Friends of Guadalupe River Park and Gardens

CHAPTER 3

Principles for Ecologically Sound Riverfront Design

Renewing urban riverfronts entails restoring natural river systems, redeveloping riverfront sites, or both. Restoring ecological systems such as riverbanks and stream buffers contributes to a healthier environment and improves conditions for activities such as fishing, boating, swimming, and wildlife watching. Environmentally sensitive redevelopment of riverfronts to include public amenities such as parks and trails, cultural attractions, commercial buildings, and housing can draw new investments to a city and improve the quality of life for its residents.

Urban riverfront planning must reconcile development, flood control, and recreation with environmental designs and strategies that enhance the river's ecological systems. As a consequence, every riverfront requires a unique combination of environmental strategies that reflect:

- the intensity of current development,
- the nature and intensity of planned development or redevelopment,
- the geometry and constraints of the riverfront, and
- the intended riverfront purposes and management, preferably defined as an outcome of a community planning process (Schueler 2003).

TAILORING THE PLAN TO THE RIVERFRONT CORRIDOR AND ITS WATERSHED

Too many urban riverfront plans suffer from a "me-too" mentality. Politicians and planners mistakenly want their urban riverfront to become just like the San Antonio Riverwalk or Baltimore's Inner Harbor. They soon find that attempts to transplant ideas from other places often don't work.

Every urban riverfront is different and requires planning solutions appropriate to its unique conditions. Before considering how to apply these principles, planners must carefully define their urban riverfront, including its characteristics, measurements, and boundaries. Factors to consider are described in the following sections.

River Size and Geometry

Each riverfront corridor has its own geometry, including length, width, and high-water mark, established by common site constraints such as floodplain, public infrastructure, municipal landownership, and historical development patterns. The riverfront corridor can be delineated and mapped on the basis of such factors.

River Classification

An urban river is a specific entity that is quite different from rural rivers or streams. In an urban river corridor, a fourth-order or higher stream or river intersects with areas that have been developed as neighborhoods or for commerce. (See Figure 2-9 on page 24 for a description of stream hierarchies.) A fourth-order stream or river is on average 12 miles long and has a mean watershed size of 109 miles (Riley 1998). Rivers can be classified as high as tenth-order, the size of the world's largest rivers. By contrast, the Allegheny River in the eastern United States is a seventh-order river, the average length of which is 147 miles with a mean drainage area of 11,700 square miles. Accurately classifying a river is essential to developing a suitable riverfront plan: what works for a fourth-order river will be unsuitable for a seventh-order one.

The development intensity of a riverfront corridor can be classified according to the degree or percentage of impervious cover—hard surfaces such as buildings, streets, parking lots, and sidewalks—found within the corridor.

Intensity of Development

The development intensity of a riverfront corridor can be classified according to the degree or percentage of impervious cover—hard surfaces such as buildings, streets, parking lots, and sidewalks—found within the corridor. A basic classification system might be:

- ultra-urban (80 to 100 percent impervious cover),
- urban (40 to 79 percent impervious cover), and
- suburban (10 to 39 percent impervious cover) (Schueler 2003).

A riverfront may have sections within each classification, from densely developed downtown-commercial riverbanks to stretches of more naturalized riverbanks in suburban-residential areas. Planners whose goal is restoring ecological systems and developing or redeveloping land parcels therefore should create a classification system that responds to the specific site conditions, as well as to the overall master plan or mission of riverfront redevelopment.

Infrastructure

Every urban riverfront is crisscrossed by a unique network of roads, bridges, sewers, and storm-drain pipes, all of which can present significant challenges to the environmental restoration of the riverfront and the river itself. Planners must be sure to identify all infrastructure features and incorporate them fully into any riverfront plan. Infrastructure can also play an important role in revitalizing a river: water quality, wildlife habitat, and public access can all benefit, for example, from reconfigured sewers and stormwater systems that reduce combined sewer overflows (CSOs).

Watershed Planning

Riverfront corridor planning must also consider the river's watershed, or the land area drained by a river and its tributaries. The health and vitality of a river cannot be improved without the comprehensive treatment of stormwater and other erosion and pollution sources across the whole watershed (Schueler 2003).

OVERVIEW OF ECOLOGICAL PRINCIPLES

This chapter provides an overview for planning and designing riverfront renewal and discusses the comprehensive, holistic, and regionally specific approaches needed to improve the ecological and economic health of urban riverfronts. It makes a strong case for a regional planning approach that begins at the scale of the watershed and prescribes small, incremental changes.

The following three major sections in this chapter offer concrete examples of planning and design principles put into action.

The first section presents **five general principles** for ecologically sound riverfront design. It states that economic and ecological goals can work in concert, although compromises may be necessary, and the public always must be engaged.

The second section offers **five planning principles** that emphasize regional planning, the celebration of natural and cultural history, and broad public access for riverfront recreation.

Eight design principles in the third section suggest how to implement the general and planning principles. These include an overview of zoning measures that preserve riverbanks and buffers, river restoration techniques, and innovative programs to interpret the natural resources and cultural history of rivers.

Many techniques described in this chapter have succeeded in a variety of settings. After the description of each principle, a brief case study illustrates a specific instance of implementation of that principle.

The most important principle of this chapter, however, is to reject the conventional wisdom of the past that accepted dams, stream culverts, and floodplain development as inevitable. There is no substitute for a healthy, intact river or stream ecosystem where no portion of the system is impaired. Thus, when faced with a healthy, intact river or stream, planners must strive to preserve water quality, hydrology, riverbanks, and riparian vegetation with buffers that will protect the river or stream from the damaging effects of new development.

Yet this is a somewhat rare scenario. Most cities founded before 1900 were built close to the riverfront in the floodplain to provide access to shipping and water sources. River valleys are logical conduits for highways and railroads, which can easily follow their contours. Decisions made for ease of commerce and engineering have degraded many riverfronts and made them difficult to access and enjoy.

As this chapter will show, some municipalities have reclaimed their floodplains by removing buildings and other structures. This encouraging trend is not going to be repeated everywhere; nor, as we acknowledged in the preface to this report, is it feasible for all riverfronts. Some dams, levees, highways, rail yards, and floodwalls may be removed, but others will stay in place for generations. As General Principle 4 explains, there is still much room for improvement.

This PAS Report makes a strong case for a regional planning approach that begins at the scale of the watershed and prescribes small, incremental changes.

GENERAL PRINCIPLES

Riverfront reclamation has begun to transform some of the nation's most polluted, neglected, and forlorn waterfronts. Five general principles set the stage for planning success.

GENERAL PRINCIPLES

General Principle 1: Ecological goals and economic development goals are mutually beneficial

General Principle 2: Protect and restore natural river features and functions

General Principle 3: Regenerate the riverfront as a human realm

General Principle 4: Compromises are necessary to achieve multiple objectives

General Principle 5: Make the process of planning and designing riverfronts broadly participatory

General Principle 1: Ecological goals and economic development goals are mutually beneficial

Public and private development that brings people to the waterfront to live, eat, shop, relax, recreate, and participate in cultural events builds a sense of connection and stewardship for the river.

Healthy, functioning rivers are appealing and attractive to residents and businesses. An engaged public that enjoys riverfront features and activities also cares about the river's long-term health.

Healthy, functioning rivers are appealing and attractive to residents and businesses. An engaged public that enjoys riverfront features and activities also cares about the river's long-term health. Communities are beginning to understand the allure of a more natural riverfront to residents and visitors. Beyond supporting tourism, these benefits include cost-effective flood control, improved water quality, reduced infrastructure costs, and increased property values and tax base.

For example, a generation ago, the South Platte River in Denver was little more than an urban ditch, filled with abandoned cars, sewage, and other debris. But after the river's devastating flooding in 1965—when communities from Denver to the Nebraska border suffered $540 million of damage and 28 deaths—the city launched efforts to clean and improve it (Massengill 1998). By the mid-1970s, a coalition of citizens and governments started planning and building greenway trails, which soon became one of Denver's most popular recreation facilities.

The scene of Denver's worst flood now teems with life. Since the mid-1970s, some 150 miles of hiker/biker trails, boat launches, whitewater chutes, and parks have been built in four counties and nine municipalities. Even transportation infrastructure has been modified. The city negotiated with railroads to consolidate 16 freight tracks along the riverfront into one line. Hundreds of downtown acres were freed up. This land has been transformed into city parks, reclaimed wetlands for natural flood control, and new riverfront neighborhoods. A $2 million initial investment in the project has been parlayed many times over.

As access to the river improved, citizens viewed their polluted river with new eyes. From 1995 through 2003, Mayor Wellington Webb launched programs to build a string of parks, many of which incorporated flood control into wetlands and included native plants for wildlife habitat. Water-rights agreements have ensured minimum flows to support wildlife habitat, fishing, and boating. Rafting chutes were built to span check dams and other river obstacles. In 2001, the city of Denver built the $30-million Commons Park in Lower Downtown on a 20-acre tract that had been a rail yard.

As a direct result of municipal investments, the Central Platte Valley, some 650 acres of once-derelict industrial land just above the floodplain, has become valuable urban property and a prime spot for private investment. About 1,100 people now live in 1,600 condos and apartments in eight residential projects, and 1,600 people work in this once-barren area. All told, the revitalized Central Platte Valley has attracted $1.24 billion of public and private investment in the last 10 years.

Since 1995, the Central Platte Valley has become the setting for a new baseball stadium, a Six Flags amusement park, a sports arena, a skateboard park, an aquarium, and the first half of a planned 6-million-square-foot mixed-use neighborhood built on abandoned rail yards. Historic buildings also have been refurbished, including a former trolley powerhouse that has become the nation's largest REI store. The adventure-sports equipment store celebrates its location at the confluence of Cherry Creek and the South Platte with river access that features a kayak course. A new light-rail line connects all these amenities (Welty 2003).

Other river-based development has accelerated along the South Platte. In north Denver, the 14-acre, $4.1-million Northside Park was built in 2001 on the reclaimed site of an abandoned wastewater plant. Featuring a wetland pond and grasslands where local children can take camping trips, the park is designed to attract "clean" industries to adjacent lands zoned for redevelopment, bringing new jobs to the working-class Globeville and Swansea neighborhoods. In 2001, the project also was awarded the U.S. Environmental Protection Agency's Region 8 Phoenix Award, presented annually to recognize innovative brownfield redevelopment (Wenk 2002).

