1) environmental benefits of flood control, water quality protection, habitat creation, air quality control, carbon sequestration, enhanced urban microclimate, and soil protection and remediation, 2) economic benefits of increased property value, investment, retail sales, and local employment, and 3) social benefits of promoting public environmental education, increased recreational activities, and enhanced aesthetics. Projects in different context (downtown, urban, suburban, and rural) have different environmental, economic, and social benefits. In this study projects in downtown contexts provided the most comprehensive sets of benefits: perhaps because of increased economic and social needs in urban cores compared to less developed areas.

There are possibilities to incorporate water quality protection into multi-benefit stream restoration and waterfront redevelopment projects in urban waters. Strong partnerships are needed in project planning, implementation, and long-term management. Project outcomes should be pre-determined to integrate or reduce competing interests. Achieving water quality protection and urban economic development simultaneously can be challenging. A broader meaning of water quality protection should also be considered in decision making, such as public environmental education, sustainable stormwater management, and brownfield remediation.

1 Introduction

Humans have been changing stream channels for more than 4,000 years (Gregory, 2006). Many of today's streams share little similarities with streams that existed before human influence (Vought & Lacoursiere, 2010). Stream ecosystems are affected by human activities in both direct and indirect ways and the impacts are complex (Allan, 2004). In urban areas, streams have been greatly affected by urban expansion. Urbanization increases the loading of water and pollutants simultaneously while reducing a stream's ability to function as a natural ecosystem (Bernhardt & Palmer, 2007). Urbanization has created large amounts of impervious areas and greatly modified original natural hydrological regimes of many stream systems. The use of engineered water conveyance facilities in urban areas has altered or eliminated many important natural processes associated with water quality and water cycles (e g. sedimentation, plant uptake of nutrients, and groundwater recharge). Urbanized watersheds also create flashy streams, a condition of low base flows and high peak flows. Expanded impervious areas, increased pollutant loads, and changed hydrological flow path, can all contribute to decreased water quality in urban streams (Cadenasso et al., 2008).

For rural streams, agricultural activities in the past one and a half centuries have decoupled streams and their floodplains. Many agricultural lands in temperate North America were developed from floodplains. To maintain efficient water drainage, drainage-tile networks were constructed and stream channels had to be lowered. Many rural streams became simple drainage ditches, channelized and deeply incised. Natural nutrient filtering systems were thus bypassed, contributing to nutrient pollution in downstream waters (Vought & Lacoursiere, 2010). Studies showed that decreased water quality in watersheds is attributed to increased agricultural and urban land use. (Allan, 2004; Johnson, Richards, Host, & Arthur, 1997; Roy, Rosemond, Paul, Leigh, & Wallace, 2003).

Nonpoint source pollution from urban lands is an ongoing challenge for environmental agencies who seek to protect waters of the United States. Restoration of natural hydrological regime is needed to protect water quality of many urban streams. However, in-channel restoration alone should not be advocated as a compensatory mitigation measure, considering the limited evidence to date on its nitrogen (N) removal performance (Bernhardt, Band, Walsh, & Berke, 2008). In this report N removal denotes the reduction of N pollutants (reactive N). A holistic view is needed for N pollutant control in urban watersheds, recognizing the spatially distributed nature of urban land-water boundaries (Cadenasso et al., 2008). One possible strategy to control nonpoint source pollution is to promote the integration of water quality objectives into various multi-objective landscape projects in stream catchments. Bernhardt et al. (2008), suggest integrating N reduction strategies in urban land use and development objectives in urban areas. New urban projects and public investment should be evaluated according to their effects on N loading: ecological, economic, and social impacts of land-use and development decisions on N reduction are issues which need to be considered (Bernhardt et al., 2008).

Water quality protection and multi-purpose stream projects

In recent years there has been an increased recognition of the inter-connected benefits provided by restored stream ecosystems (Everard & Moggridge, 2012). In post-industrial societies, streams are increasingly viewed as ecosystems with multiple values instead of simply viewed as water resources (Graf, 1996), and sustainable stream management projects are conducted (Downs & Gregory, 2004) (Table 2-1). Stream restoration is an increasingly popular measure to improve the physical and ecological conditions of urban streams (Bernhardt & Palmer, 2007). But restorations are rarely about restoring sites back to historical natural conditions (Smith, 2013). To gain local support, raise project funds, and ensure long-term success, multiple objectives need to be addressed in restorations of stream ecosystems, including economic and social (aesthetic and recreational values) objectives (Everard & Moggridge, 2012; Graf, 1996; Tjallingii, 2012). To achieve water quality protection in sustainable ways, comprehensive and integrated restoration approaches are needed and synergies among the environmental, economic, and social aspects should be explored (National Research Council, 2011).

Table 1-1. Chronological phases of river use and management measures used

Chronological phases	Characteristic developments	Management methods
Pre-industrial era	Flow regulation Irrigation Drainage schemes Fish weirs Water mills Navigation	River diversions Ditch, canal construction Dredging Dam construction Land drainage In-channel structures
Industrial era	Flow regulation Irrigation Water supply Power generation Flood control Integrated use river projects Conservation management	Large dam construction River diversions Channelization Canal construction Structural and bioengineered revetments River basin planning Mitigation and restoration techniques
Post-industrial era	Conservation management Re-management of rivers Sustainable use river projects	Integrated river basin planning Hybrid and bioengineered revetments Mitigation and restoration techniques

(Adapted from Downs and Gregory (2004))

Stream restoration practices seek to enhance the quality and function of streams. A large scale stream restoration project could include the entire floodplain area, restoring more natural processes and recreating natural channel forms. Using green infrastructure can help restore stream systems by promoting sustainable drainage and biodiversity (RESTORE Partnership, 2013). Although ecosystem restoration has not traditionally been a practice to address water quality, the U.S. EPA is interested in its potential for water quality improvement. Restoration may be conducted on landscape components (e g. soil and plants) of watersheds to meet the goal of water quality protection in indirect ways (Jorgensen & Yarbrough, 2003). Therefore, this study proposes that stream restoration and waterfront redevelopment projects may be opportunities to restore natural site hydrology and protect water quality in watersheds by modifying landscape components of stream systems.

Creating sustainable stream systems that provide water quality protection

Water quality protection is one of many benefits that could be provided by stream restoration projects (Table 1-2). In this writing the term sustainable stream landscape system denotes stream systems that promote optimized multiple environmental, economic, and social benefits, under appropriate human management. Water quality protection is a requisite component of a sustainable stream system; a sustainable stream system promotes the protection and appropriate use of waters. This report explores the opportunities of integrating environmental objectives in urban waters. A systematic water quality control scheme could be integrated into various urban stream restoration and waterfront redevelopment projects to promote sustainable stormwater systems in municipalities.
The projects may better be promoted in communities if environmental, economic, and social benefits are balanced and optimized.

Table 1-2. Potential benefits of stream restoration

Environmental	Economic	Social
Flood control Erosion control Sustainable drainage systems Water quality protection Improved soil quality Wildlife habitat Water temperature control	Reduced cost of flood protection Increased land and property value Urban regeneration Employment and professional training Cost-saving stormwater management (use of natural systems)	Attractive waterfronts Sense of place Open space Engagement of local communities in decision-making about their environment

(Adapted from (J. Campbell et al., 2010; RESTORE Partnership, 2013))

The Urban Waters Federal Partnership, established in June 2011, to revitalize the nation's urban waters and waterfront municipalities, suggests ways to enhance the value and health of urban waters: 1) promote clean urban waters at watershed scales (including rural areas), 2) reconnect people to water landscapes (for environmental education and as a catalyst for economic development), 3) conserve water (by using design techniques and public education on water saving), 4) promote economic revitalization in urban waters (attract urban investment, increase employment), and 5) Encourage community involvement by forming partnerships (cross-agency at different levels of government, and with local stakeholders) (Urban Waters Federal Partnership, 2011).

By conducting a stream restoration or waterfront redevelopment, ecosystem processes and functions could be modified, along with the change in composition and organization of landscape elements (e g. stream channel, riparian wetlands, floodplain, and bank vegetation) in the systems. Therefore, there might be opportunities to integrate water quality protection in various landscape projects, including restoration and redevelopment projects. Environmental restorations are context-embedded, influenced by the historical, present, and projected future uses of lands (Smith, 2013). The natural processes and functions of urban streams may vary in different geological, hydrological, and social contexts. To explore using restorations to sustainably manage nutrient in watersheds, there is a need to look for project performance patterns according to project specifications and practices, performance benefits, and site context. The possible result may help to develop site prioritization to support decision making for watershed water quality protection. Therefore, there is a need to collect project information to learn: 1) how did the projects differ in their environmental, economic, and social performance, considering project specifications and practices, performance benefits, and site context? 2) How did these projects vary in their benefits on water quality protection, if we consider broader issues that relate to water quality (e g. enhanced stormwater management, increased riparian vegetation, and public appreciation of stream landscapes)? Restoration and redevelopment projects in different contexts could have different priorities on environmental, economic, and social objectives. A holistic view is needed and site context should be considered, when exploring ways to achieve sustainable water quality protection in urban waters.

2 Methods

The projects included in this analysis (Table 2-1) were selected based on availability of project information and representativeness of diverse site contexts. A total of 15 projects were analyzed. Project information was retrieved from a range of sources, including case study reports, project summaries, and journal articles. This study primarily uses online sources that include the websites of Landscape Architecture Foundation, American Society of Landscape Architects (ASLA), design firms, project partnerships, and local government (Table 2-2).

The data collected was organized into categories of: project specifications and practices, project performance benefits, and project context information (e g. municipality demographics, stream order, and stream type). Based on a preliminary review of project data, we speculated that site context of development density (downtown, urban, suburban, and rural) is potentially an important factor influencing the environmental, economic, and social performance benefits of restoration projects. Therefore, it was used to group the projects in individual project descriptions in this report. The 15 projects were sorted into 4 categories based on density of development: 1) downtown, 2) urban (refers to municipal areas excluding downtown and suburban, in this study), 3) suburban (or peri-urban, urban areas close to municipal boundary), and 4) rural. There were three downtown, eight urban, three suburban, and one rural project (Figure 2-1).

Background information on the projects collected are provided as follows. Ten restored small streams (stream order <=3), four restored large streams (stream order >3), and one lakefront project. The stream classification method used was: the smallest headwater tributaries are 1st-order streams; a 2nd-order stream is created where two 1st-order streams meet; a 3rd-order stream is created where two 2nd-order streams meet; and so on (Ward, D'ambrosio, & Mecklenburg, 2008). Among the projects located in the U.S., municipal population of 2010 census ranged from 2,626 (Blue Hole, Wimberley, TX) to 2,695,598 (63rd Street Beach, Chicago, IL). Five of these projects involved stream daylighting. All projects were located in municipalities with diverse income levels, with 2008-2012 median household income (from U. S. Census Bureau, 5-Year Estimates) ranged from $26,339 (Gilkey Creek, Flint, MI) to $112,679 (Tassajara Creek, Dublin, CA). But the majority of these municipalities in this study had household incomes between $40,000-60,000. The project sites had land use types of park, mixed-use, institutional, and residential. Five projects were constructed on greyfields and four on brownfield sites. The sizes of the projects varied from 2.7 acres (Thornton Creek) to 1,011 acres (Napa River). The budget of these projects varied from $0.78 million (Wissahickon Creek) to $550 million (Napa River).

Nine of the projects are located in areas that receive, on average, more than 30 inches of annual rainfall, and five projects receive below 30 inches (1981-2010 Climate Normals Annual rain totals, NOAA national climatic data center). And, the streams in these projects cover diverse stream types: three on streams of Western Mountains, three on Xeric, three on Temperate Plains, two on Southern Appalachians, two on Southern Plains, and one on Upper Midwest (stream types determined by mapping project locations, using the Nitrogen and Phosphorus Pollution Data Access Tool (NPDAT) by USEPA).

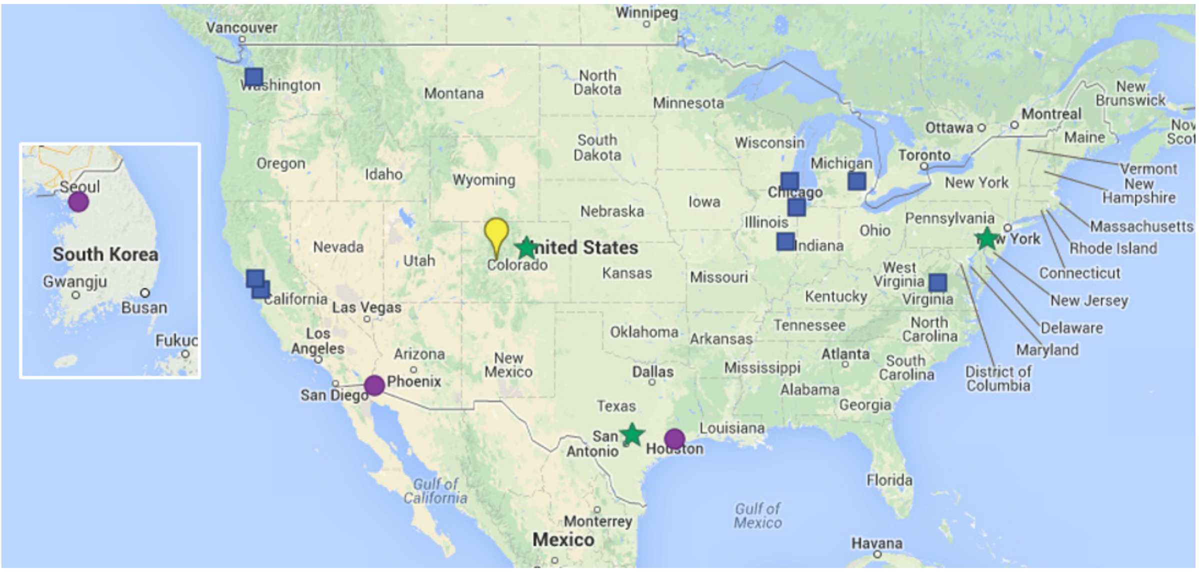


Figure 2-1. Location of projects collected. Purple circle marks represent projects in downtown context, blue square in urban, green star in suburban, and yellow balloon in rural. Basemap from Google Maps.

Table 2-1. Project names and brief summaries

Project name	Simplified project name	Brief summary
Cheonggyecheon Stream Restoration	Cheonggyecheon	Daylighted a downtown stream, with an elevated freeway removed
Buffalo Bayou Promenade	Buffalo Bayou	Transformed an urban greyfield under freeways into an inviting waterfront
Yuma East Wetlands, Phases 1 and 2	Yuma East	Restored a 350-acre wasteland with invasive plants and high salinity soils along Colorado River.
Thornton Creek Water Quality Channel	Thornton Creek	Daylighted a stream once covered by a parking lot, serving as public open space
Ruth Mott Foundation Gilkey Creek	Gilkey Creek	Restored and daylighted a stream portion for flood control and environmental education
The Dell at the University of Virginia	The Dell	Daylighted a buried stream to create a recreational and educatonal campus amenity
Boneyard Creek Restoration, Scott Park and the Second Street Detention Basin	Boneyard Creek	Restored an once channelized stream, providing stormwater holding and recreational benefits.
Tassajara Creek Restoration	Tassajara Creek	Restored a stream for flood control and as an amenity for residents of adjacent neighobhroods.
Menomonee Valley Redevelopment	Menomonee Valley	Restored and remediated an former industrial land along Menomonee River for redevelopment.
Napa River Flood Protection	Napa River	Restoration and remediation of a stream riparian system for flood and pollution control.
63rd Street Beach, Jackson Park	63rd Street Beach	Created a dune grassland landscape on lakefront as public open space.
Westerly Creek at Stapleton	Westerly Creek	Restored and remediated a stream landscape for flood control and recreational purposes.
Wissahickon Creek Park	Wissahickon Creek	Restored a stream in a commmunity park for stormwater management and recreational values.
Blue Hole Regional Park	Blue Hole	Restored a stream landscape in a park where economic sustainability is emphasized.
Riverside Ranch	Riverside Ranch	Restored a riparian residential landscape for aesthetics and on-site stormwater management.

Table 2-2. List of sources on designs and performances of 15 projects

Project	Literature
Cheonggyecheon	Robinson, A., & Hopton, M. (2011). Cheonggyecheon Stream Restoration Project.
Buffalo Bayou	Ozdil, T. R., Modi, S., Stewart, D., & Dolejs, M. (2013). Buffalo Bayou Promenade.
Yuma East	Kondolf, G. M., Rubin, Z. K., Atherton, S. L., 2013. Yuma East Wetlands, Phases 1 and 2. Yuma Crossing National Heritage Area, 2013. Yuma East Wetlands Progress Report. Phillips, F., Flynn, C., & Kloppel, H. (2009). At the end of the line: restoring Yuma east wetlands, Arizona. Ecological Restoration, 27(4), 398-406. Sorvig, K., (2009). The same river twice. Landscape Architecture, 99(11), 42-53.
Thornton Creek	Landscape Architecture Foundation, (n.d.). Thornton Creek Water Quality Channel. SvR Design Company, (2009). Thornton Creek Water Quality Channel: Final Report. Seattle Public Utilities.
Gilkey Creek	Landscape Architecture Foundation, (n.d.). Ruth Mott Foundation Gilkey Creek Relocation and Restoration. SmithGroupJJR, (n.d.). Gilkey Creek Restoration; 8 Keys to Successful Urban Ecological Design. ASLA Michigan Chapter, (2010). SITES: Winter 2010.
The Dell	Thatcher, E., Hughes, M., (2011). The Dell at the University of Virginia. American Society of Landscape Architects(ASLA), (2009). Honor Award: The Dell at the University of Virginia, Charlottsville, VA. University of Virginia, (n.d.). The Dell: Day-lighting Meadow Creek. ASLA Virginia Chapter, (2007). The Dell at the University of Virginia.
Boneyard Creek	Kim, J., Whalen J., Farnsworth C., Underwood M., (2014). Boneyard Creek Restoration, Scott Park and the Second Street Detention Basin. Wenk Associates, & HNTB. (2008). Boneyard Creek Master Plan.
Tassajara Creek	Kondolf, G. M., Atherton, S. L., Cook, S., (2013). Tassajara Creek Restoration Project.
Menomonee Valley	Landscape Architecture Foundation, (n.d.). Menomonee Valley Redevelopment and Community Park. Menomonee Valley Partners, (n.d.). Menomonee Valley History; Menomonee Valley: A Decade of Transformation. Landscapes of Place, (n.d.). Menomonee Valley Landscape Restoration; Making a Wild Place in Milwaukee's Urban Menomonee Valley.
Napa River	Kondolf, G. M., Atherton, S. L., Iacofano, D., 2013. Napa River Flood Protection Project (1998-2012). Campbell, B. (n.d.). EPA Clean Water State Revolving Fund: Napa County "Living Riving Strategy" to Provide Flood Protection.
63rd Street Beach	Mattson, M. P., Guinn, R., & Horinko, K., 2013. 63rd Street Beach, Jackson Park.
Westerly Creek	Canfield, J., Koehler, K., & Cunningham, K. (2011). Westerly Creek at Stapleton.
Wissahickon Creek	American Society of Landscape Architects, (n.d.). Wissahickon Creek Park Infiltration Basins and Riparian Corridor. Montgomery County, (2009). Lansdale Borough Wissahickon Project. Metz Engineers, (2014). Wissahickon Creek: Infiltration Basins and Riparian Corridor.
Blue Hole	Canfield, J., Fagan, E., Mendenhall, A., Spears, S., Risinger, & E. 2013. Blue Hole Regional Park.
Riverside Ranch	Yang, B., Blackmore, P., Binder, C., Mendenhall, A., Callaway, D., & Shaw, R., (n.d.). Riverside Ranch. American Society of Landscape Architects, (n.d.). Sustainable Landscapes: Transformative Water. American Society of Landscape Architects, (2010). Honor Award: Transformative Water.

Table 2-3. Sorting of projects based on density of development (downtown to rural), stream order category (small to large), and population (large to small).

Project	Location	Density of develop-ment	Stream size[1]	Population[2]	Household income[3]	Land use	Size (acres)	Completion date
Cheonggyecheon	Seoul, South Korea	Downtown	Small (daylighted)	>1,000,000	Not known	Transportation, Park	100	2005
Buffalo Bayou	Houston, TX	Downtown	Large	>1,000,000	40,000-60,000	Greyfield, Park	23	2006
Yuma East	Yuma, AZ	Downtown	Large	10,000-100,000	40,000-60,000	Greyfield, Park	350	2010
Thornton Creek	Seattle, WA	Urban	Small (daylighted)	100,000-1,000,000	60,000-100,000	Greyfield, Mixed-use	2.7	2009
Gilkey Creek	Flint, MI	Urban	Small (daylighted)	100,000-1,000,000	<40,000	Greyfield, Institutional	16	2008
The Dell	Charlottesville, VA	Urban	Small (daylighted)	10,000-100,000	40,000-60,000	Greyfield, Institutional	11	2004
Boneyard Creek	Champaign, IL	Urban	Small	10,000-100,000	40,000-60,000	Park	10	2010
Tassajara Creek	Dublin, CA	Urban	Small	10,000-100,000	>100,000	Park	35	1999
Menomonee Valley	Milwaukee, WI	Urban	Large	100,000-1,000,000	<40,000	Brownfield, Park	140	2006 (phase I, II)
Napa River	Napa, CA	Urban	Large	10,000-100,000	60,000-100,000	Brownfield, Park	1011	2015 expected
63rd Street Beach	Chicago, IL	Urban	Large[4]	>1,000,000	40,000-60,000	Park	3 (2004)	2004, 2010
Westerly Creek	Denver, CO	Suburban	Small (daylighted)	100,000-1,000,000	40,000-60,000	Brownfield, Park	75	2004
Wissahickon Creek	Lansdale, PA	Suburban	Small	10,000-100,000	40,000-60,000	Park	6.7	2009
Blue Hole	Wimberley, TX	Suburban	Small	<10,000	40,000-60,000	Park	126	2011, 2012
Riverside Ranch	Pitkin County, CO	Rural	Small	10,000-100,000	60,000-100,000	Brownfield, residential	-	2006

1: Large stream: stream order >3, small stream: stream order <=3.