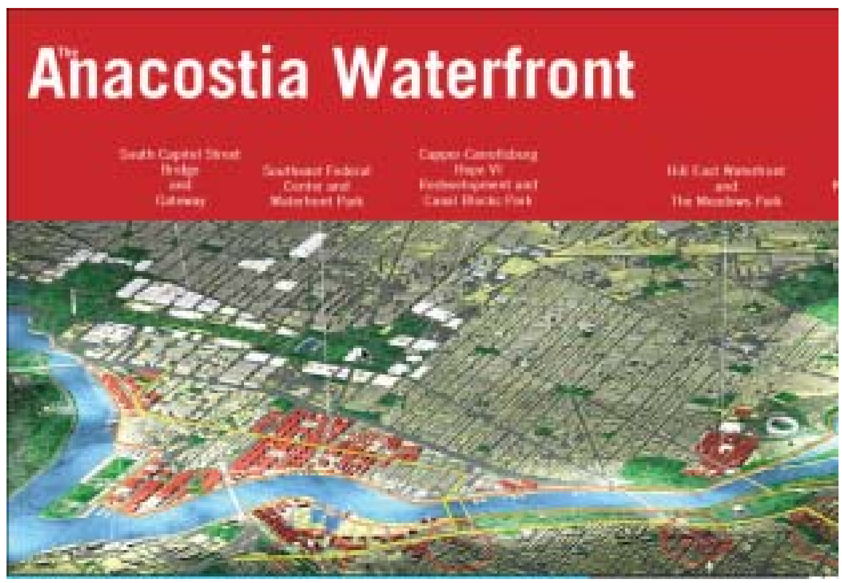
Confluence Park is one of a string of parks that Denver has built since 1995 to combat flooding and promote wildlife habitat on the South Platte River.

Civitas

General Principle 2: Protect and restore natural river features and functions

Rivers provide vital natural benefits that must be protected. Natural river features such as meanders, backwaters, wetlands, and gradually sloped banks serve essential ecological functions. They also provide human benefits such as cleaner water and flood storage. In many urban settings, it may not be possible to restore these features, but even small efforts can have a positive impact. Environmental improvements can be made along even the most heavily impacted rivers.

For example, the Anacostia River—Washington, D.C.'s "other" river—has often been viewed as the district's dumping ground and a dividing line between rich and poor neighborhoods. By the Civil War, the river had already been silted-in by deforestation and poor agricultural practices and was no longer navigable by ocean-going vessels. Today's problems range from overflowing sewers that carry raw sewage into the river to limited access from adjacent neighborhoods, which are among the city's poorest. More than 70 percent of the Anacostia watershed is urbanized. The Anacostia is one of the Chesapeake region's most polluted rivers (Anacostia Waterfront Initiative 2002).



Anacostia Waterfront Initiative

The Anacostia Waterfront Initiative envisions an energized waterfront. AWI seeks to revitalize neighborhoods, enhance and protect parks, improve water quality, and increase access to waterfront destinations.

Despite its poor water quality, the Anacostia offers rich wildlife habitat for bald eagles, heron, and osprey. Since 2000, the members of the Anacostia Waterfront Initiative (AWI)—a partnership between the District of Columbia and 17 federal agencies, who together own 90 percent of the Anacostia shoreline—has worked to improve the river by coordinating the rebuilding of ecological settings, wildlife habitats, parklands, and neighborhoods on both sides of the river. Since 2000, these partners have developed a master plan for seven miles of river, covering 2,830 shoreline acres, or 4.4 square miles.

To enhance the floodplain with a broader, more natural edge, the AWI plan proposes creating a major riverfront park system by stitching 900 acres of public lands owned by different agencies together with reclaimed brownfields. In some places, the plan proposes bioengineering banks to create a 150-foot-wide floodplain. These banks will aid flood control while providing natural filtration of runoff. All of the river's tributary creeks will be "daylighted" and naturalized with wetland edges and buffers of native plantings.

By 2002, the U.S. Army Corps of Engineers had already reclaimed 42 acres of wetlands by regrading portions of the Anacostia's bank. To provide access to new park lands, the U.S. EPA and the District of Columbia have committed $8 million toward environmental restoration of Poplar Point, a former nursery site contaminated by remnant fertilizers, herbicides, and pesticides. Washington's mayor, Anthony Williams (2002), has set a goal of swimming and fishing in the Anacostia "within our lifetime."

Key elements of the plan are currently moving ahead. In 2003, the U.S. Congress approved $10 million toward design and construction of a 12-mile riverfront trail system. To remove major barriers to the waterfront, infrastructure such as bridges, highways, and sewers have been reconstructed. Canoe trails are planned through restored wetlands.

Environmental restoration is being closely tied to economic redevelopment, which included $1.1 billion committed in private funds and $600 million in public funds by June 2003 (Berger 2003). At that time more than a dozen riverfront projects were completed or underway with a goal of revitalizing commercial areas, preserving historic buildings and homes, and adding 10,000 new homes near the river for people of different income levels. For example, the U.S. Navy has invested $200 million to restore historic structures at the Navy Yard, which has also brought 5,000 new jobs to the riverfront. The U.S. Department of Housing and Urban Development has committed $35 million toward redevelopment of the Arthur Capper and Carrollsburg Dwellings public housing project as a mixed-income neighborhood. These projects are being carefully coordinated with efforts to protect and improve the river's buffers, floodplains, and wetlands (AWI 2002).

General Principle 3: Regenerate the riverfront as a human realm

A riverfront project may have to overcome physical, political, social, and economic barriers to increase public use and enjoyment of this public resource.

Many successful projects are designed to include spaces that specifically accommodate parks, walkways, docks, and special events such as concerts and festivals. Good riverfront designs consider the needs of all neighborhoods, ages, and cultures in the community. They allow community members to experience the river up close. In turn, this physical and visual access helps create lively, diverse places that encourage a sense of community and an appreciation for nature.

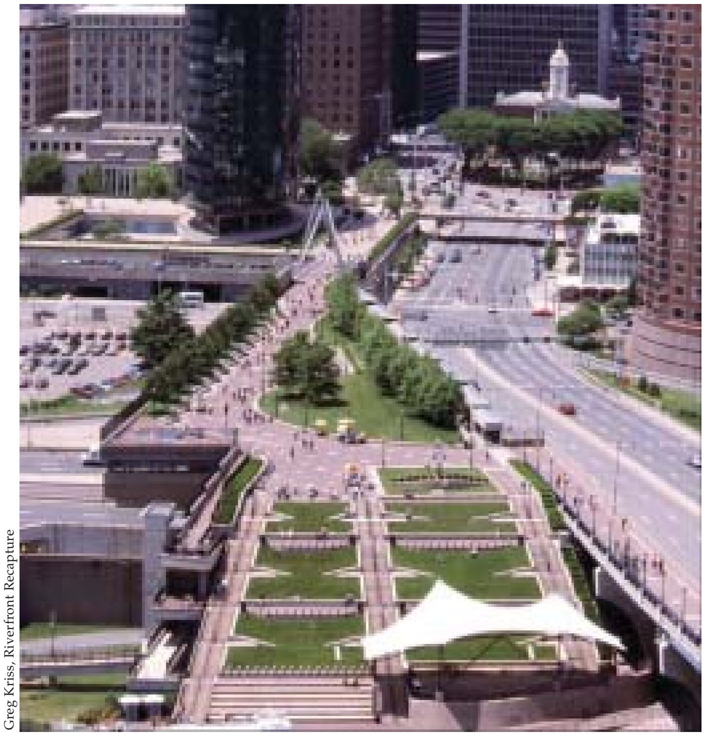
Good riverfront designs consider the needs of all neighborhoods, ages, and cultures in the community. They allow community members to experience the river up close.

Consider Hartford, Connecticut. A highway once severed downtown Hartford from the Connecticut River. Now the $22-million Riverfront Plaza spans Interstate 91 and floodwalls, both of which formerly were barriers to the river. The plaza connects downtown to a riverfront promenade, terraces, trails, docks, and an evolving four-mile riverfront park system. The new 1.5-acre plaza encourages residents to see and enjoy the river for the first time in a generation.

By bridging barriers to waterfront access—made possible by $200 million in highway improvements to the interchange of I-84 and I-91—and creating comfortable, attractive, and versatile gathering spaces, this riverfront project has become a popular venue for concerts, boating, and fishing.

In 2001, Riverfront Plaza, programmed by the nonprofit group Riverfront Recapture, attracted 850,000 visitors and pumped $17 million into the local economy. The revitalized riverfront is generating investment through redevelopment in a city that badly needs new economic vitality. The foremost example is Adriaen's Landing, a 30-acre, $770-million mixed-use develop-

Riverfront Plaza spans Interstate 91, removing barriers to riverfront access in Hartford.



Greg Kriss, Riverfront Recapture

ment scheduled to be completed by 2005 and connected to the river by Riverfront Plaza (Dillon 2000; Riverfront Recapture 2002).

General Principle 4: Compromises are necessary to achieve multiple objectives

Urban waterfronts are meeting grounds for sometimes-competing interests. Recreational trails and wetlands are often interwoven with waterfront condos and port facilities. It is not possible or even desirable to focus exclusively on economic development or environmental concerns along most urban rivers. Because of existing development, few cities could re-create a completely natural river environment. But riverfront redevelopment aimed at boosting a city's economic vitality need not eliminate natural features, compound riverfront damage, or limit public access. Riverfront communities will benefit from integrating and balancing ecological, social, and economic concerns.

The Big Rivers Partnership in Minnesota is a team of nonprofit and government agencies that seeks to protect and improve river valley habitat along three major rivers in the seven-county Twin Cities metropolitan area. Recognizing that complete restoration of a natural river environment often is impossible, the Big Rivers Partnership uses the term "conversion" for efforts such as replanting native species or replacing impervious ground with porous cover. These measures will not restore the complex and fully functioning ecosystem of presettlement times. But they will enhance and create habitat and improve water quality (Karasov 2002, 2003).

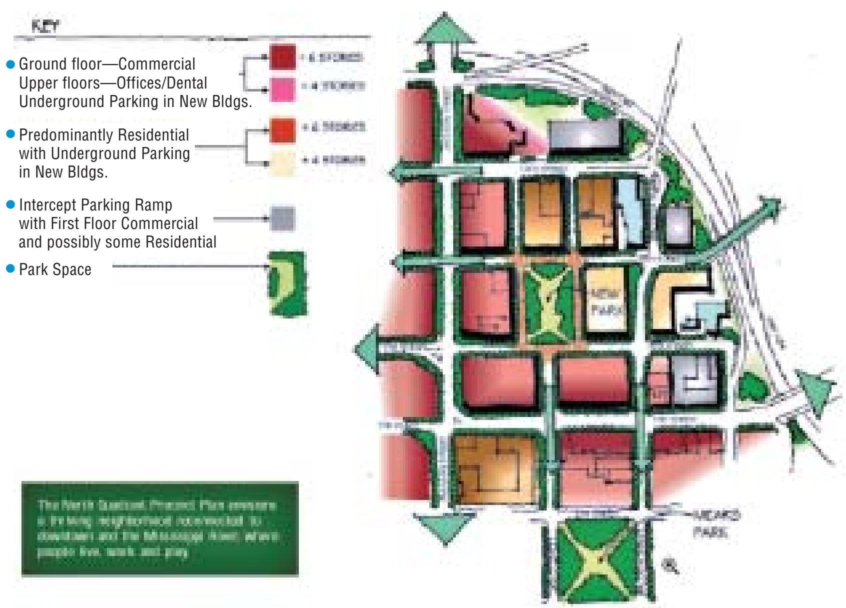
At the heart of this watershed, in downtown Saint Paul, the continuing revitalization of the Mississippi River seeks to insert natural values alongside intensive redevelopment. Since 1984, this effort has been led by the Saint Paul Riverfront Corporation (SPRC), a nonprofit organization chartered by the city to coordinate revitalization. This effort accelerated in 1992 when a large private employer left downtown. City leaders recognized they needed a comprehensive strategy to fill the economic gap. The SPRC commissioned architect Ben Thompson—a Saint Paul native who designed Boston's Fanueil Hall Market and other successful "festival marketplaces"—to forge this new vision for downtown based on riverfront revitalization. That effort led to development of the *Saint Paul on the Mississippi Development Framework* (Urban Design Strategies 1997), which was fleshed out by the *Saint Paul River Corridor Urban Design Guidelines* (Close Landscape Architecture et al. 2000).

The *Saint Paul River Corridor Urban Design Guidelines* divided this urban section of river into seven types of landforms. It identified areas suitable for development and opportunities for natural restoration and enhanced water quality through wetlands, ponds, improved tributary streams, and underground sand filters (Martin 2001).

As a result of these planning efforts, since the mid-1990s the city's riverfront has seen the construction of new cultural facilities, businesses, and thousands of homes. Meanwhile, shipping continues to thrive on this working waterfront . Roads have been moved to increase access to the river through five miles of new trails and 92 acres of new parks, including a newly revitalized historic park on Harriet Island (SPRC 2003).

Although these efforts have included construction of some concrete banks and a U.S. Army Corps of Engineers levee, the revitalization planning also has reclaimed seven miles of industrial lands along the river. Here the non-

FIGURE 3-1. SAINT PAUL NORTH QUADRANT PRECINCT PLAN



Source: Urban Design Strategies (1997)

profit organization Great River Greening (GRG), which works on Mississippi restoration in the Twin Cities region, has leveraged $1 million in funding and the work of 10,000 volunteers to clear weeds and plant 35,000 native trees. Volunteer projects also are being harnessed to restore native vegetation to two eroded river bluffs in Saint Paul (Karasov 2002).

GRG and the city's Department of Parks and Recreation are collaborating on a master plan for ecological management of 16 city parks along Saint Paul's 17 miles of riverfront. These will be managed as complementary ecosystems rather than as discrete, stand-alone parks. One of these park units, the 500-acre Crosby Natural Area, a rare riverfront ecosystem that

Nearly 200 volunteers helped plant native trees, shrubs, prairie grasses, and wildflowers along Saint Paul's Smith Avenue High Bridge on the banks of the Mississippi.

Great River Greening

hosts endangered species such as the Blandings turtle, will have its own management plan to balance preservation, restoration, and human use (BRW, Inc. et al. 1999; Karasov 2003).

General Principle 5: Make the process of planning and designing riverfronts broadly participatory

Riverfront planning and design must include the participation of a wide variety of community members. The process must extend beyond identifying traditional stakeholder groups and reach out to neighborhoods that historically may not have used the riverfront. The needs of various neighborhoods and constituencies may differ. Riverfront designs will be more vibrant, inclusive, and successful when they consider these different priorities. Local officials and developers, as well as planning staff, must participate in public meetings to ensure that everyone works toward the same vision, and that all important considerations are made known.

The Schuylkill River Development Council (SRDC) put this principle in practice. In 2001, SRDC, armed with nearly $3 million in foundation and state grants, launched a nine-month process to create a master plan for 8.5 miles of the Schuylkill, a tidal river flowing through Philadelphia. SRDC made concerted outreach efforts to involve residents of river neighborhoods, which included both gentrified and low-income areas. Rather than simply scheduling public meetings, SRDC interviewed city officials to identify target audiences and then made special presentations to church, community, and school groups. A measure of success emerged when Vare Middle School, a public school in South Philadelphia, integrated Schuylkill River projects into its curriculum.

Recognizing that not everyone uses e-mail or the Internet, the SRDC informed residents about meetings by placing posters around neighborhoods and buying ads in community papers. Those who attended meetings were given large, easy-to-read worksheets that allowed them to locate their own homes on a map and trace preferred routes for river access.

Residents were also invited to tour the Schuylkill on a flat-bottom boat. Many had never been out on the river before. The residents' ideas were charted on "idea maps" folded into the final plan. In all, 25 to 30 community groups and hundreds of residents from both sides of the river participated in the process. The final plan envisions a new Schuykill River Park with related greenways (Hodge 2002).

In 2002, a critical first phase of this park was constructed: a $6.7 million, 1.8-mile greenway stretching from the historic Fairmount Waterworks to Locust Street. This greenway provides many residents with their first-ever safe access to the riverfront. The project incorporates plans for many other river improvements, such as retrofits of auto bridges with ramps and stairs to allow pedestrian access to the waterfront, ramps over railroad tracks, $600,000 of new docks at Fairmount Waterworks, and fish ladders on dams (Torres 2003).

PLANNING PRINCIPLES

Planning for riverfront revival must consider regional development patterns, natural and cultural history, flood control, public access, recreation, and education. The following five principles should be integrated into master plans and implemented through zoning and building codes, engineering standards, and site plans and designs.

PLANNING PRINCIPLES

Planning Principle 1: Demonstrate characteristics of the city's unique relationship to the river in the riverfront design

Planning Principle 2: Know the river ecosystem and plan for a scale larger than the riverfront

Planning Principle 3: Because rivers are dynamic, minimize new floodplain development

Planning Principle 4: Provide for public access, connections, and recreational uses

Planning Principle 5: Celebrate the river's environmental and cultural history through public education programs, riverfront signage, and events

Planning Principle 1: Demonstrate characteristics of the city's unique relationship to the river

Every river city has a unique relationship and history interwoven with its river. San Antonio and Chicago, for example, have very different riverscapes, scales of development, and historic uses along their rivers. Riverfronts should have a look and feel that evokes and celebrates their city's special character and relates directly to their natural history.

Citizens must understand that their city's river is a place that grants their region its identity, one that provides wildlife habitat, recreation, drinking water, and jobs. When citizens value these factors, they become advocates for protecting and restoring their riverfronts.

The St. Louis region, for example, plans a 40-mile Confluence Greenway and Conservation Area linking cities and towns to the spot where Lewis and Clark launched their 1804 expedition. The project will knit together cultural and natural resources into a 200-square-mile park system in Missouri and Illinois. Stretching from downtown St. Louis at the Gateway Arch to the confluence of the Missouri and Mississippi Rivers, the greenway system will encompass natural and restored wildlife and conservation

The Confluence Greenway and Conservation Area links cities and towns in Missouri and Illinois and makes it possible for cyclists and others to visit the spot where Lewis and Clark launched their 1804 expedition.

Trailnet

areas, parks, neighborhoods, river towns, agriculture, and commerce. The Confluence Greenway will stimulate recreation and tourism dollars by offering extensive waterfront access.

At the confluence, the new Edward "Ted" and Pat Jones-Confluence State Park is being developed in St. Charles County, Missouri. The state's Department of Natural Resources is creating access through entry roads and trails that lead to the confluence while providing opportunities for wildlife observation and river recreation. The park will also interpret the historical significance of the rivers. Park development will be linked to the Lewis and Clark bicentennial celebration of 2004.

The project aims to restore and protect environmentally sensitive land, plants, and wildlife, while assisting flood control and reducing stormwater runoff. Community members will be trained as trail rangers to provide information about the river.

In January 2003, this project took a major step forward. A partnership of 13 local, state, and federal agencies and private organizations collaborated to expand Confluence State Park from 253 acres to 1,118 acres. For example, a $1 million federal grant made under the North American Wetlands Conservation Act allowed the Missouri Department of Natural Resources to add 350 acres of protected wetlands to the park. Using an interest-free loan from a local foundation, private nonprofit conservation organizations acquired and held another 515 acres until public agencies could raise funds to purchase this parkland.

Planning Principle 2: Know the river ecosystem and plan for a scale larger than the riverfront

Planners should consider riverfront development in the context of the river's natural structure, including:

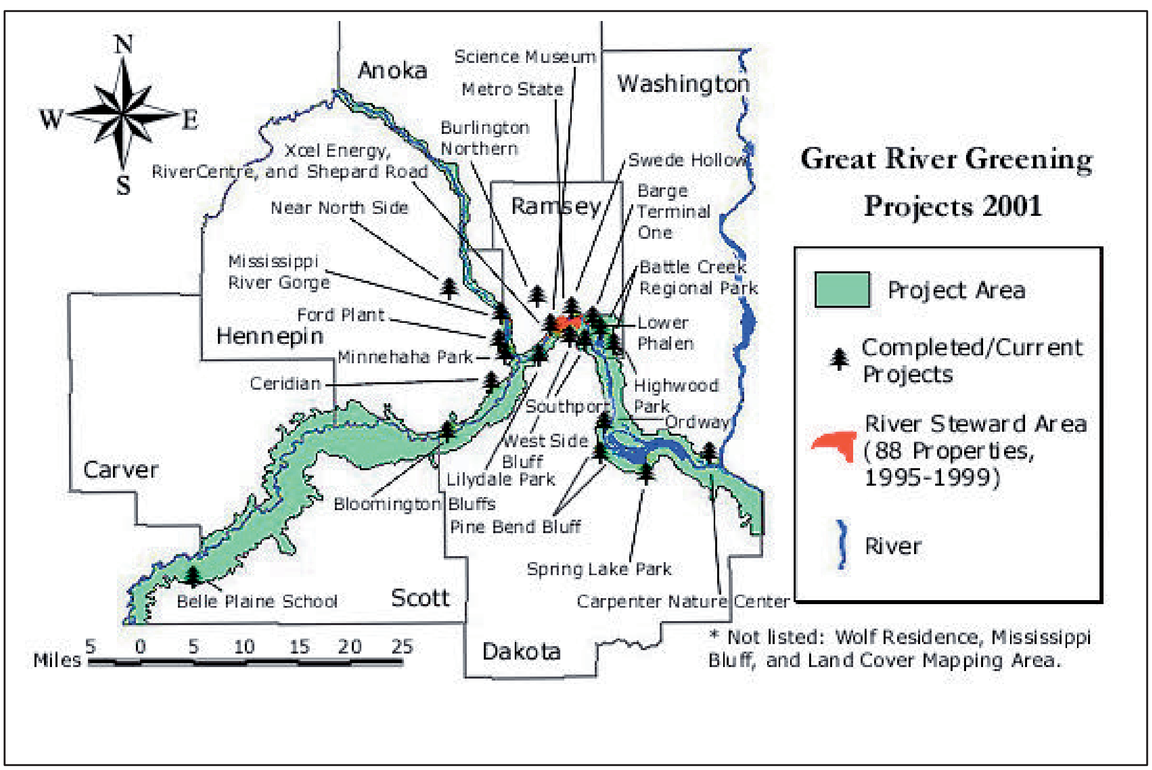
- characteristics of the watershed (the land area drained by a river and its tributaries);
- the floodplain and the river channel with the structure of its bed and banks;

- hydrology (water flows and timing);
- water chemistry; and
- the biological needs of wildlife, including insects, fish, amphibians, reptiles, birds, and mammals.