2: Based on data from 2010 US Census and Korea Tourism Organization, 2014, http://english.visitkorea.or.kr/enu/AK/AK_EN_1_4_3.jsp.

3: Median household income (2008-2012) in dollars, from http://quickfacts.census.gov/qfd/index.html.

4: Lake Michigan.

Table 2-4. Precipitation and water quality information of municipalities projects located.

Project	Location	Annual rainfall[1]	Stream type2	N incremental yield[3]	Drinking water[4]
Cheonggyecheon	Seoul, South Korea	-	-	-	-
Buffalo Bayou	Houston, TX	>=30	Western Mountains	>1500	S, G
Yuma East	Yuma, AZ	<30	Xeric	-	S, G
Thornton Creek	Seattle, WA	>=30	Western Mountains	>2000	S, G
Gilkey Creek	Flint, MI	>=30	Upper Midwest	<500	G
The Dell	Charlottesville, VA	>=30	Southern Appalachians	1500-2000	S, G
Boneyard Creek	Champaign, IL	>=30	Temperate Plains	>2000	G
Tassajara Creek	Dublin, CA	<30	Xeric	-	G
Menomonee Valley	Milwaukee, WI	>=30	Temperate Plains	500-1000	S, G
Napa River	Napa, CA	<30	Xeric	-	S, G
63rd Street Beach	Chicago, IL	>=30	Temperate Plains	>2000	S, G
Westerly Creek	Denver, CO	<30	Southern Plains	1000-1500	S, G
Wissahickon Creek	Lansdale, PA	>=30	Southern Appalachians	>2000	G
Blue Hole	Wimberley, TX	>=30	Southern Plains	<500	G
Riverside Ranch	Pitkin County, CO	<30	Western Mountains	-	S, G

1: Using 1981-2010 Climate Normals Annual rain totals (in) of the municipalities where projects located, from NOAA national climatic data center.

2: Stream types determined by mapping project locations using the Nitrogen and Phosphorus Pollution Data Access Tool (NPDAT), http://gispub2.epa.gov/npdat/.

3: SPARROW Total Nitrogen Incremental Yield 2002 for Major River Basins (kg/km²/yr), based on project location, using NPDAT, http://gispub2.epa.gov/npdat/.

4: S: surface water as drinking water in municipal boundary; G: ground water as drinking water in municipal boundary, using NPDAT, http://gispub2.epa.gov/npdat/.

3 Findings

The projects in this study provided a variety of environmental, economic, and social benefits. Environmental benefits included flood control, water quality protection, habitat creation, air quality control, carbon sequestration, enhance urban microclimate, and soil remediation; economic benefits included increased property value, investment, retail sales, and local employment; and social benefits included promoting public environmental education, increased recreational activities, and enhanced aesthetics.

3.1 Summary of project practices and performance benefits

3.1.1 Project practices

Restoration of riparian vegetation was found to be the most commonly used practice. Seven projects integrated Green infrastructure, five restored stream meander, three conducted soil pollutant remediation, and one utilized sediment removal (Table 3-1). All projects used native plant species. More than half of the projects emphasized site connectivity for enhanced public access and use of the sites (e g. constructing trails and pedestrian bridges). A few projects went through a public process (communication and collaboration among stakeholders) on project design.

3.1.2 Project performance benefits

Environmental benefits

Based on information available, flood control was a frequently addressed environmental consideration in both the stream restoration and waterfront redevelopment projects (Table 3-2). Project performance on flood control ranged from 1-year storm event (Wissahickon Creek, small stream) to 200-year flood (Cheonggyecheon, small, day-lighted stream). Many projects also attempted to address water quality, but there was limited data on water quality improvement. Projects that specifically addressed water quality goals were mostly small streams and one exception is the project on Chicago's lakefront (63rd Street Beach). Habitat value was also a consideration for many projects; some projects greatly improved habitat value and biodiversity based on data available (Yuma East, 350 acres, created habitat for 330 species of wildlife; Cheonggyecheon, 100 acres, increased overall biodiversity by 639% during 2003-2008). There were two restoration projects that measured carbon sequestration. One project showed air quality improvement and reduction of urban heat island effect.

Economic benefits

Based on information available, 12 of the 15 projects included economic performance. Eight projects produced economic benefits from increased property value, investment, or employment. Two projects increased retail sales or attracted tourists. Seven used design techniques to reduce project cost or maintenance expenses. All three Projects in the downtown context increased local investment and two projects in cities with population of more than 1 million (Seoul, South Korea, and Houston, TX) also increased retail sales and employment. Projects that used design techniques to reduce project or maintenance costs were all in urban, suburban, and rural contexts, and all were on small streams (except the 63rd Street Beach project on a lakefront). Also, the cost of these projects that adopted practices to reduce project or maintenance costs were under half million dollar per acre (Riverside Ranch data not available).

Social benefits

Ten projects addressed public education (e g. engaging volunteers in restoration and education activities, taking educational tours, using informational signs educating people on project design, site history, and wildlife). Eight projects promoted recreation values (for users of pedestrians, bikers, and boaters) and two showed increased visits after restoration. Aesthetics of the projects were rarely measured and only a survey of one project showed improved site aesthetics.

Table 3-1. Project design techniques (based on information available)

Project	Restored riparian vegetation	Green infrastructure used	Daylighting	Restored meander	Remediation	Pumping water to sustain water flow	Sediment removal
Cheonggyecheon	*		*			*	
Buffalo Bayou	*						
Yuma East	*						*
Thornton Creek	*	*	*	*			
Gilkey Creek	*	*	*				
The Dell	*	*	*	*			
Boneyard Creek	*	*		*			
Tassajara Creek	*			*			
Menomonee Valley	*				*		
Napa River	*				*		
63rd Street Beach	*1						
Westerly Creek	*	*	*	*	*		
Wissahickon Creek	*	*					
Blue Hole	*	*					
Riverside Ranch	*	*					

1: Restored lakefront dune ecosystem.

Table 3-2. Performance of projects (based on information available)

Project	Environmental			Economic		Social			Cost[1]
	Flood control	Water quality	Habitat	Property value/ investment/ employment	Retail sales/ tourists	Project cost/ maintenance	Public education	Recreation	
Cheonggyecheon	*		*	*	*			*	3.8
Buffalo Bayou	*			*	*		*	*	0.65
Yuma East	*		*	*			*	*	0.03
Thornton Creek		*	*	*					5.44
Gilkey Creek	*			*		*	*		0.07
The Dell	*	*	*			*	*	*	0.09
Boneyard Creek	*	*					*		1.07
Tassajara Creek	*			*		*			0.14
Menomonee Valley	*		*	*			*		0.29
Napa River	*		*	*			*	*	0.54
63rd Street Beach		*	*			*	*	*	0.40
Westerly Creek	*	*	*			*	*	*	0.21
Wissahickon Creek	*	*	*						0.12
Blue Hole		*	*			*	*	*	0.03
Riverside Ranch		*	*			*			-

1: Million dollar per acre.

3.2 Projects categorized by site context

The 15 projects were grouped into four categories, by project context: 1) downtown, 2) urban (in this study, it denotes municipal areas excluding downtown and suburban), 3) suburban (or peri-urban, urban areas close to municipal boundary), and rural contexts. The study finds that different context types tend to be associated with different sets of environmental, economic, and social benefits.

Figure 3-1 shows different sets of environmental, economic, and social benefits provided by these projects, based on their context of development density (downtown, urban, suburban, and rural). As the development density increases, the variety of benefits provided increase. Projects in downtown context provided the most comprehensive settings of benefits. However, downtown projects did not cover all benefits, such as water quality protection or maintenance cost saving provided by projects in lower density areas.

	Downtown	Urban	Suburban	Rural
Environmental benefits	Flood control Habitat Air quality Reduction of heat islands	Flood control Water quality Habitat Soil remediation	Flood control Water quality Habitat Soil remediation	Water quality Habitat Soil remediation
Economic benefits	Property value Investment Employment Retail sales Tourists	Property value Investment Employment Maintenance cost	Park entrance revenue Maintenance cost	Maintenance cost
Social benefits	Public education Recreation Aesthetics	Public education Recreation Aesthetics	Public education Recreation Aesthetics	Aesthetics

Figure 3-1. Different settings of environmental, economic, and social benefits created by projects based on their context of development density. (Photos from Google Maps)

3.2.1 Downtown restoration and redevelopment projects

Projects in a downtown context had the most comprehensive set of environmental, economic, and social benefits, as compared to projects in a lower density context. The three downtown projects included in this study were Cheonggyecheon (Seoul, South Korea), Buffalo Bayou (Houston, TX), and Yuma East (Yuma, AZ). Cheonggyecheon, as a project in a city with population of more than 1 million and on a small stream, was a relatively "engineered" stream. Buffalo Bayou, in a city with a population of more than 1 million and on a large stream, was more "naturalistic" compared to Cheonggyecheon. Yuma East, in a municipality with population of less than 100,000 and on the Colorado River, restored a large area of "wild" landscape. Economic and social values were of great concerns for all three projects in downtown context.

Cheonggyecheon (downtown, small stream, population >1,000,000)

Cheonggyecheon project (Figure 3-2) demonstrated the complexity of restoration work in a high density area. Prior to restoration the stream was hidden under highways and the stream water did not flow year-round. The elevated freeway was aging and needed to be repaired or removed. The local government wanted to enhance connectivity between areas divided by the freeway. Reducing traffic congestion was a challenge when removing the freeways to daylight the stream, so public transportation was enhanced and car use discouraged in the area. Water was pumped from adjacent sources to keep water flow in channel. Business owners on stream sides initially opposed the project and there were vendors who had to move out due to construction work, so economic support was provided and special agreements made. More than 4,200 meetings were held by the Seoul Metropolitan Government to build consensus during the design process. This project provided economic benefits (including increased property values, number of businesses, and local employment), environmental benefits (flood control, increased biodiversity, and air quality protection), and social (recreation and aesthetics) benefits (Table 3-3) (Robinson & Hopton, 2011).

Table 3-3. *Cheonggyecheon project*

Design		
Stream restoration measures		Stream daylighted by removing elevated freeway; Pumping water from adjacent sources to maintain water flow; restoration of riparian wetlands.
Plant material used		Native willow swamps, shallows and marshes were constructed in 29 locations along the restored stream
Site connectivity		Created a 3.6-mile green corridor for pedestrians and bicyclists. Added 22 bridges (12 pedestrian, 10 for automobiles and pedestrians), connections with 5 nearby subway lines, and 18 bus lines to improve site connectivity.
Public process in project development		Local government held ~4,200 meetings to build consensus with business owners. Economic support was given to businesses which had to move due to project construction.
Performance		
Environmental	Flood control	Accommodate 200-year flood event
	Habitat	Increased overall biodiversity by 639% during 2003-2008: plant species from 62 to 308, fish species from 4 to 25, and bird species from 6 to 36.
	Air quality	Protected air quality through reducing small-particle air pollution by 35% from 74 to 48 µg/m3.
	Microclimate	Reduces the heat island effect due to the removal of freeway above the stream and increased plantings: site temperatures were 3.3° to 5.9°C cooler than on a parallel road 4-7 blocks away.