It is also important to understand how a river's structure has been altered and how it may change in the future. Rivers are affected by what happens in their watersheds, and riverfront activity, in turn, affects areas beyond the river's edge. Planners must keep in mind the consequences of riverfront design and activities on *all* areas of the watershed. Each river has a watershed that is nearly always much greater in area that the riverfront corridor. One cannot improve the health of the river without comprehensively addressing stormwater and other pollution sources across the entire watershed. Thus, riverfront corridor planning is best performed within the context of sound watershed planning, which is conducted at a much greater scale (Schueler 2003).

In Minnesota's Twin Cities region, the nonprofit group Great River Greening (GRG) is refurbishing natural functions in the Mississippi, Minnesota, and St. Croix River valleys. To determine priorities for a series of ecological "conversion" projects, GRG created a geographic information system (GIS) database of the 54,000-acre Mississippi National River and Recreation Area (MNRRA), designated as part of the National Park System in 1988. However, less than 10 percent (about 4,600 acres) of the MNRRA is currently preserved as public parkland (National Park Service 2003; Overson 2002). The rest is the commercial, institutional, and residential land of a metropolitan area—from airports to landfills to subdivisions. GRG and its partners seek to increase public lands, trail access, and ecological function along with the region's commerce and culture.

FIGURE 3-2. GREAT RIVER GREENING PROJECTS



Source: www.greatrivergreening.org/downloads/Gorge_Management_Plan.pdf.

Throughout the region, the GIS database records such elements as land use, tree canopy, slopes, soil conditions, water quality, and areas with invasive plant species. The data is used to create benchmarks for factors such as tree cover, impervious surface, and stormwater filtration for different types of urban, suburban, and natural landscapes (Karasov 2002, 2003).

Completed in December 2002, this database is available for free on CD-ROM to Twin Cities communities through the Trails and Open Space Partnership, a project of the MNRRA. Established in 1996, the partnership works with more than 50 government agencies, institutions, nonprofits, and private landowners toward the goal of a continuous 72-mile greenway within the MNRRA. The GIS database allows communities to earmark funds to acquire the most sensitive natural areas and build the most critical trail connections. Communities also can download this information as PDFs and zoom in on individual parcels for detailed information. The information allows communities to evaluate development proposals based on their potential to damage or to enhance sensitive natural areas.

By 2003, nearly 50 miles of public trail were built in the MNRRA corridor, with plans to acquire another 2,000 acres of public parklands. By thinking regionally, the Trails and Open Space Partnership has attracted $7 million from government agencies and nonprofit organizations to help realize these projects (Overson 2002).

Planning Principle 3: Because rivers are dynamic, minimize new floodplain development

Rivers by nature change continually. For example, on some rivers, spring flood elevations exceed nonflood levels by 20 feet or more. Some rivers freeze in winter. Others experience little seasonal change. The effects of changes upstream and in the surrounding watershed can significantly alter these natural variations, often with disastrous results. Extreme cases of flooding—often made worse by floodplain development—constitute the nation’s most destructive natural disasters.

Undeveloped, connected floodplains are essential to river health. New development on the riverfront, including trails and parks, should be designed to minimize floodplain intrusions. Where new development must occur, structures or facilities should be designed to:

- ensure that contaminants will not be released during flooding;
- cause no net decrease in flood storage capacity; and
- cause no flooding or other downstream impacts.

Large permanent structures should not be built within the 100-year floodplain because they increase the amount of impervious surface, exacerbate runoff problems, and increase the risk of costly flood damage.

Habitat diversity and water quality become severely compromised when as little as 10 percent of a floodplain is paved or covered with an impervious surface. A floodplain that is more than 50 percent paved will result in a waterway with little wildlife habitat and few natural features (MacBroom 1998).

Structural flood-control approaches—such as dams, levees, and channelization—do not necessarily prevent floods, but they do destroy habitat, recreation, and other river values. These engineering techniques should be used sparingly, if at all, to protect new floodplain development.

Located along the Mississippi River, Davenport, Iowa, is one of the largest river cities in the United States without hard-engineered flood structures. In 1984, Davenport (pop. 100,000) rejected a U.S. Army Corps of Engineers proposal to build a $50 million levee. The city believed the cost of the levee would far outstrip the cost of potential damage from flooding. Since then, Davenport has moved to expand its floodplain and to "flood proof" its downtown. (The city owns and controls six of its nine riverfront miles, which signficantly enables these efforts.)

Numerous downtown businesses have been moved to higher ground, with the abandoned sites converted to open parkland that enhances recreation and tourism. The city has bought and removed 65 residences and retrofitted another 20 historic buildings in the floodplain with waterproof gates and sump pumps (Lloyd 2002).

In addition, River Action, Inc., a nonprofit group that addresses riverside beautification and flood control, is participating with the U.S. Environmental Protection Agency to cleanse the 513-acre Nahant Marsh within city limits on the riverfront. Under a 1998 master plan adopted by the city council, River Action has acquired 252 acres of the flood-absorbing marsh with plans to open this riverfront area to the public with a boardwalk, interpretive areas, and staging areas for field trips (Wine 2002, 2003).

The city realizes flooding is a riverwide problem that it cannot solve alone. Thus River Action is working with 12 riverfront communities in Illinois and Iowa to encourage healthy river designs that will enhance flood control (Wine 2002).

Despite these efforts, Davenport has not been exempt from flood damage. In July 2001, the river rose seven feet above normal, causing the second-worst flooding in the city's history. Cleanup costs were $3.1 million, with the federal government picking up 90 percent of the costs. Yet Davenport's share of $310,000 still compares favorably to the $250,000 annual cost of maintaining a levee. After this flood, the city revisited a levee proposal and is now designing a small levee to protect the municipal water supply (Wine 2003).

Davenport's approach has been highly controversial. During the 2001 floods, the director of the Federal Emergency Management Agency attacked the city for refusing to build a floodwall. River advocates remain steadfast that flood engineering generally doesn't work, and that floodwaters can no more be prevented than earthquakes or hurricanes. Moreover, cities with levees were also threatened and damaged by the rising waters in the flood years of 1993 and 2001. River advocates maintain that Davenport's approach of protecting the floodplain and expanding wetlands—where a single acre can absorb 1.5 million gallons—will benefit other Mississippi River communities as well as other watersheds (Wine 2002).

Eric Eckl

Physical contact with a river is important. New developments along a river should always provide direct access to the river.

Planning Principle 4: Provide for public access, connections, and recreational uses

Easy access is vital to draw people to a riverfront. Visual connections to the river from nearby commercial and residential areas also are important. Physical and visual access should not be reserved only for select neighborhoods or businesses along the redeveloped river. Riverfronts can include many recreational uses, from bicycling to bird watching. Riverfront communities should provide areas or facilities for as many of these uses as possible.

People should be able to touch and interact with the river in appropriate locations, whether through wading, fishing, launching a boat, or sitting on the riverbank. Economic revitalization along riverfronts, such as new mixed-use development with housing, restaurants or cafes, and open space, is more successful when it includes visual and physical access to the water.

In Norwalk, Connecticut, for example, a capped 13-acre landfill on the tidal Norwalk River has become the platform for a new $6.5 million, 20-acre riverfront park and riverwalk, started in 1991 and still evolving. Oyster Shell Park features stormwater channels that cut diagonally across the landfill cap and drain into a five-acre pond on the riverfront. A riverwalk located three feet above the 100-year floodplain provides access to the pond, which freezes for winter ice-skating. A west-facing slope is expected to become a popular sledding hill. An adjacent 80-acre site above the floodplain is being redeveloped with a hotel, shops and restaurants, and office space.

The riverbanks have been regraded to encourage intertidal wetlands, which are expected to regenerate oyster beds in an area that already rivals the Chesapeake Bay for productivity. Increases in heron and river otter population have already been reported, while the water-quality commission plans to monitor the return of oysters (MacBroom 2002; Overton 2002).

Planning Principle 5: Celebrate the river's environmental and cultural history

Riverfronts are rich in both human and natural history. Interpretive and path-finding systems can describe the river, its environment, and how river and city history are intertwined. Educational and cultural programs, performances, and public art entice people to the riverfront.

Ecological education is especially meaningful along urban rivers because so much of the original ecosystem has been erased. As active, visually rich environments, rivers can be powerful tools for science and nature education. Educating the public about the river and its natural systems will generate a sense of stewardship and a connection to the river's history.

On New Jersey's Hackensack River, artist and environmentalist Richard Mills created low-cost "signworks" that illustrate the river's natural and cultural history. Arrayed along a 3.5-mile greenway in Teaneck, the signs combine text with images created by schoolchildren and other local residents, maps, historical photos, satellite images, postcards, and interviews with local historians. The artist hopes to "get people to fall in love with the river" so they will want to see it protected and restored (Mills 2002).

Richard Mills

This is one of 16 signs created along the Hackensack River illustrating the river's natural and cultural history.

A walk along the greenway encompassing all the 16 signworks begins with the era of Native American villages, includes the age of schooner traffic and the industrial pollution of the 1950s, and ends with today's restoration efforts. Printed digitally and mounted on aluminum, the two-by-three-foot signworks cost only $75 each to produce. Low-cost printing makes it practical to revise and update signs. The costs of the construction and installation of stanchions ($1,000 each) have been donated by local governments and the utility company PSE&G. The artist also donated 3,500 hours of work. Erected in 1998, the Hackensack River Stories Project has given residents a new perspective on the potential to regenerate one of the nation's most polluted and threatened rivers (Mills 2000, 2002).

DESIGN PRINCIPLES

"First, do no harm" summarizes the ethic of the Hippocratic Oath. Planners for riverfront revival must also follow this dictum. The best way to ensure the health of an urban waterway is, first, to protect its healthiest features, whether they are water quality, wetlands, or urban forests. Allowing development to disturb these features and then attempting to reconstruct them—even using best management practices—is no substitute for protecting the intact elements of a healthy ecosystem.

DESIGN PRINCIPLES

Design Principle 1: Preserve natural river features and functions

Design Principle 2: Buffer sensitive natural areas

Design Principle 3: Restore riparian and in-stream habitats

Design Principle 4: Use nonstructural alternatives to manage water resources

Design Principle 5: Reduce hardscapes

Design Principle 6: Manage stormwater on site and use nonstructural approaches

Design Principle 7: Balance recreational and public access goals with river protection

Design Principle 8: Incorporate information about a river's natural resources and cultural history into the design of riverfront features, public art, and interpretive signs

This section provides an overview of some of the most effective preservation techniques, including protective zoning, buffer conservation, and open space preservation programs. It also describes the best practices for reconstructing the ecological features of urban rivers, including efforts to remove dams, reduce pollution from runoff, rebuild in-stream habitat, and restore healthy, natural riverbanks.

Design Principle 1: Preserve natural river features and functions

Preserving the natural features and functions of America's 3.6 million miles of streams and rivers contributes greatly to urban riverfronts. Through zoning, land preservation practices, and careful site design, communities can protect sensitive areas of rivers and streams from development. As part of the preservation process, communities should determine ecological goals for urban riverfronts and identify missing or altered natural features.

RIVER PRESERVATION TOOLS FROM THE PLANNER'S TOOLBOX

Growth Management

In recent years, Maryland, New Jersey, Oregon, and Washington have enacted smart growth legislation to encourage revitalization of cities and towns while preventing sprawl. Municipalities such as Portland, Oregon, and Boulder, Colorado, have established urban growth boundaries.

Some municipalities offer incentives for development in higher-density areas. Others refuse to subsidize development in "greenfield" areas through public construction of sewers or roads. Or they may impose development moratoria or limitations on the number of building permits issued.

The most successful programs combine incentives for infill or brownfield redevelopment with strategies to protect or enhance natural areas and open space.

Comprehensive regional planning helps mitigate the environmental and economic impacts of urbanization. Especially when combined with effective stormwater management, concentrating development within a metropolitan region can reduce the region's overall impervious surface. The most heavily urbanized sites with the greatest concentration of impervious surface, however, may still require substantial structural stormwater measures. But as long as these measures are carefully designed, a compact metropolitan area guided by smart-growth principles will generate fewer negative impacts and preserve more of a river's natural features than an area dominated by sprawl (Lehner et al. 2001).

Transit-Oriented Development

Transit-oriented development (TOD) concentrates development around public transit, bike and pedestrian routes, and carpooling facilities. Commercial uses located near transportation nodes can reduce vehicle miles traveled as well as the number and land area of roads and parking lots. TOD thus produces less impervious cover, stormwater runoff, and pollution discharge. Transportation-related hard surfaces account for more than 60 percent of the total imperviousness in many suburban areas (May et al. 1997).

Traditional Neighborhood Design

Traditional neighborhood design minimizes the impervious footprint of a neighborhood through compact development patterns that feature narrower roads, smaller lots, shorter front setbacks, shared alleys, and protected open space. New Urbanist developments go a step further by varying housing types and densities and featuring mixed uses. Stores, offices, schools, daycare centers, recreation facilities, and mass transit are included on site or within walking distance, which reduces reliance on automobiles and thus reduces the impervious cover generated by streets and driveways.

Clustering and Conservation Subdivision Design

Clustering concentrates homes on a limited portion of a site and leaves the rest for open space and wildlife habitat. This approach also includes narrower roads, shared driveways, and shorter setbacks from residential streets. Conservation subdivision design reduces the amount of impervious road surface for residential

(continued)

In stable streams and rivers, natural equilibrium controls the water flow and sediment supply. Yet many urban rivers have been greatly altered by dams and flood-control structures. Preserving natural river features and functions means avoiding the use of new dams and other engineering solutions,

RIVER PRESERVATION TOOLS FROM THE PLANNER'S TOOLBOX *(continued)*

developments. Some municipalities expand the concept to treat native landscapes as functional elements of a development. In such cases, open space, often through restoration and management practices, is used to treat stormwater, enhance biodiversity and wildlife habitat, and provide an enjoyable environment for residents (Lehner et al. 2001).

Land Purchases by Environmental Trusts

The Land Trust Alliance's 2002 census recorded 6.2 million acres of natural lands in the United States protected by 1,263 local and regional land trusts. These lands are in addition to those protected by the nation's top land conservation organizations: the Trust for Public Land (TPL), the Nature Conservancy, the Conservation Fund, and Ducks Unlimited (Aldrich 2003; Land Trust Alliance 2003a). Since 1972, TPL alone has helped protect more than 1.4 million acres in 45 states, from recreation areas to small city parks. In June 2002, the Conservation Fund helped transfer 860 acres worth $4.5 million along Plum Creek in Louviers, Colorado, from the DuPont corporation to Douglas County's open space program. These lands, featuring mature cottonwoods and undisturbed riparian areas, preserve a key wildlife corridor for the region, and create a greenbelt for Louviers, a historic company town formerly owned by DuPont (Macy 2002).

Conservation Easements

Conservation easements are legal agreements between a landowner and a land trust or a government agency that permanently prohibit or limit land uses to protect conservation values. Conservation easements allow landowners to continue to own and use the land and to sell it or pass it on to heirs. By removing the land's development potential, the easement lowers its market value, which in turns lowers estate tax. If the landowner donates the easement, and the donation benefits the public by permanently protecting important conservation resources while also meeting other federal tax code requirements, it can qualify as a tax-deductible charitable donation. The amount of the donation is the difference between the land's value with the easement and its value without the easement.

Conservation easements are popular and commonly used. From 1990 to 2000, local and regional land trusts in the U.S. protected 2.6 million acres through easements (Land Trust Alliance 2003a; Palone and Todd 1998).

Transfer of Development Rights

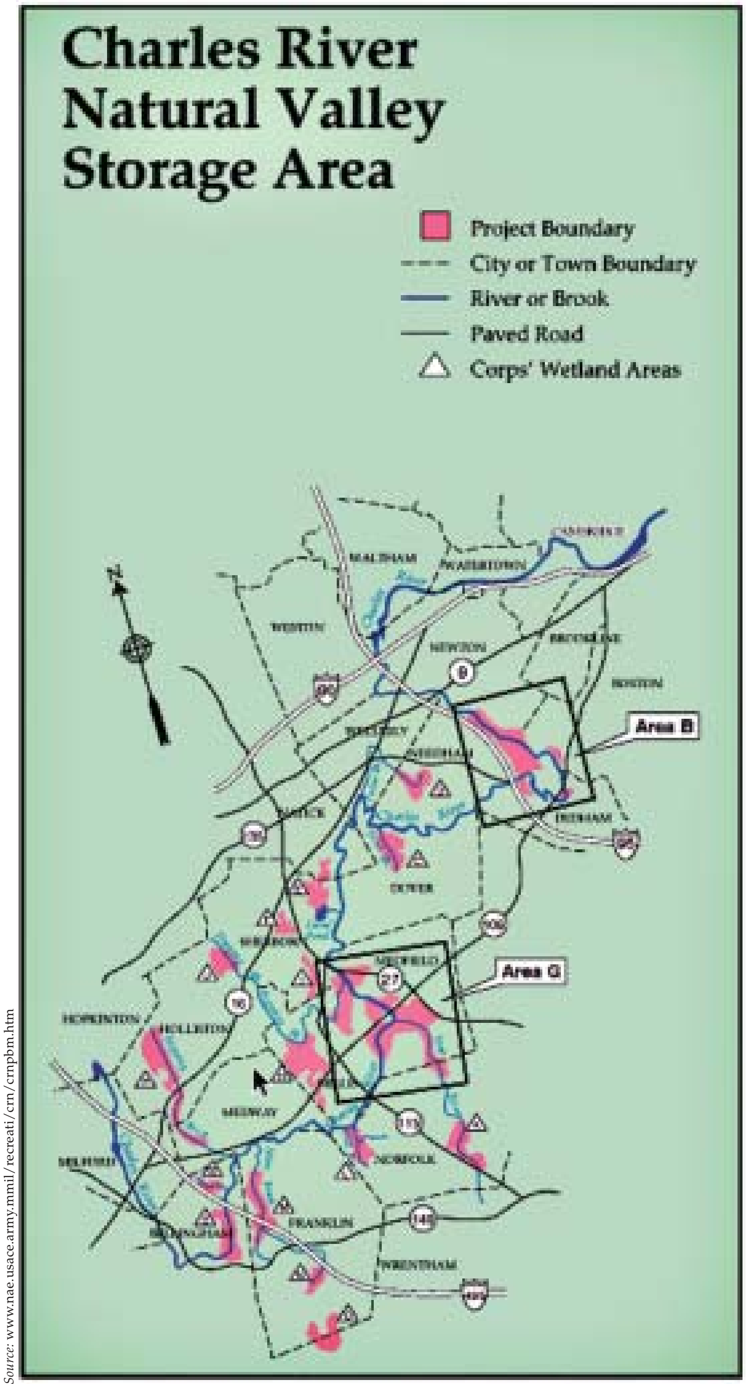
Transfer of development rights (TDR) programs allow municipalities to preserve unique and environmentally sensitive natural areas. A form of overlay zoning, TDRs protect landowner property values because landowners are permitted to transfer their right to develop, based on the underlying zoning district, to an area designated for more intense development. TDRs therefore allow riparian corridors and other sensitive areas to be permanently deed-restricted from development without diminishing the land's value. TDRs are also used to encourage higher-density development within urban growth boundaries or other specified areas. However, TDRs are complex to negotiate and thus are less frequently used.

such as straightening, channelizing, or placing streams in underground pipes and culverts.

Fully restoring the ecological features and functions of most urban rivers and streams may be impossible. Yet communities have numerous opportunities to preserve critical areas that support a more natural riverfront. Many urban rivers retain surprisingly rich and extensive predevelopment features, such as forested banks, fish and bird habitat, and wetlands. Preservation of these natural watershed features also can save money.

The U.S. Army Corps of Engineers, for example, found that buying land or easements to preserve a network of natural wetlands in the Charles River Valley outside of Boston cost $8 million, compared to the estimated $100 million cost of building a dam. Maintaining these natural wetlands benefited the aesthetic and ecological qualities of the floodplain and increased the value of adjacent properties (Lehner et al. 2001).

FIGURE 3-3. THE CHARLES RIVER NATURAL VALLEY STORAGE AREA



Source: www.nae.usace.army.mil/recreati/crn/crnpbm.htm

Working with the Charles River Watershed Association, the Corps studied marshes, swamps, and meadows throughout the upper watershed. These wetlands act like huge sponges, storing floodwaters and slowly letting them go over several weeks. The Corps determined that, compared to constructing a dam or levees, preserving the wetlands would not only cost less but would also result in greater storage capacity. These wetlands could temporarily store 10 vertical feet of water.

In 1974, Congress authorized the Charles River Natural Valley Storage Area to acquire and protect 17 wetlands throughout the watershed. By 1979, the Corps had purchased 8,103 acres and today maintains the wetlands. The Massachusetts Division of Fisheries and Wildlife manages some of the acres as open space (Zimmerman 2003).

Development and River Degradation

Poorly conceived urban development can degrade a river's natural processes and destroy or fragment wildlife habitat. Development generally increases impervious surfaces, which in turn increases stormwater runoff. The greater volume and velocity of stormwater runoff erodes riverbanks and enlarges river and stream channels. The combination of erosion and channelization increases sediments, destroys aquatic habitats, and creates an unstable channel that can increase flooding downstream.

Damage can also occur when infrastructure—including water and sewer mains and transmission lines—is installed in the hyporheic zone, the area below and surrounding the stream channel where critical chemical, biological, and habitat functions occur (see Chapter 2). Digging in these sensitive areas causes severe long-term damage. Riverfront development plans should be especially careful to preserve these less-visible natural features.

Low impact development (LID) is a stormwater management approach that seeks to integrate the built environment with a functioning part of the ecosystem. LID mimics a site's predevelopment hydrology through design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. This approach relies on engineering technologies to maintain or restore a watershed's hydrologic and ecological functions. Such techniques include permeable pavers, bioswales, and maintaining buffer zones. The results control pollutants, reduce runoff volume, and manage runoff timing (Low Impact Development Center 2003).