Economic	Economic benefits	Increased land price by 30-50% for properties within 50 meters of the project, doubling the rate of business growth in downtown during 2002-2003; Attracted $1.98 billion investment; Increased the number of working people in project area by 0.8%, versus a decrease in downtown; Attracted 1,408 foreign tourists daily who contributed ~$1.9 million in visitor spending to the city.
Social	Recreation	Attracted ~64,000 visitors daily.
	Aesthetics	Created consistent water flow as urban visual amenity by engineering measures.

(Project information from (Robinson & Hopton, 2011))

Figure 3-2. Cheonggyecheon, Seoul, South Korea. A) Birds-eye view of restored stream landscape (visitors can walk on boulders in channel, which are for flow control), B) Riparian vegetation and flow control structures (create habitat area for wildlife), C) Terraced stream bank for art work display and pedestrian walkway (stream accessible when water fluctuates). Permission from ©Alexander Robinson.

Buffalo Bayou (downtown, large stream, population >1,000,000)

Buffalo Bayou Promenade project (Figure 3-3) restored a waterfront greyfield to an inviting 23-acre open space. Unlike the Cheonggyecheon project that removed elevated highways as part of the restoration project, Buffalo Bayou restored riparian areas located under highways. To resolve the shade issue created by the highways, plant species that grow in low-light conditions were selected and a lighting system constructed for night time public use. Invasive species were removed and replaced with native and naturalized plants. Together with gabion sacks and cages, installed plantings were used to stabilize stream banks and control erosion. The plantings were also used to soften harsh urban structures and improve stream landscape aesthetics (Table 3-4) (Ozdil, Modi, Stewart, & Dolejs, 2013).

Table 3-4. Buffalo Bayou project

Design		
Stream restoration measures		Stream bank stabilization; restoration of riparian plantings
Plant material used		Native plants
Site connectivity		Constructed a new pedestrian bridge connects the north and south stream banks, 12 street-to-bayou entryways, and 1.4 miles of paved trails linking more than 20 miles for the entire Bayou area.
Performance		
Environmental	Flood control	Trees intercept 337,411 gallons of stormwater run-off.
	CO_2 sequestration	Tree plantings could sequester 29.74 tons of CO_2 annually.
Economic	Economic benefits	The number of establishments increased from 54 to 236; Employment increased during 2008-2012; Retail sales increased from $10,467,000 to $57,281,000.
Social	Recreation	Provides recreational and education opportunities for ~22,500 visitors per year. Used by pedestrians, bikers and boaters. Improves the quality of life for 99% of 108 park users surveyed and increases outdoor activity for 88% of the respondents.
	Public education	One of its goals is educating and serving citizens living along the stream; interpretative signage used.

(Project information from (Ozdil et al., 2013)

Figure 3-3. Buffalo Bayou, Houston, Texas. A) Stream landscape under freeways, B) Stream riparian as public open space, C) Riparian landscape promote recreation activities and provide water view, D) Lighting for park use during evening hours. Photographs by Tom Fox, courtesy of @SWA.

Yuma East (downtown, large stream, population 10,000-100,000)

Yuma East Wetlands project (Figure 3-4) sought to restore the ecological function and public value to a large wetland area near the historic downtown of Yuma, Arizona. As compared with the previously mentioned downtown projects, the project area is larger while the municipality population is much smaller (Table 2-3). It should be noted that Yuma East covered a continuum of lands, including downtown and less developed areas. Yuma, AZ is on one side of the Colorado River, which is different from the other two projects with stream sections located within municipality boundary. The project faced many challenges including invasive species, high salinity soils, and intitial opposition from local farmers who were concerned about water rights. Invasive plants were removed and the site replanted. Water from water treatment plants were reused to feed the wetland (rather than draw water from the stream). A partnership among a diversity of stakeholders was created and this cooperation among local tribes, farmers, property owners, and government contributed to the project accomplishment (Table 3-5) (Kondolf, Rubin, & Atherton, 2013; Phillips, Flynn, & Kloppel, 2009; Sorvig, 2009; Yuma Crossing National Heritage Area, 2013).

Table 3-5. Yuma East project

Design	
Stream restoration measures	Modification of site hydrology: reused water to feed wetlands; transformation of fallow agricultural land to sheet-irrigated habitat; invasive species removal (350 acres cleared); sediment removal.
Plant material used	Native, local plants; over 300,000 native plantings in restored wetland provide plant material for other restorations.
Site connectivity	Over 2.5 miles of pedestrian trails connect to the Gateway Park to facilitate hiking, jogging, and birding activities.
Public process in project development	The Yuma Crossing National Heritage Area (YCNHA) Corporation (a partnership among government agencies, nonprofit groups and civic organizations) is instrumental in project development.

Performance

Environmental	Flood control	Reduced flows: 22,000 average annual cfs at Yuma before the dams to 300-600 average annual cfs after.
	Habitat	Created habitat for 330 species of wildlife, including 2 federally threatened and endangered species and 4 additional species of concern. Bird density and diversity have increased.
Economic	Economic benefits	More than $50 million has been found for the city's riverfront by YCNHA; Training skilled workers for a projected $500 million lower-Colorado restoration industry.
Social	Recreation	Attracted ~220 visitors per day during the summer (90% people swim each day) and 130 people per day during the rest of the year (76% people swim each day).
	Public education	Engages and educates over 200 volunteers annually (1,600 volunteer hours); Hosts 100-150 people annually to celebrate the region's biodiversity through the Yuma Birding and Nature festival.
	Culture	Restored wetlands enhance cultural heritage for stakeholders (e g. Quechan Tribe).

(Project information from (Kondolf, Rubin, et al., 2013; Phillips et al., 2009; Sorvig, 2009; Yuma Crossing National Heritage Area, 2013))

Figure 3-4. Yuma East Wetlands, Yuma, Arizona. A) Site birds-eye view (wetlands on top, downtown Yuma on right of the Colorado River), B) Wetlands during flooding, C) Rparian vegetation and visitors on bank. Permission from ©Fred Phillips.

3.2.2 Urban stream restoration and redevelopment

Projects in the urban context provided a similar set of benefits to the downtown projects. But maintenance became a consideration in project designs. Project summaries are organized first by those that included daylighting of small streams (Thornton Creek project), then those that restored large streams (Napa River project), and lastly one that restored a large water body (63rd Street Beach project). Large stream projects showed more consideration for flood control and the landscapes were closer to natural systems (less "garden" look). Also, projects in the mixed-use land use area (Thornton Creek project) and institutional area (The Dell project) were smaller-sized; park projects both had small size (Tassajara Creek) and large size ones (Menomonee Valley project).

Thornton Creek (Urban, small stream, population 100,000-1,000,000)

Thornton Creek project (Figure 3-5) showed how to improve stormwater management in a high density urban area. The project sought to remove pollutants from stormwater runoff, provide public open space, and facilitate local economic development. The design team worked with a group of environmental, business, and local community stakeholders and created a channel design integrating environmental and commercial purposes. Once covered by an asphalt parking lot, the stream channel was created to filter stormwater (runoff of both site area and adjacent lands) and serve as a neighborhood amenity. To achieve water quality control, a system of conveyance and detention features were built and plantings installed. Due to land space limitation in urban areas, the project used engineering methods to mimic natural flows in a systematic way (rather than restoring it to a natural system) for water quality purpose (Table 3-6) (Landscape Architecture Foundation, n.d.-c; SvR Design Company, 2009).

Table 3-6. Thornton Creek project

Design		
Stream restoration measures		Stream daylighted from an abandoned parking lot. Constructed meander channels and vegetated riparian landscapes. Restored channel to allow deep flows through wide densely vegetated terraces to control water quality.
Green infrastructure		A system of channels, pools, and terraces
Plant material used		Used native plant species. Native volunteer plants found onsite. Plantings and stream channel allowed to evolve over time
Site connectivity		Provided pedestrian walkways from adjacent commercial and residential areas. Shortened walking distance by 50%.
Public process in project development		The design team worked with local stakeholders, developers, and Seattle Public Utilities to meet economic and water quality needs.
Performance		
Environmental	Water quality	Designed to remove ~40-80% of total suspended solids from 91% of the average volume of annual runoff from the drainage basin of 680 acres.
	Habitat	Within one month after opening, native birds were observed at the project.
Economic	Economic benefits	Catalyzed $200 million in residential and commercial development.

(Project information from (Landscape Architecture Foundation, n.d.-c; SvR Design Company, 2009))

A B C

D

E

Figure 3-5. Thornton Creek, Seattle, Washington. A) Birds-eye view of previous site, B) Birds-eye view of stream channel after project completion, C) Stream channel during rain event, D) Vegetated bioswale, E) View access of stream channel in residential neighborhood. Permission from ©SvR Design Company.

Gilkey Creek (Urban, small stream, population 100,000-1,000,000)

Previously a stream portion that was enclosed in a culvert pipe, the natural flow of the stream was restricted during flood events. Through stream daylighting, riparian restoration, and wetland construction, the Gilkey Creek project sought to resolve flooding issues while achieving diverse performance benefits. Stormwater management and filtering, habitat, and public environmental education are among the benefits of this project. It reflected the mission of Ruth Mott Foundation on community vitality and served as a demonstration project that promotes sustainability and environmental education (Table 3-7) (ASLA Michigan Chapter, 2010; Landscape Architecture Foundation, n.d.-b; SmithGroupJJR, n.d.-a, n.d.-b).

Table 3-7. Gilkey Creek project

Design		
Stream restoration measures		Restoration of stream riparian corridor and wetland
Green infrastructure		Pond with wetland fringe constructed for stormwater management
Plant material used		Native seed mix, along with 200 trees, 300 shrubs, and 1,200 aquatic plants.
Performance		
Environmental	Flood control	Accommodate 100-year flood event. Reduced impervious surfaces and stormwater runoff by 22% and used natural landscapes for runoff detention.
Economic	Economic benefits	Costs for flood-related restoration and cleanup dropped more than 95%, saving $10,000-$15,000 annually. Utilizing contractors from the surrounding region for 80% of work. Reduced maintenance costs by 50% using native landscapes.
Social	Public education	Environmental education outreach through the development of programming with a focus on habitat restoration, wetland ecology, and stormwater management.

(Project information from (ASLA Michigan Chapter, 2010; Landscape Architecture Foundation, n.d.-b))

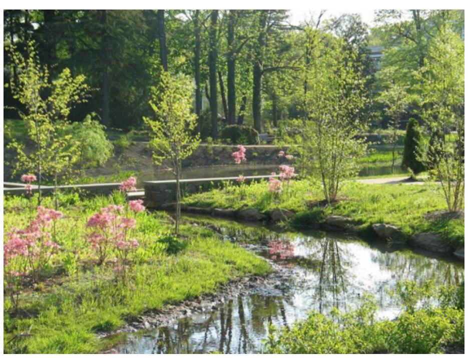
The Dell (Urban, small stream, population 10,000-100,000)

The Dell project (Figure 3-6) is located in the center of the University of Virginia campus. Project goals were to restore the piped stream to provide enhanced ecological value, more efficient stormwater management, and public amenity. The buried stream was day-lighted and a stormwater pond and sediment forebay was constructed to manage stormwater for several downstream projects. This project provided various benefits including stormwater management and water quality improvement (Table 3-8) (American Society of Landscape Architects, 2009; ASLA Virginia Chapter, 2007; Thatcher & Hughes, 2011; University of Virginia, n.d.).

Table 3-8. The Dell project

Design		
Stream restoration measures		Restoration of stream meander and riparian wetland
Green infrastructure		Rain gardens
Plant material used		Native plants (99%)
Performance		
Environmental	Flood control	Accommodate 2-year storm event, larger storm diverted by a flow-splitter
	Water quality	Reduces total suspended solids by 30-92%, phosphate by 23-100%, and nitrate by 50-89%.
	Habitat	There was increase in wildlife (e g. deer, red fox, turtles, songbirds, and great blue heron) sightings since the project completion.
Economic	Economic benefits	A cost-effective way to mitigate downstream stormwater run-off.
Social	Recreation	Provides recreational opportunities for ~10,000 users (university members, local residents, and visitors) each year.
	Public education	It has been the subject of research and outdoor classroom year-round.
	Aesthetics	Designed to enhance visual appearance in a highly visible site.

(Project information from (American Society of Landscape Architects, 2009; ASLA Virginia Chapter, 2007; Thatcher & Hughes, 2011; University of Virginia, n.d.)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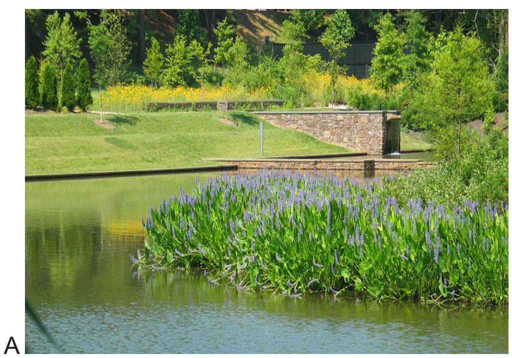
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Figure 3-6. The Dell, Charlottesville, Virginia. A) Stream meander, B) Flowering plants in pond. Permission from ©Nelson Byrd Woltz.

Boneyard Creek (Urban, small stream, population 10,000-100,000)

Boneyard Creek was once a channelized and engineered stream that drained runoff from the central business district of the city and campus area of the University of Illinois. To resolve poor water quality and flooding issues, the City and University developed a multi-phase redevelopment plan for Boneyard Creek. As Phase 2 of the master plan, the project on the second street detention basin enhanced stormwater management and served recreation purposes. Stream meander was restored and stream bank stabilized with natural stones (Figure 3-7). Vantage view-points were created throughout the basin. Bioswales and rain gardens were used for detention and filtering of stormwater runoff. Several environmental and social benefits were provided by this project (Table 3-9) (Kim, J., C., & M., 2014; Wenk Associates & HNTB, 2008).

Table 3-9. Boneyard Creek project

Design		
Stream restoration measures		Restoration of stream meander and riparian vegetated landscapes.
Green infrastructure		Bioswale, rain garden.
Plant material used		Established a native plant species-dominated culture; used 250 shade trees, 100 shrubs, and ~2,000 perennials.
Performance		
Environmental	Flood control	Accommodate 100-year flood event, could collect 15 million gallons of storm-water generated during the event.
	Water quality	Reduces Water pH from 7.93 to 6.96 in Scott Park and 7.54 to 6.89 in the North Basin.
	Habitat	A rise from 58 and 69 (2008) to 133 and 135 (2012) in USEPA Rapid Bioassessment habitat scores for the basin and stream.
Social	Public education	The annual Boneyard Creek Community Day attracts ~300 volunteers to remove litter and invasive plants. Since 2010, over 150 professionals, students and senior citizens have taken educational tours.
	Aesthetics	Visual appearance is one of the main considerations of the project, techniques enhance aesthetics include restoring meanders and bank stabilization.

(Project information from (Kim et al., 2014; Wenk Associates & HNTB, 2008))

Figure 3-7. Boneyard Creek, Champaign, Illinois. Permission from Hitchcock Design Group, ©Foth Infrastructure & Environment, LLC.

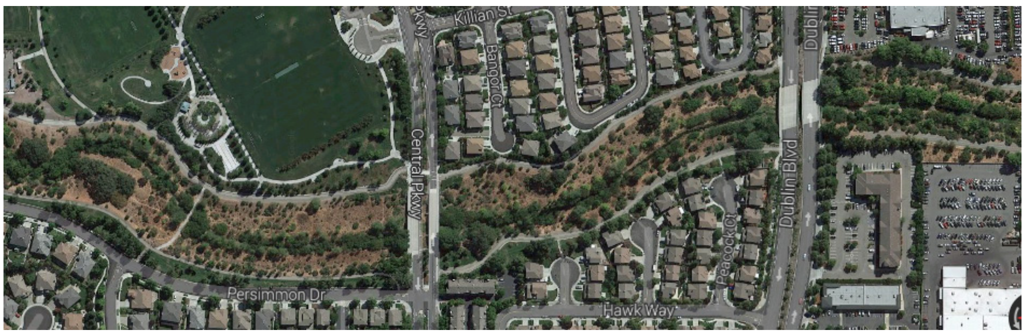
Tassajara Creek (Urban, small stream, population 10,000-100,000)

The Tassajara Creek (Figure 3-8) was incised and hydraulically disconnected from its floodplain. Proposed developments adjacent to the stream necessitated a way to control erosion and flooding. A constructed floodplain terrace was created to reduce channel flow velocities and bed-shear stresses during high flows. The project provided easy access to the creek and pedestrian steps were integrated into a grade control structure. The restored stream landscape serves as an amenity for local residents (Table 3-10) (Kondolf, Atherton, & Cook, 2013).

Table 3-10. Tassajara Creek project

Design		
Stream restoration measures		Restored stream meander and floodplain
Plant material used		Terrace was planted with native species; 18 native plant species were planted and 3 volunteer plant species (2 native, one invasive) appeared in riparian corridor.
Site connectivity		Paved, multi-use trails were added on both sides of the creek, connecting the new residential neighborhoods to adjacent parks.
Performance		
Environmental	Flood control	Accommodate 100-year flood event (peak flows of 5,200 cfs)
Economic	Economic benefits	During 2004-2013, adjacent homes had estimated market values 135-158% (4- and 5-bedroom homes) and 111-126% (2-and 3-bedroom homes) of the city median; Saves $5,000-$42,000 on annual channel maintenance comparing to a traditional trapezoidal channel.

(Project information from (Kondolf, Atherton, & Cook, 2013))



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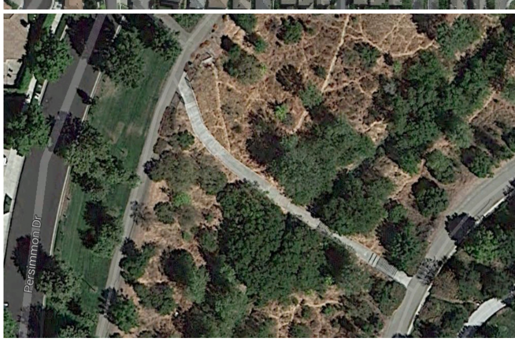

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Figure 3-8. Tassajara Creek, Dublin, California. A) Site plan view, B) A pedestrian pathway through the stream channel. From Google Maps.

Menomonee Valley (Urban, large stream, population 100,000-1,000,000)

Historically a wetland area home to the Native Indians, the Menomonee Valley experienced extensive development during industrial development that transformed the stream landscapes. Milwaukee was once home to many industrial giants during the early 20th century. After the decline of the manufacturing sector, the valley was left with abandoned brownfields.

The redevelopment project (Figure 3-9) sought to revitalize the valley, by promoting economic development, providing recreation benefits, and creating environmental values (Table 3-11). Local partnerships played an important role in project planning; the project was promoted as a model of economic and environmental sustainability (Landscape Architecture Foundation, n.d.-a; Landscapes of Place, n.d.-a, n.d.-b; Menomonee Valley Partners, n.d.-a, n.d.-b).

Table 3-11. Menomonee Valley project

Design		
Stream restoration measures		Restoration and remediation of stream floodplain from an industrial brownfield; Contaminated soil managed on site.
Plant material used		Native (~500 trees), drought-tolerant plants.
Site connectivity		The first Wisconsin state trail in urban setting was built on site. Added 3 pedestrian/bicycle bridges and 7 miles of multi-use trails, linking communities to the park and Menomonee River.
Public process in project development		Menomonee Valley Partners was critical in project development.
Performance		
Environmental	Flood control	Accommodate 100-year flood event
	Habitat	Over 3,000 feet of the riverbank restored serve as habitat areas.
Economic	Economic benefits	Thirty-nine firms have moved to or expanded in the Valley and 5,200 jobs created in the past 10 years. Increased developer yield by 10-12% more than conventional development by clustering development and consolidating stormwater management. Increased site property values by 1,400% during 2002-2009. Created 2,000 jobs by 2006.
Social	Public education	Uses river valley as an outdoor classroom, receiving 10,000 student visits annually. About 70% of the 500 native trees added were planted by local student, community and advocacy groups. The involvement of Urban Ecology Center is key to the project plan, to promote participatory education in restorations.

(Project information from (Landscape Architecture Foundation, n.d.-a; Landscapes of Place, n.d.-a, n.d.-b; Menomonee Valley Partners, n.d.-a, n.d.-b))

Figure 3-9. Menomonee Valley, Milwaukee, Wisconsin. A) stormwater park in dry condition, B) stormwater park collects stormwater runoff, C) Stream riparian during low flow (provides sitting area), D) Stream riparian during high flow (designed to allow floods to pass), E) Riparian flowing plants, F) Wildlife on site, G) Educational signs, H) Children playing on streamside. Permission from Nancy M. Aten, ©Landscapes of Place.

Napa River (Urban, large stream, population 10,000-100,000)

The Napa River project (Figure 3-10) integrated waterfront redevelopment with wetland restoration. Stakeholder collaboration was critical in project planning and development.

Flood control was the primary goal of the Napa River project due to flooding issues in the City of Napa. The restored site area increased water conveyance capacity, enhanced ecological health of the stream, and provided social and economic benefits (Table 3-12) (B. Campbell, n.d.; Kondolf, Atherton, & Iacofano, 2013).