Land Protection Strategies

Communities can help determine the quality of urban streams and rivers through their land-use decisions. The following strategies for land protection can be a part of a program to maintain the ecological integrity of urban rivers and riverfronts.

Watershed planning considers all resources in the watershed as a single, interrelated system.

Watershed planning. Watershed planning considers all resources in the watershed as a single, interrelated system. A watershed is an area of land that drains water, sediment, and other materials downslope to the lowest point. The water moves through a network of drainage pathways, both underground and on the surface. Generally, these pathways converge into streams and rivers, which become progressively larger as the water moves on downstream, eventually reaching an estuary and the ocean (adapted from Watershed Professionals Network 1999). Watersheds can occur at multiple scales, from the multistate watersheds of the Mississippi and Columbia Rivers to the watersheds of small streams that measure only a few acres.

Watershed boundaries—the land area or catchment that contributes water to a specific river or stream—are the basic unit of management, rather than political boundaries. The premise of watershed planning is that impervious

SMART-GROWTH DEVELOPMENT

Smart-growth development features:

- Mixed land uses
- Compact site design that uses less land than conventional suburban development
- A range of housing opportunities and choices
- Walkable neighborhoods
- Distinctive, attractive communities with a strong sense of place
- Open space, farmland, and critical environmental areas
- Development or redevelopment of existing communities
- Transportation choices
- Predictable, fair, and cost-effective development decisions
- Community and stakeholder collaboration in development decisions

Source: Adapted from Smart Growth Online (2003).

cover, rather than population density, is the best measure of growth impact and future stream quality.

Watershed planning begins with an evaluation of current and ideal conditions for each body of water in the watershed, as well as comprehensive mapping of land-use practices. Planners then determine land uses that promote healthier rivers, streams, wetlands, and lakes. Public officials, residents, and other stakeholders create a watershed plan and land-use ordinances that designate the locations, levels, and types for new development or redevelopment that will protect or enhance the watershed (Lehner et al. 2001).

Infill and brownfield development. Infill and brownfield development recycles urban infrastructure. Reuse and renovation of these urban and suburban sites provide opportunities for economic development and can reduce impervious surfaces, depending on the site design (old parking lots can be replaced by mixed-use buildings and open space, for example). Like other smart growth strategies, infill development may present challenges to communities and developers, but the benefits to local watersheds can be significant (Northeast-Midwest Institute and Congress for the New Urbanism 2001).

Open space and buffer preservation. In many communities, zoning ordinances protect open space and buffers around streams, steep slopes, and other sensitive areas. Many municipalities also purchase land as a cost-effective way to reduce stormwater runoff and control flooding while adding natural areas. This strategy has attracted strong public support. Through LandVote 2002, the Trust for Public Land and the Land Trust Alliance found that voters approved a total of 139 of 188 measures in 2002, generating about $10 billion in conservation and conservation-related funding, including land acquisition (Trust for Public Land 2003b; Land Trust Alliance 2003b).

Protective zoning. Many communities write watershed preservation into zoning codes. Examples of protective zoning include:

- *Overlay zones.* Overlay zones superimpose natural resource protection zoning on traditional zoning to protect riparian buffers and other critical areas while still allowing underlying uses in suitable forms. This strategy gives municipalities legal control of an area without having to own the property (Palone and Todd 1998).

- *Performance standards*. Rather than specifying land uses, municipalities may create performance standards for open-space preservation, impervious surface area, maximum pollution emissions, or other criteria. Some performance zoning ordinances rank proposed developments on a point scale based on the degree to which they achieve objectives, such as reducing potential pollutant runoff. Only projects that exceed a minimum threshold are approved. Performance standards may also include incentives, such as density bonuses for projects that exceed standards or provide additional natural amenities such as natural restoration within the development (Lehner et al. 2001).

- *Resource protection zoning.* Municipalities can protect riparian areas through resource protection zoning that establishes a natural resource right-of-way similar to a utility right-of-way. Setback width is then determined before construction begins. When applied to streams and rivers, resource protection zoning ordinances typically establish either

THE FOCUS OF SMART GROWTH

Smart growth focuses on:

- *Community quality of life*, helping create community and a sense of place through housing and transportation choices, urban green spaces, recreational and cultural attractions, and policies and incentives that promote mixed-use neighborhoods.

- *Design,* promoting resource-efficient building and community designs, green building practices, low-impact development, and mixed-use and walkable neighborhoods with health, social, economic, and environmental benefits.

- *Economics,* encouraging community-based small businesses, local employment opportunities, and new businesses and industries, with efficient government services and public and private investments aimed at quality-of-life improvements.

- *Environment and health*, conserving energy and reducing threats from air and water pollution and indoor air contaminants through resource-efficient building design. Transportation options such as mass transit, bike lanes, and pedestrian walkways also engage residents and workers in a more active, healthy lifestyle.

- *Housing,* combining diversity of lifestyles and socio-economic levels with mixed-use, affordable housing, and compact development.

- *Transportation*, promoting new transportation choices and transit-oriented development that offers alternatives to automobile-dependent communities.

Source: Adapted from Smart Growth Online (2003)

(1) a fixed buffer, which prohibits development within a certain distance of the high-water line of a perennial stream, or (2) a floating buffer, which varies in width depending on site, soil, and runoff characteristics (Palone and Todd 1998).

- *Large-lot zoning.* Large-lot zoning is low-density zoning. In some areas, this reduces density to one home per two acres; in other areas, it reduces density to one home per 35 acres. Ostensibly created to disperse the impact of development and reduce stormwater runoff, large-lot zoning actually contributes to sprawl by requiring longer road networks that, in turn, increase impervious cover (Schueler 1995c).

Suburban sprawl also contributes to water scarcity and increased stormwater runoff and pollution by promoting more and larger lawns. According to a study conducted in the Seattle metropolitan area, large suburban "estate" properties consumed up to 16 times more water than homes on smaller lots within a traditional urban grid. Suburban soils beneath lawns are often as impervious as roads and parking lots because they have been compacted by heavy grading equipment used to create subdivisions. Stormwater runoff from turf areas also is more likely to contain pollutants such as pesticides and fertilizers (American Rivers et al. 2002; Schueler 1995b).

Design Principle 2: Buffer sensitive natural areas

Buffers are areas next to a shoreline, wetland, or stream where development is restricted or prohibited. They protect a river's ecological integrity, enhance connections between wildlife habitats, and allow rivers to function more naturally. A network of buffers acts as the right-of-way for a river or stream and functions as an integral part of the stream ecosystem. Buffers of varying widths protect natural areas around rivers and streams, especially fragile areas such as steep slopes and wetlands.

Well-designed buffers protect water quality and plant and wildlife habitats. Buffers provide shade that lowers water temperature and protects fish habitat.

Buffers also reduce a site's overall imperviousness, and they filter sediments and such stormwater pollutants as fertilizer and pesticide runoff. In their role as filters, buffers can reduce water treatment costs by preventing pollutants from entering drinking water sources. Preserving open spaces as buffers along the river provides a cost-effective means of stormwater and flood control. Buffers also reduce erosion caused by uncontrolled runoff and stabilize riverbanks with vegetation.

Well-designed buffers protect water quality and plant and wildlife habitats. Buffers provide shade that lowers water temperature and protects fish habitat. Trees, shrubs, grasses, and other native plants provide cover and food for birds, mammals, and other animals that live along the river. Humans can also benefit: flourishing buffers are visually appealing and often double as greenbelts, parks, and recreation areas.

Creating buffers that benefit the river ecosystem can mean giving up some traditional notions of what is "attractive." Manicured lawns, formal landscape designs, and pruned shrubs, for example, do not encourage biodiversity, often require harmful pesticides, and do not provide the food and shelter that wildlife needs.

Identifying Buffer Areas

Locations in need of a buffer can be easily identified: a walk along any riverfront will reveal the areas where erosion, channelization, and other signs of degradation are greatest. Generally, the most critical areas to buffer possess steep slopes, wetlands, erodible soils, and endangered or threatened animal or plant species. Geographical information systems (GIS) and aerial photos are the most effective tools for identifying buffer sites of more than several miles. Buffers should be recorded on official maps and protected through conservation easements, regulations, and signs.

In the Twin Cities region, Great River Greening (GRG) is working to identify, protect, and restore buffers. With the help of a staff landscape ecologist, aerial photos, and GIS technology, the organization has identified the highest-quality buffers along a seven-county stretch of the Mississippi River. Using this information, GRG formulates priorities for ecological restoration, protecting and buffering natural areas, and preserving and creating wildlife habitat, especially for songbirds (Karasov 2002).

GRG also has worked with the Friends of the Mississippi River and more than 100 landowners to protect and enhance buffers. A prime example is their plan to create the 1,300-acre Pine Bend Bluffs Natural Area overlooking the Mississippi. This area includes 700 acres owned by Flint Hills Resources, an operator of local oil fields and refineries that is participating in restoration efforts. Although largely untouched since the nineteenth century, the area was choked by nonnative plants when efforts began in 2000 to restore original oak savanna, oak forest, and prairie habitats. Volunteers cleared invasive plants from 78 acres and identified native species. By late 2001, the area had been replanted with native prairie wildflowers and grasses.

With financial support from Flint Hills, the National Fish and Wildlife Foundation, the Trust for Public Land, the Minnesota Department of Natural Resources' Metro Greenways program, and other public and private organizations, the multistage project has enhanced the river buffer with native plants and porous cover. Ultimately GRG hopes to protect all 1,300 acres in this important river corridor (Friends of the Mississippi River 2003; Great River Greening 2003; Karasov 2002, 2003).

Laws, Ordinances, Design Guidelines, and Standards

State laws and local planning ordinances can help preserve buffers through development regulations. For example, the Georgia Planning Act of 1990 limits land-disturbing activities within a 100-foot buffer on all protected rivers. Georgia's Metropolitan Rivers Protection Act goes further, establishing a 2,000-foot stream corridor on both sides of the Chattahoochee River and its impoundments for the 84 miles between Buford Dam and the downstream limits of Atlanta. Within this corridor, the law, administered by the Atlanta Regional Commission, specifies a 150-foot setback for impervious surfaces (Atlanta Regional Commission 2003).

A collection of planning practices known as "better site design" can conserve natural areas, reduce watershed pollution, save money, and increase property values.

A collection of planning practices known as "better site design" can conserve natural areas, reduce watershed pollution, save money, and increase property values. Better site design is a fundamentally different approach from typical subdivision design for residential and commercial development. These practices seek to accomplish three goals: reduce impervious cover, conserve more natural lands, and use porous areas for effective stormwater treatment.

In 1996, the Center for Watershed Protection convened a national site-planning roundtable composed of experts in planning, design, development, and environmental sciences, as well as representatives of local governments. The roundtable created 22 model development principles, organized into three areas: residential streets and parking lots, lot development, and conservation of natural areas (see sidebars on pp. 54 and 76–77).