Table 3-12. Napa River project

Design		
Stream restoration measures		Restoration of stream riparian system (include brackish marsh 289 acres, seasonal wetland 112 acres, mudflat 324 acres, tidal channel 28 acres, woodland 84 acres, and grasslands 165 acres); Channel widening; Removal of contaminated soil; Construction of a bypass channel allows water to move safely through downtown during high flows.
Plant material used		About 120 acres of terracing were hydro-seeded or drill seeded with native grasses and trees
Site connectivity		Integrated 2.5 miles of trail along the east bank of the Napa River into the developing San Francisco Bay Trail network (a continuous 500-mile recreational corridor). Along the western bank, a 1.25-mile paved trail connects Trancas Crossing Park. Installed 3 pedestrian bridges.
Public process in project development		The project was designed by a coalition included 27 local organizations, the Army Corps of Engineers, EPA, and 25 other environmental agencies.
Performance		
Environmental	Flood control	Accommodate 100-year flood event, increased capacity from 13,000 cfs to 43,000 cfs.
	Habitat	After restored the historic wetlands, it resulted in 71 species of migratory and resident birds observed on-site.
Economic	Economic benefits	The project reduces flood damage in city and downstream communities. Floods caused $26 million in property damage annually in Napa County previously. Created an estimated 1,373 temporary jobs and 1,248 permanent jobs.
Social	Recreation	A 0.5-acre terraced park, designed to flood during significant rain events, provides space for social gatherings.
	Public education	Engages ~575 volunteers annually in restoration and education projects on site.

(Project information from (B. Campbell, n.d.; Kondolf, Atherton, & Iacofano, 2013))


A


B

Figure 3-10. Napa River, Napa, California. A) Meander stream and the city, B) Wetland habitat. Permission from ©Napa County Flood Control and Water Conservation District.

63rd Street Beach (Urban, large water body, population >1,000,000)

The 63rd Street Beach project (Figure 3-11) was a part of urban redevelopment efforts along Chicago's shoreline. Instead of restoring the original wetland system to a pre-settlement condition, this project sought to create a stable native dune grassland landscape that serves several purposes, including: stormwater management, shoreline protection, and urban amenity. It also demonstrated that waterfront redevelopment projects can be opportunities to rebuild urban infrastructure for water quality protection. The project rerouted the most polluted runoff (that previously went directly into Lake Michigan) to a sewer system. By creating a dune grassland landscape with native trees, shrubs, and herbaceous plants (found in remnant shorelines south of the city), irrigation was minimized and erosion control better achieved compared to conventional design. Public access was enhanced to encourage recreational activities in this public open space (Table 3-13) (Mattson, Guinn, & Horinko, 2013).

Table 3-13. 63rd Street Beach project

Design		
Stream restoration measures		Created a native dune grassland system at the beachfront of Lake Michigan to sustain wave and wind action.
Plant material used		Native trees, shrubs, and grasses found in local remnant shorelines; pre-grown regionally occurring plants used.
Site connectivity		Pedestrian access was enhanced with the addition new underpasses. Chicago's only beach boardwalk was installed to provide a separate path for beach-goers.
Performance		
Environmental	Water quality	Reroutes the most polluted runoff to the city sewer system (originally went directly to the lake).
	Habitat	Provides habitat for over 200 species of birds. Increased the Biomass Density Index by ~150%.
Economic	Economic benefits	Construction costs for the project being significantly less than a conventional design approach, less than $10/SF; Saves ~450,000 gallons of potable water and over $1,300 annually using native species (2004 Restoration).
Social	Recreation	Helped to reduce the number of swim ban days and swim advisory days by 72% and 62% by 2010, respectively. A pedestrian underpass provides access to beach from Jackson Park.
	Public education	The Great Lakes Action Days program conducts monthly stewardship days, engaging ~200 volunteers a year since 2005.

(Project information from (Mattson et al., 2013))


A


B

Figure 3-11. 63rd Street Beach, Chicago, Illinois. A) Pedestrian underpass enhances site connectivity, B) Beachfront dune grassland landscape created. Photo source: Google Maps Street View.

3.2.3 Suburban restoration and redevelopment

Suburban projects in this study were generally low cost by acreage (Table 3-2). They had similar setting of environmental and social benefits while lower performance on economics compared to projects in higher density context.

Westerly Creek (Suburban, small stream, population 100,000-1,000,000)

The Westerly Creek project (Figure 3-12) included the integration of stormwater and flood management into redevelopment on a brownfield site. Stapleton, a suburban neighborhood of Denver, is located on the site of a former airport. This suburban project sought to provide stormwater management and serve residents of adjacent communities as an open space. The project integrated stream daylighting, brownfield remediation, and habitat restoration and provided various benefits including stormwater management, flood control, and recreational value. To protect stream water quality stormwater flows through a runoff treatment train that includes forebay basins and vegetated ponds, before entering the creek. By using native prairie vegetation and applying adaptive management schemes, the park conserves water, saves fuel, and reduces fertilizer and herbicides application compared to conventional parks. Aesthetic and recreational benefits were provided by this suburban project, allowing local residents to have more contact with restored stream landscape (Table 3-14) (Canfield, Koehler, & Cunningham, 2011).

Table 3-14. Westerly Creek project

Design		
Stream restoration measures		Stream daylighted from an abandoned airfield; Restored stream meander and riparian vegetation
Green infrastructure		Vegetated water quality ponds
Plant material used		Native (locally grown) and naturalized species 85%. Uses a pre-vegetated mix of contract-grown woody and herbaceous species to promote immediate habitat establishement and visual appeal. Prairie seed mixes include at least three species of forbs for blooming in different seasons.
Site connectivity		Provides over 3 miles of ADA walking trails, 1.3 miles of jogging trails, and a connection to Denver's regional trail system.
Performance		
Environmental	Flood control	Accommodate 100-year flood event, Flood flows were reduced by an average of 44%, Reduced water velocities to ~1-5 fps at low flow, and ~3-5 fps at peak flow.
	Water quality	Improves downstream water quality by increasing dissolved oxygen and reducing suspended sediment.
	Habitat	The variety and abundance of wildlife found onsite increased.
	CO_2 sequestration	Native prairie vegetation of 50 acres can sequester ~240 tons of carbon annually (24 times more than using bluegrass sod).
Economic	Economic benefits	Saves ~27.9 million gallons of water and ~$72,000 in annual irrigation; saves ~$2,240 per acre per year over the cost of maintaining a traditional Denver park.
Social	Recreation	Survey showed 67% of 262 Stapleton residents use the park at least once a week and 22% every day.
	Public education	Informational signs were installed to educate residents about cohabiting with wildlife and minimize potential conflicts.
	Aesthetics	Several design measures were used for enhanced visual appeal, include using gentle channel meanders and vegetated banks, pre-vegetated plants, and diversity of plants.

(Project information from (Canfield et al., 2011))

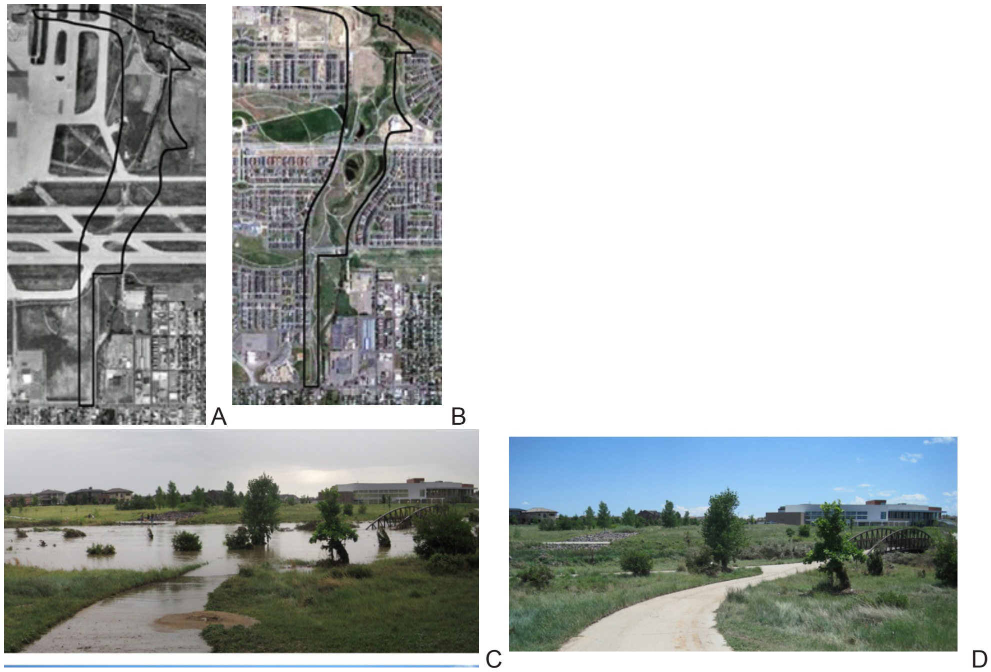

Figure 3-12. Westerly Creek, Denver, Colorado. A) Site prior to restoration, B) Site after restoration, C) Bridge designed to withstand flooding, C) Bridge promotes site connectivity when flood recedes. Permission from ©Jessica Canfield. (A, B adapted from Google Earth).

Wissahickon Creek (Suburban, small stream, population 10,000-100,000)

The Wissahickon Creek project is located in Lansdale, Pennsylvania, a borough close to the City of Philadelphia. Compared to projects in high density areas or large municipalities that promoted urban investments or retail sales, this project provided limited economic benefits. The project was to restore the stream landscape for stormwater management and recreation purposes in this suburban community park, in a municipality with population less than 20,000. Vegetated swales, ponds, and riparian landscape were constructed to regulate stormwater runoff hydrology, protect stream water quality, recharge groundwater, and enhance habitat value (Table 3-15) (American Society of Landscape Architects, n.d.; Metz Engineers, 2014; Montgomery County, 2009).

Table 3-15. Wissahickon Creek project

Design		
Stream restoration measures		Restored riparian vegetation
Green infrastructure		Bioswale, infiltration basins
Plant material used		Native plants
Performance		
Environmental	Flood control	Accommodate 1-year storm event, three infiltration basins collect stormwater runoff from 28.4 acres of drainage area
	Water quality	Basins and swales designed to filter sediment and other pollutants from both sheet flow and stormwater outfalls.
	Habitat	Stream corridor system was restored to serve as ecological habitat.

(Project information from (American Society of Landscape Architects, n.d.; Metz Engineers, 2014; Montgomery County, 2009))

Blue Hole (suburban, small stream, population <10,000)

The Blue Hole project, with the smallest budget by acreage among the 15 projects (Table 3-2), is located in a municipality with population less than 3,000. The project sought to increase recreational benefits while protecting local ecosystems. By reducing impervious surfaces and installing stormwater control measures, natural hydrology of the site could be restored and water quality protected. Plantings (quick establishing, deep-rooted species) and structures were designed to be resilient to high flows. All trees and paving areas remained intact during flooding events right after project implementation. The project enhanced park visual appeal and increased the number of annual visitors. Increased visitation helps sustains park operations economically, since park entrance revenue is its major budget source (Table 3-16) (Canfield, Fagan, Mendenhall, Spears, & Risinger, 2013).

Table 3-16. Blue Hole project

Design		
Stream restoration measures		Restored riparian vegetation
Green infrastructure		Bioswale, stormwater pond
Plant material used		Native (100%), deep-rooted plants; added 31 hardwood, prairie grass, and forb species.
Public process in project development		Community members and stakeholders provided design input.
Performance		
Environmental	Water quality	Reduces impervious surfaces to less than 8% of the site.
	Habitat	Protects 96% (93 acres) of the undisturbed area of the site that identified as potential habitat for 19 endangered, threatened, or species of concern.
Economic	Economic benefits	Increased visitation by 60% in the first year with ~ $112,000 in entry fee revenue. Visitation nearly doubled and generated ~$217,000 in the second year. Saves ~600,000 gallons of potable water per month, saves annual cost of $25,500.
Social	Recreation	Increased visitation by 60% in the first year. Visitation nearly doubled in the second year.
	Public education	Interpretive signs were used to educate visitors on sustainable designs, local geology, site history, and native plant species.
	Aesthetics	Increased park visual appeal by 75%.

(Project information from (Canfield et al., 2013))

3.2.4 Rural restoration and redevelopment

There is limited published information on the performance benefits of rural projects, and only one rural project is included in this study. Compared to projects in cities, the rural project still served environmental, economic, and social purposes, but the variety of performance benefits was more limited.

Riverside Ranch (rural, small stream, population [county] 10,000-100,000)

As a redevelopment project on rural brownfield, the Riverside Ranch project did not incorporate the recreational or economic goals of the urban projects. Historically the site has been through a series of transitions from a homestead built in the 1880s, to a rail road stop, and an asphalt plant in the mid-twentieth century. The project sought to transform the brownfield site into a private residential property. Aesthetics was a major consideration in the project design. Installed plantings provide a buffer to unpleasant noise and views associated with the adjacent highway. The historical hint of the site was preserved through preservation of old building structures on the property. A riparian wetland system was created to manage stormwater runoff on-site (Table 3-17) (Yang et al., n.d.).

Table 3-17. Riverside Ranch project

Design		
Stream restoration measures		Restoration of riparian wetland
Plant material used		Native, naturally occurring plants; considered survivability, aesthetics, habitat, and availability.
Performance		
Environmental	Water quality	Temperature, pH, and alkalinity to be within suitable ranges, according to water quality testing.
	Habitat	A series of constructed ponds and wetlands provide habitat for two trout species.
Economic	Economic benefits	Saves ~$9,485 in annual maintenance compared to site fully covered by lawn.
Social	Aesthetics	Vegetation and subtle berming are designed to function as a visual buffer to unpleasant noise and views associated with nearby highway while maintaining the pastoral feel the open space parcels required to preserve.

(Project information from (Yang et al., n.d.)

3.3 Projects that had reported performance benefits on water quality protection

Table 3-18 shows the comparison of project specifications, site context, and benefits provided between projects reported performance benefits on water quality protection (either showed water quality improvement results or applied design practices for water quality control) and those that did not. Compared to those with no reported performance benefits on water quality protection, projects with reported benefits showed much smaller average project size and budget, and were located in less developed urban areas, on smaller streams, while the population and income figures between the two groups were fairly close.

The finding that projects which addressed water quality tend to be on small streams concurred with Craig et al. (2008) that restoration work should put priority on small streams (1st- to 3rd- order) to reduce stream N loads. Stream type also needs to be considered when integrating water quality objective into projects in urban waters. All three projects on xeric streams did not address water quality. Xeric streams in southwestern areas are often flashy (Batzer & Sharitz, 2006) and therefore present challenges to stream N reduction (Craig et al., 2008).

Table 3-18. Comparison of project specifications, context, and benefits between projects that reported performance benefits on water quality protection and those did not

		Projects with reported performance benefits on water quality protection	Projects with no reported performance benefits on water quality protection
Project specifications	Average size (acres)	38.6[1]	239.3
	Average project budget (million dollars)	6.71	142.9
Project context	Density of development	4 urban, 3 suburban, 1 rural	3 downtown, 4 urban
	Average municipal population[2]	508,124	502,122
	Average municipal median household income[3]	$53,113	$54,340
	Stream size	7 small[4]	4 large, 3 small
	Stream type	2 Western Mountains, 2 Southern Appalachians, 2 Southern Plains, 2 Temperate Plains	3 Xeric, 1 Upper Midwest, 1 Western Mountains, 1 Temperate Plains[5]
Environmental benefits	Flood control	4/8 (4 out of 8 projects)	7/7
	Habitat	7/8	4/7
Economic benefits	Property value/ investment/ employment	1/8	7/7
	Retail sales/ tourists	0/8	2/7
	Project cost/ maintenance	5/8	2/7
Social benefits	Public education	5/8	4/7
	Recreation	4/8	4/7

1: One project not included: Riverside Ranch project size unknown.

2: Based on data from 2010 US Census. Cheonggyecheon project excluded (otherwise the figure for projects did not address water quality will be 1,878,552 instead of 502,122, with data from Korea Tourism Organization, 2014, http://english.visitkorea.or.kr/enu/AK/AK_EN_1_4_3.jsp).

3: Caculated by dividing the sum of the median household incomes in each set by their number. Cheonggyecheon project excluded. Median household income (2008-2012) in dollars from http://quickfacts.census.gov/qfd/index.html.

4: Excluded 63rd Street Beach project on Lake Michigan.

5: Cheonggyecheon project not applicable.

As for project benefits, there were not very apparent differences on social benefits for the two groups. The differences were mainly on environmental and economic aspects (Figure 3-13). It should be noted that for the projects with no reported performance benefits on water quality protection, they all provided flood control. The most significant difference between those two categories was on economics, especially on "Property value/ investment/ employment" aspect. Among the projects with reported performance benefits on water quality protection, only 1 project addressed it (catalyzed urban development); all projects with no reported benefits on water quality protection provided this benefit (attracted urban investment, increased property value, or improved employment). This result may indicate the potential conflicts between the objectives of water quality protection and urban development in projects of urban waters. Site development density might play a role in project outcomes: projects that did not address water quality tend to be located in high density areas and therefore economic benefits (especially property values and urban investments) were important project objectives. Higher density might also explain why these projects were less likely to promote habitat value. In addition, projects with reported performance benefits on water quality protection were more likely to integrate project cost-saving and low maintenance design techniques. Lower density, smaller stream size, project size, and project budget might explain why.

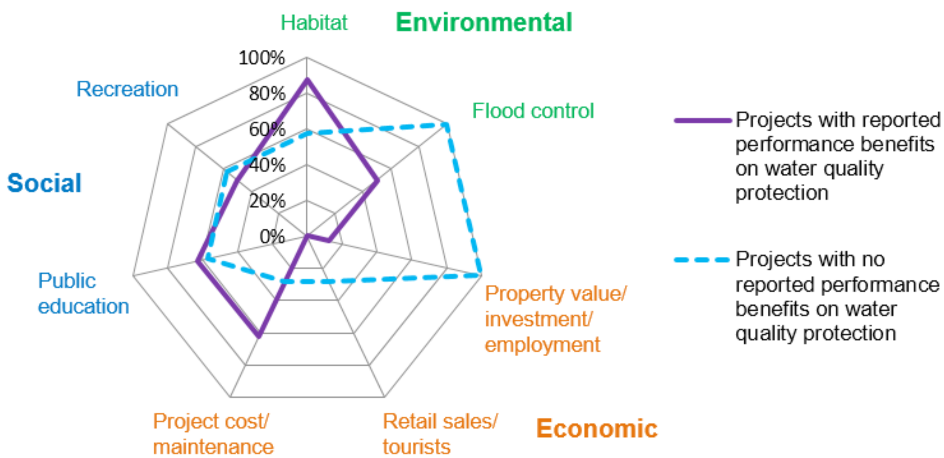

Figure 3-13. Comparison of project benefits between projects that reported performance benefits on water quality protection and those did not, using percentage of projects that provided benefits

4 Discussions and Suggestions

Results from this study on project performance benefits were found to be in line with the principles of the Urban Waters Federal Partnership, such as to promote clean urban waters and reconnect people to urban waters (Urban Waters Federal Partnership, 2011). The study results agreed with Everard and Moggridge (2012) that restored urban water ecosystems could provide environmental, economic, and social values. Integrated thinking is needed, to achieve simultaneous environmental, economic and social progress in urban waters (Dufour & Piégay, 2009; Everard & Moggridge, 2012). Based on study results, the suggested relationships among environmental policy, public education, and sustainability considerations (environmental, economic, and social aspects) were illustrated in Figure 4-1. The inter-related environmental, economic, and social considerations contribute to sustainable urban waters. These considerations should be optimized according to site geological, hydrological, and social context. Public education should be a key component of future project designs to promote people's environmental knowledge on urban water systems and public appreciation of restorations. To address water quality protection, policies need to be set to address all these aspects (environmental, economic, social, and public education on environmental topics), for sustainable water quality protection in watersheds.

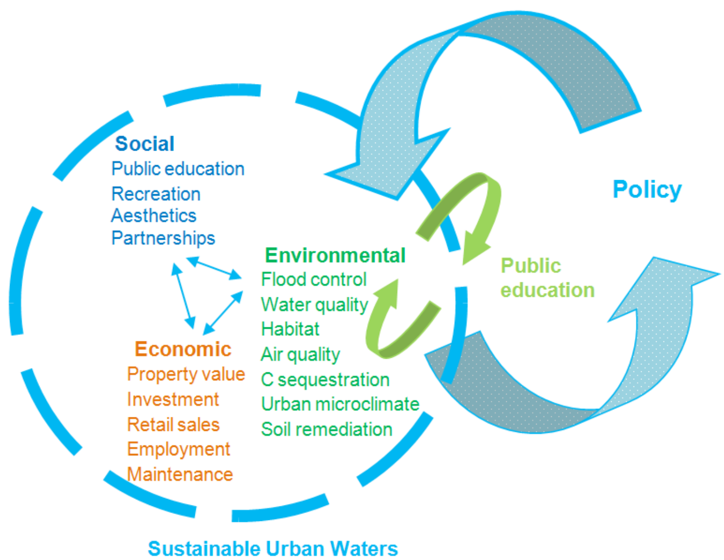

Figure 4-1. Relationships among environmental policy, public education, and sustainability considerations on urban waters.