BETTER SITE DESIGN FOR CONSERVATION OF NATURAL AREAS

The following six principles related to natural areas conservation in new suburban development are based on the roundtable's work and are adapted with permission from CWP (2003b). They are intended to help local governments modify their ordinances rather than to serve as national design standards.

1. Create along all perennial streams a variable-width, naturally vegetated buffer system that encompasses critical environmental features such as the 100-year floodplain, steep slopes, and freshwater wetlands.
2. Preserve or restore riparian stream buffers with native vegetation. Maintain the buffer system through the plan review, delineation, construction, and post-development stages.
3. Limit clearing and grading of a site to the minimum needed to build lots, allow access, and provide fire protection. Manage a consolidated portion of the community open space as protected green space.
4. Conserve vegetation at each site by preserving and planting native plants, clustering tree areas, and incorporating trees into community open space, street rights-of-way, parking lot islands, and other landscaped areas.
5. Encourage incentives and flexibility to conserve stream buffers, forests, meadows, and other areas of environmental value. Encourage off-site mitigation where it is consistent with locally adopted watershed plans.
6. Prevent new discharges of stormwater runoff into wetlands, sole-source aquifers, or sensitive areas.

If filtering pollutants is the goal, the buffer should be at least 100 feet wide. To protect wildlife habitat, a generally accepted minimum buffer width is 300 feet, though that varies with animal species.

Buffer Size

How big should a buffer be? To protect stream quality and aquatic habitat a minimum stream buffer of at least 100 feet is recommended (Stormwater Manager's Resource Center 2003). Often even that is too narrow to protect ecological values, depending on the size and topography of the river, nearby land uses, and the purpose of the buffer.

The Federal Interagency Stream Restoration Working Group (2001, 8-12) notes that "most local buffer criteria require that development be set back a fixed and uniform distance from the stream channel." Standards vary widely. Urban stream buffers range from 20 to 200 feet from each side of the stream, with a median of 100 feet, according to a national survey of 36 stream buffer programs by the Metropolitan Washington Council of Governments (MacBroom 1998).

If filtering pollutants is the goal, the buffer should be at least 100 feet wide. To protect wildlife habitat, a generally accepted minimum buffer width is 300 feet, though that varies with animal species. For large rivers, buffers should cover a significant portion of the floodplain to prevent flood damage.

The most important section of a stream buffer is the first 25 feet of land from the edge of the water. This zone—the streamside zone, which includes the stream bank, canopy trees that overhang the stream, and aquatic vegetation along the water's edge—should always be kept free from development. Next, the outer (or supplemental) buffer zone is located 100 to 200 feet from the water's edge. This outer zone provides additional river protection but can also accommodate low-impact human activities (MacBroom 1998; University of Georgia Institute of Ecology 2003; Washington County Soil and Water Conservation District 1999).

Planning ordinances specify either fixed or variable buffer widths. Fixed-width buffers typically express a political compromise between protecting a natural resource and minimizing the impact on development and private-property rights. Variable buffers, which become wider in critical natural areas and narrower in stretches of more urbanized development, can be more ecologically sound, but are often more difficult for jurisdictions to administer.

The steeper the buffer's slope, the wider the buffer must be to absorb runoff that gains speed and force as it rushes downhill. An urban buffer's ability to treat stormwater depends in part on how much the flow has been channelized before it enters the buffer. Channelization—the degree to which the flow is concentrated into a single stream, often fast, narrow, and straight—in turn determines how long stormwater will be detained in the buffer, another measure of a buffer's ability to treat runoff. If a buffer receives large amounts of runoff from a street, flow-spreading devices like multiple curb cuts and spacers can redistribute the flow and thus improve the buffer's treatment performance.

The steeper the buffer's slope, the wider the buffer must be to absorb runoff that gains speed and force as it rushes downhill. An urban buffer's ability to treat stormwater depends in part on how much the flow has been channelized before it enters the buffer.

Restoring Buffers in Industrial Floodplains

Increasingly, local governments are purchasing brownfields to restore key buffers. In downtown Saint Paul, the Bruce Vento Nature Sanctuary provides an example of this type of reclamation. Named after the late Congressman Bruce Vento, an environmental advocate, this 26-acre floodplain site is wedged between railroad tracks, I-94, and the Mississippi River. The land was abandoned 30 years ago by its owner, the Burlington Northern-Santa Fe railroad. A tributary, Phalen Creek, had been filled in and the floodplain was polluted from years of railroad and industrial use.

When the land was put up for sale, the Lower Phalen Creek partners—more than 20 organizations representing neighbors and river advocates—began a "visioning" process. Realizing that the land could link three neighborhoods to downtown along the river valley, the partners developed the Lower Phalen Creek Project, outlining plans for a nature sanctuary with a riverfront park, trail, and wetlands. Backed by $1.3 million appropriated by Congress through the National Park Service, and additional local, state, and private funding, the Trust for Public Land led acquisition negotiations and purchased the property from Burlington Northern in November 2002. It then transferred ownership to the city of Saint Paul, which is overseeing an environmental cleanup (City of Saint Paul 2003; Embrace Open Space 2002).

In another example, Toronto launched ambitious efforts in the 1980s to revitalize the city's industrial waterfront through a network of parks and open-space corridors where the Don River meets Lake Ontario (Hough et al. 1997). Known as the Port Lands, this area near downtown is well connected by highways, rail lines, and marine transportation routes. However, run-down buildings, junkyards, storage areas, tanneries, and chain-link fences made it seem derelict and unsafe. At the same time, the Port Lands' open spaces include spectacular examples of natural regeneration, such as Tommy Thompson Park, a world-renowned site for migratory birds and other wildlife.

In 2000, Toronto's Waterfront Revitalization Corporation, a nonprofit corporation, began creating a 10-year business revitalization plan for the

DESIGNING STREAM BUFFERS

Riverfronts are exceptionally difficult areas in which to create vegetated buffers because of the need for water views and access, recreation, hardscape, park management, safety, crime prevention, and flood protection. Little if any research exists on creating riverfront buffers in highly developed urban areas. In cities, buffer-sizing criteria may be based on site conditions as well as economic, legal, and ecological factors.

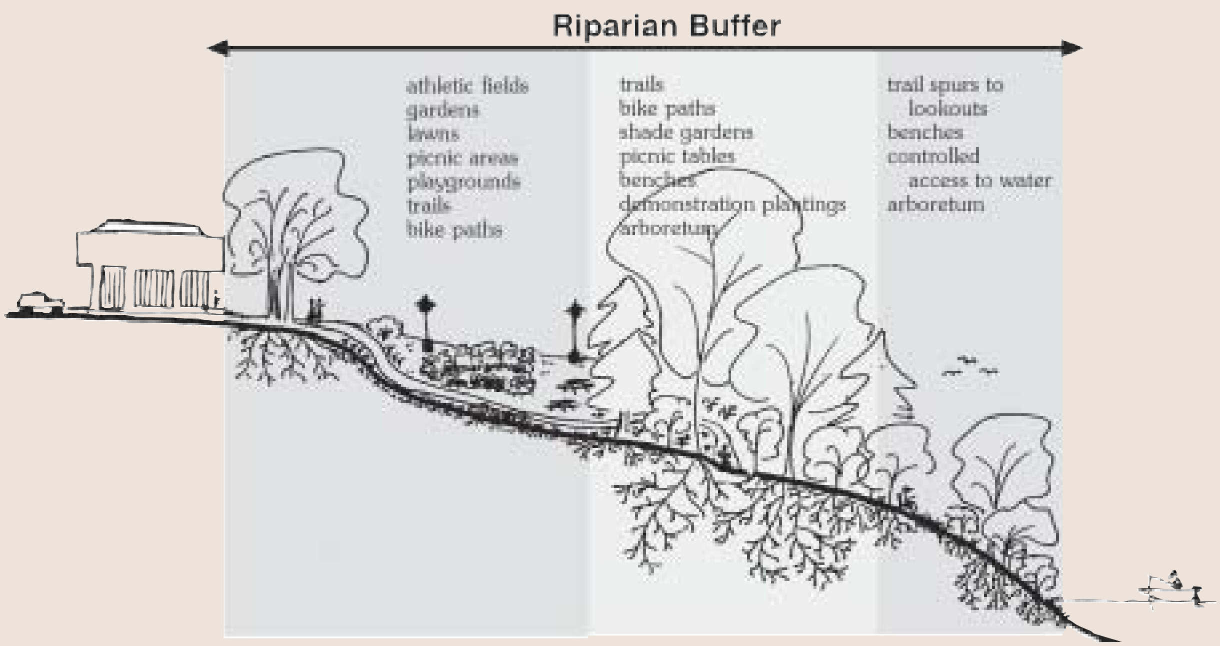
Thomas Schueler of the Center for Watershed Protection offers eight performance criteria to determine the size, management, and crossings of stream buffers. These criteria were developed for creating buffers in developing watersheds with new development on private land. They are offered here as a starting point for thinking about urban riverfront buffers:

1. Three-zone buffer system: Effective urban stream buffers have three lateral zones—streamside, middle, and outer. Each performs a different function and has a different width, vegetation goal, and management scheme.

The ***streamside zone***, ideally mature riparian forest, protects the physical and ecological integrity of the stream ecosystem.

The ***middle zone***, mature forest with some clearing for stormwater management, access, and recreational uses, extends from the streamside zone across the 100-year floodplain, adjacent steep slopes, and protected wetlands, and provides distance between the stream and upland development.

The ***outer zone*** is the buffer's buffer, an additional 25-foot setback from the outer edge of the middle zone to the nearest permanent structure. In parks or backyards, this buffer zone can be expanded by replacing lawns with native trees and shrubs.



(continued)

riverfront on both sides of the Don, which is owned by the city and the province of Ontario. The plan focuses on cleaning up toxic land and water, instituting a $15-million flood-management plan, and selling some suitable adjacent lands for mixed-use redevelopment. As part of the process, the Metropolitan Toronto and Region Conservation Authority, a regional government agency, has begun an environmental assessment of the riverfront land (Freeman 2002).

Throughout the Port Lands, "green infrastructure" will provide a framework for redevelopment, restore biodiversity, create linkages for wildlife

DESIGNING STREAM BUFFERS *(continued)*

2. Restoring buffers to predevelopment vegetation: The model for converting urban stream buffers is the riparian plant community that existed in the floodplain before development. This may include mature forest in many regions, prairie grasses in the Midwest, and indigenous shrubs such as willows and dogwoods in the arid West.

3. Buffer expansion and contraction: Many communities require expansion of the buffer's minimum width as needed. The middle zone's average width can be expanded to include the full 100-year floodplain; undevelopable steep slopes (greater than 25 percent); steep slopes (5 to 25 percent); or nearby wetlands and wildlife habitat.

4. Buffer delineation: Develop criteria for three issues: At what mapping scale will streams be defined? Where does the stream begin and the buffer end? From what point should the inner edge of the buffer be measured? Define limits and uses of the stream buffer system during each stage of development.