Recognition of integrated benefits that can provided by restorations and formation of strong partnerships are critical to the development of multi-objective projects in urban waters, especially on easing potential local oppositions and attracting funding support (Everard & Moggridge, 2012; RESTORE Partnership, 2013). Resolving the competing interests of different stakeholders is a challenge (Beem, 2014). For municipal leaders, restoration and redevelopment projects in urban waters are opportunities to leverage local economy by attracting an influx of capital and people; for environmental organizations, restoration work can increase wildlife habitat; for local residents restoration can provide valuable recreational benefits; and for environmental agencies the goal of water quality improvement (Beem, 2014; Canfield & Gibson, 2014; Cho, 2010). An education component is suggested to be added to public meetings during project design process for enhanced understanding of ecological benefits (Mattson et al., 2013). Setting appropriate expectations for project outcomes is important. Urban projects in different context need different sets of functions and benefits associated with water quality. Although urban stream projects in high density context could have limited direct effect on water quality improvement (Beem, 2014), there are many aspects of project benefits associated with water quality protection, such as sustainable stormwater management, low-maintenance design, soil remediation, and public environmental education. Those aspects should be considered in project designs and management, if effective water quality protection in urban stream systems is to be achieved.

Urban water projects vary in their considerations of water quality protection, due to different contexts such as development density, stream size, and municipal population (Figure 4-2). The associations between site context and N control were discussed. In extreme scenarios such as projects with higher density, smaller stream size, and larger municipal population context, human influence is dominant in landscape creation and management. Water quality improvement might not be a primary objective however there are opportunities to create high performance stream landscapes. Improvement in this context, even on a small-scale, could potentially have considerable social benefits associated with environmental protection. These projects offer opportunities for the integration of natural and social sciences in designs of urban stream landscapes. Aesthetics and public attitudes toward stream landscapes should be considered (Paul & Meyer, 2001). In comparison, projects in lower density, larger stream, and smaller municipal population context are the other side of the scenario: the force of nature is dominant. There are opportunities to restore stream landscapes to a more natural status. While they were less expensive, there might not be much economic returns (therefore potentially less incentives to fund the projects). Low maintenance is key in project designs. By restoring stream riparian wetlands, floodplains, and riparian buffers, they could potentially better restore site hydrological regimes and protect stream water quality.

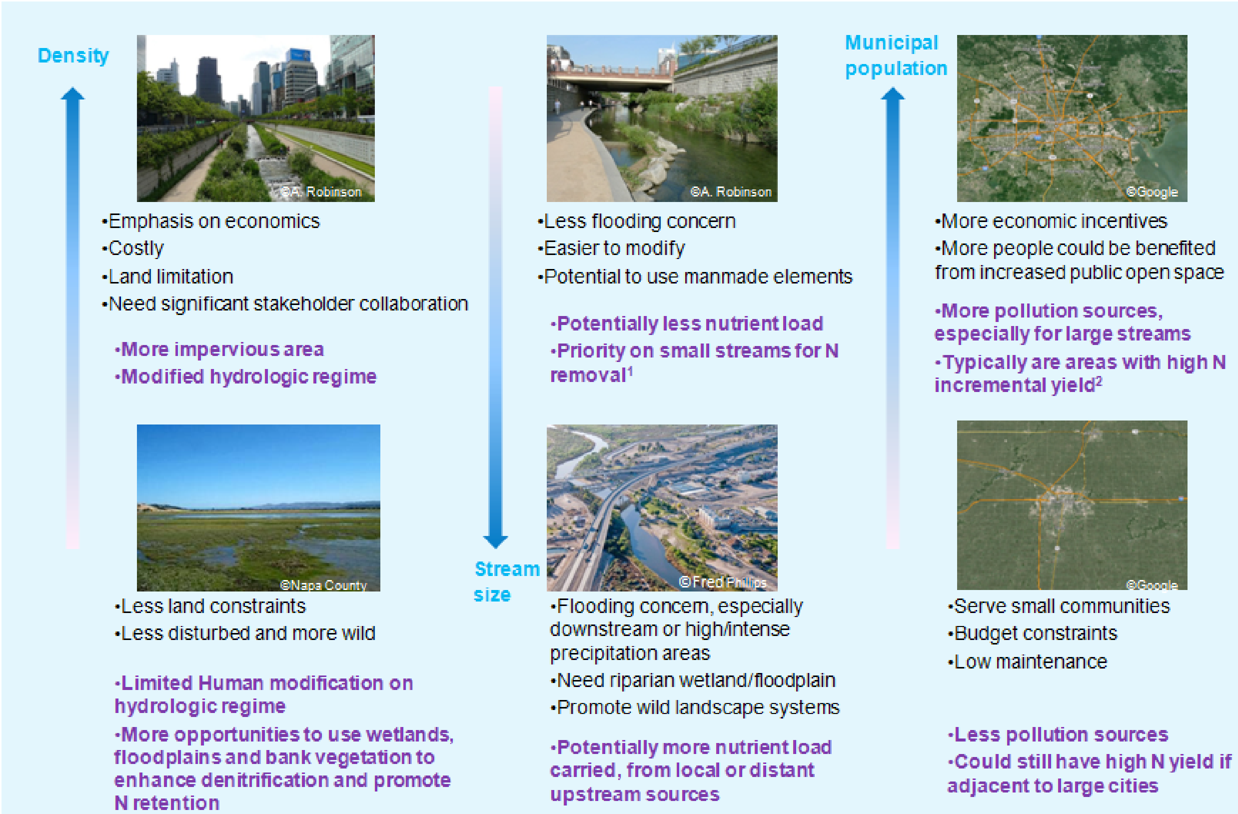

Figure 4-2. Considerations of water quality protection for landscape projects in different context (development density, stream size, and municipal population). Photo sources: Alexander Robinson, Fred Phillips, Napa County Flood Control and Water Conservation District, and Google Maps.

1: Craig, L. S., Palmer, M. A., Richardson, D. C., Filoso, S., Bernhardt, E. S., Bledsoe, B. P., ... & Wilcock, P. R. (2008). Stream restoration strategies for reducing river nitrogen loads. Frontiers in Ecology and the Environment, 6(10), 529-538.

2: SPARROW Total Nitrogen Incremental Yield 2002 for Major River Basins, based on project location (kg/km²/yr), from http://gispub2.epa.gov/npdat/.

This study recognizes the potential effect of project context on the variations in environmental, economic, and social performances of stream restoration and waterfront redevelopment projects. The results of this study suggest that the following strategies be integrated into water quality protection goals for urban waters:

1) In high density areas, underscore social aspect of water quality protection in projects. Projects in high density areas often emphasize economic and social benefits and these restoration works tend to have more “engineered” style (limited natural features for water quality protection) compared to projects in low density areas, especially for small stream projects. For sustainable water quality protection in watersheds, public environmental education on stream protections should be promoted. This might better be achieved if stream aesthetics are enhanced and public visitation increased, especially for children. Many kids first encounter nature playing in streams (Paul & Meyer, 2001). Restored streams can offer recreational opportunities for children to interact with the water’s edge (Figure 3-9H) (J. Canfield, personal conversation, June 3, 2014) and their environmental stewardship could be cultivated. Streams are also outdoor classrooms for students to

conduct water monitoring and testing (Thatcher & Hughes, 2011).

2) Explore how to promote a healthy relationship between streams and urban infrastructures in high density, large population situations. Two important factors in the project design include light and public transportation. Light is particularly crucial for stream landscape sections under urban infrastructures. If budget allows, waterfront infrastructure should be reshaped to promote public transportation, which in turn reduces emissions of gaseous N. If N deposition in urban areas decreased, its loading in stream catchments might be reduced accordingly (Bernhardt et al., 2008). Sustainability should also be implemented in development of every project to provide adequate options with respect to transportation infrastructure (buses and subways) and to promote self compliance of people to change their transportation behavior (Chung, Kee, & Yun, 2012).

3) Utilize the opportunities of redevelopment in urban greyfield or brownfield sites, to integrate design techniques that restore natural hydrology and help with water quality control. Different environmental objectives (associated with water quality protection) could be achieved simultaneously, such as soil remediation and air quality improvement. In addition, recycling of site material for project construction should be promoted to reduce project cost and minimize environmental impact.

4) In low density or small municipal population areas, explore opportunities to restore stream-wetland systems and focus on small streams, for optimized water quality improvement. Projects of this context type could potentially function better in improving natural hydrologic regime and protecting water quality using natural mechanisms, compared to projects in high density or large municipality context. The restoration of stream, riparian wetlands, and floodplains is increasingly a critical part of water quality improvement strategies (Bernhardt et al., 2008). The creation of managed “wild” stream landscapes could also provide valuable habitat for wildlife favored by local communities (Canfield & Gibson, 2014). Public observation of natural waters and understanding of their natural mechanisms could better be promoted, as social aspects of water quality protection.

5) Implement environmentally-friendly landscaping practices for water quality protection. Plant species that require intensive fertilizer use should be restricted and the use of native and naturalized plant species should be promoted, for reduced N loads in urban streams (Bernhardt et al., 2008). It should be noted that project benefits should be balanced and conflicts minimized for projects in high density urban areas: they tend to demand larger variety of benefits (and therefore might result in conflicts among the benefits) than in low density areas. When native plant species were installed to replace turf in the 63rd Street Beach project in Chicago, local community opposed the design insisting the lawns were essential social gathering spaces. The newly restored landscapes were then replanted with turf. The public meeting process is not always effective in balancing ecological and social considerations in project designs (Mattson et al., 2013). When promoting environmental benefits in project designs, it is important to minimize the adverse effects of conflicts among three sustainability dimensions (environmental, economic, and social considerations).

5 Conclusions

This review showed possibilities to incorporate water quality protection into restoration and redevelopment projects in watersheds. The projects in this study provided various environmental, economic, and social benefits. Development density was associated with a variety of benefits: the variety of project benefits increase with development density. Projects in downtown context provided the most comprehensive set of benefits. Also, to achieve integrated benefits, strong partnerships are needed in project planning, development, and perhaps more importantly, long-term management (to sustain integrated benefits). To resolve the competing interests of different stakeholders, setting appropriate expectations for project outcomes is needed. A broader meaning of water quality protection should also be considered (such as public environmental education, sustainable stormwater management, and brownfield remediation), when developing strategies to improve water quality by means of restoration and redevelopment projects in urban waters.

Quality Assurance Statement

All research projects making conclusions or recommendations based on environmentally related measurements and funded by the Environmental Protection Agency are required to participate in the Agency Quality Assurance Program. This project did not involve any physical measurements and relied solely on evaluating the secondary data. It should be noted that evaluating secondary data with respect to their "original intended application" could be a difficult task to accomplish especially without having access to all the QA/QC requirements collected with the original data and the data quality objectives, which are usually not available. However, it is not always necessary to make this determination. In this regard, the project QAPP proposed the following disclaimer: the data and information used in this report have not been evaluated by the EPA for "their original intended application." Neither EPA, EPA contractors nor any other organizations cooperating with EPA are responsible for inaccuracies in the original data that may be present.

This report reviewed a large number of published case studies that incorporated water quality protection into restoration and redevelopment in various settings. In terms of

"completeness," the sites under this report varied significantly in scope and size, and as expected, in few cases information was lacking for some sites, which was appropriately identified with each study. Furthermore, this did not have an impact on the report's conclusions as we relied on factors shared by all studies and relevant to water quality protection in terms of pillars of sustainability, which included environmental, economic and social benefits.

Disclaimer

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