5. Buffer crossings: Stream buffers should maintain a corridor of riparian forest (or other appropriate native vegetation) and allow for fish passage. However, provisions must be made for roads, bridges, underground utilities, and enclosed storm drains that cross streams and rivers.

6. Stormwater runoff: Although buffers are an important component of stormwater treatment systems for developed sites, they generally treat runoff from less than 10 percent of the watershed. The remaining 90 percent must be managed by using different approaches known as best management practices elsewhere in the watershed.

7. Buffer education and enforcement: Educate the public and enforce protection by making buffers "visible." Encouraging awareness and stewardship among adjacent property owners by:

- marking buffer boundaries with signs that describe allowable activities;
- publishing educational pamphlets;
- conducting stream walks and meetings with property owners;
- ensuring new owners are informed about buffer limits and uses when property is sold or transferred;
- guiding a stewardship program, including reforestation and backyard "bufferscaping" programs; and
- conducting annual buffer walks to check on encroachment.

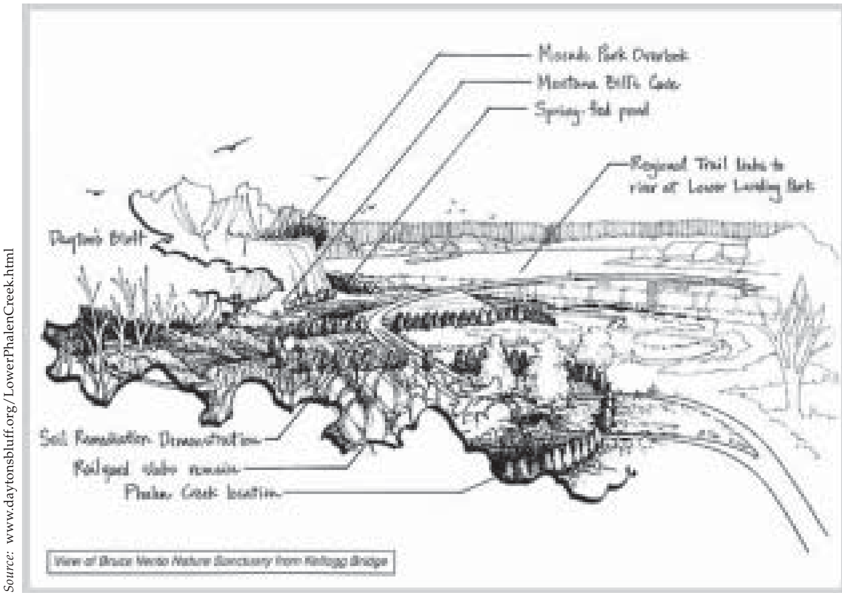
8. Buffer flexibility: In most regions, a 100-foot buffer will take about 5 percent of the total land area of a watershed out of use or production. This may represent a hardship for landowners. Communities concerned that buffer requirements may constitute an uncompensated "taking" of private property should make it clear that buffer programs modify the location of development, but not its overall intensity. Buffer ordinances can include such flexible measures as: maintaining buffers in private ownership, buffer averaging, transferring density to other locations, variances, and conservation easements.

Source: Adapted from Schueler (1996, 155–163)

and humans, and improve the area's image and sense of place. This effort includes proposed trails connecting major parks, including new open space at the mouth of the Don, where the river will be moved from a channel into a more natural setting with wetland buffers.

So far Toronto has commitments of $1.5 billion for waterfront renewal from the municipal, provincial, and federal governments, including $300 million for the first four projects. One of the first projects underway is a $2 million environmental assessment to renaturalize the mouth of the Don and provide flood control for the West Don Lands area. Other projects will

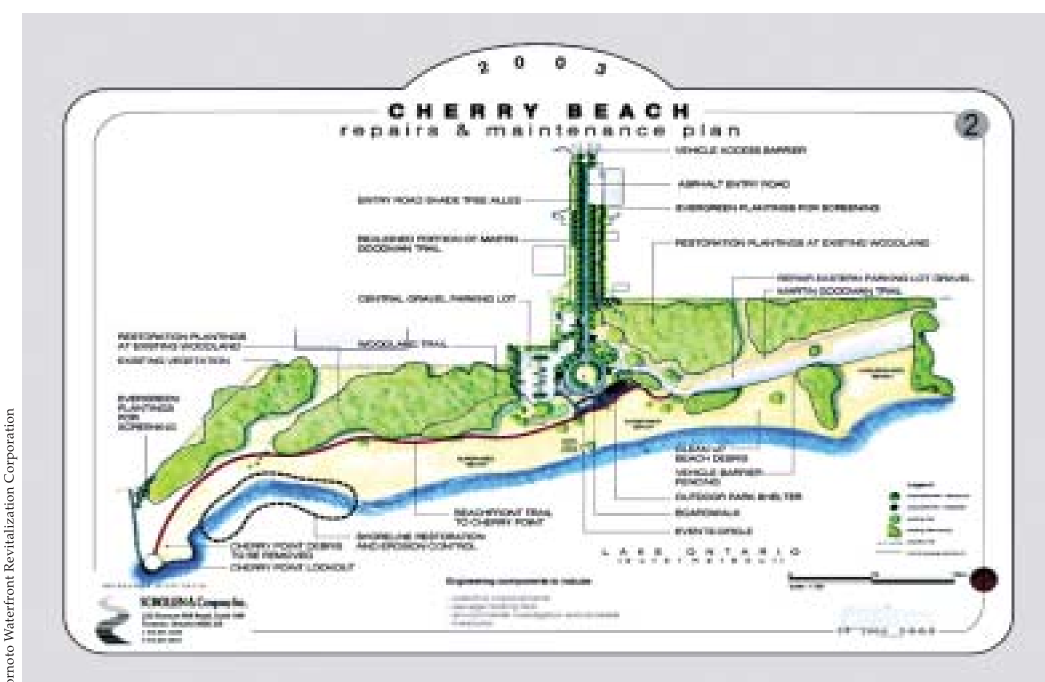
FIGURE 3-4. VIEW OF BRUCE VENTO NATURE SANCTUARY FROM KELLOGG BRIDGE



Source: www.daytonsbluff.org/LowerPhalenCreek.html

prepare the Port Lands' underused and contaminated land for redevelopment and construct a subway platform and a street to connect the waterfront with transit. In summer 2004, the revitalization of Cherry Beach in the Port Lands' Central Waterfront will debut. The Toronto Waterfront Revitalization Corporation is investing $1.5 million to clean up the beach and install a tree-lined grand entrance and parking, which will become part of a planned waterfront regional park (City of Toronto 2003; Toronto Waterfront Revitalization Corporation 2003).

FIGURE 3-5. TORONTO'S CHERRY BEACH REVITALIZATION PLAN



Tornoto Waterfront Revitalization Corporation

Beyond the Port Lands, decade-long efforts have been underway to revitalize other parts of the Don watershed, which is more than 80 percent developed and home to more than 800,000 people. In 1992, the Metropolitan Toronto and Region Conservation Authority formed a task force (later called the Don Watershed Regeneration Council), which published 40 recommendations on restoring water quality, natural areas, and community access to the river. The Council issues a report card every three years that charts the region's progress (Don Watershed Regeneration Council 1994, 2000).

Design Principle 3: Restore riparian and in-stream habitats

Restoring riparian habitat requires action far beyond simply replanting indigenous plants. First, planners must address watershed and regional factors to establish healthy hydrological cycles and water quality. For example, planted buffer zones must be created and maintained, stormwater controlled and cleansed, and new dams and reservoirs avoided or removed where possible. Likewise, in-stream flows from reservoirs and dams must be managed to protect wildlife habitat.

It is also necessary to conduct research on upstream and downstream natural communities to identify likely restoration areas and habitat types for fish, birds, and other animals. Planners should consider these areas in the context of the larger river system (for example, the relationship of smaller feeding or nursery areas to larger upstream or downstream habitats). After water quality and habitat are improved, native fish and other species dependent on healthy aquatic ecosystems can be reintroduced.

Successful habitat restoration projects should combine at least four major elements:

1. *Natural channel design:* A rebuilt channel should closely resemble its original, natural shape. The reconfiguration and reconstruction of a degraded channel should allow for meanders and other elements of a naturally flowing river or stream.

2. *In-stream habitat structures:* New boulders, gravel, logs, and other natural materials can be deposited to create river features such as riffles, pools, and rapids.

3. *Vegetation management:* Vegetation management includes removing exotic plants and replanting native species, enforcing no-mow zones in riparian buffers, and working with businesses, homeowners, and public agencies to remove impervious surfaces and to promote native plantings in watershed landscapes.

4. *Bioengineering:* Native plants and other natural materials can stabilize and rebuild eroded banks. Live woody cuttings or poles of readily sprouting species can be inserted deep into the soil of a bank or anchored by other means. Bioengineering is discussed as part of Principle 4.

This section addresses natural channel design, daylighting creeks, in-stream habitat structures, dam removal, and vegetation management.

Natural Channel Design

In the 1950s, Luna Leopold, then a senior research hydrologist for the U.S. Geological Survey, led a comprehensive research project that measured streams across the United States. He found that natural features such as oxbows, floodplains, and eddies helped slow floodwaters and prevented river channels from clogging with sediments—problems that plague hard-

CASE STUDY

BRONX RIVER *New York, New York*

Brooklyn Bridge Coalition

Bronx River, New York, New York.

River Issues. After three centuries of development and industrialization, the Bronx River was considered an "open sewer." More recently, abandoned industrial areas, neglected parklands, channelization, and riverbank erosion have only added to the stresses on the river. Few tidal wetlands remain, and riparian habitats have been destroyed. In addition, excessive stormwater runoff, flooding, and nonpoint source pollution have contributed to the ecological damage to the river.

What Has Been Accomplished. The Bronx River is the only freshwater river in New York City. For much of the twentieth century, the reality of a river flowing through the Bronx was ignored and forgotten as the city grew up around it. More often, the waterway was perceived as an open dumping ground for trash, abandoned cars, and appliances. The last quarter century, however, has seen a revitalization and transformation of the Bronx waterfront to a place where people in the city can go for recreation, education, and enjoyment of nature. To redress current threats to the river, local groups have developed joint strategies to mobilize greater community involvement in the restoration of the river and the city's parks.

The Bronx River Alliance serves as the new voice in restoring and protecting the Bronx River. Starting with the Bronx River Restoration Project in 1974, there is a rich history of restoration work in the area. The goal of the Alliance is to: "serve as a coordinated voice for the river and work in harmonious partnership to protect, improve, and restore the Bronx River corridor and greenway so that they can be healthy ecological, recreational, educational, and economic resources for the communities through which the river flows."

Emphasizing the focus of public participation and community involvement, the Bronx River Alliance serves as the coordinated voice for the river. The Alliance is made up of more than 75 community groups, government agencies, schools, and businesses. Among the major partners are the Bronx River Working Group; Partnerships for Parks, Waterways, and Trailways; Bronx Riverkeeper Program; and New York City Department of Parks and Recreation.

engineered flood control projects. Leopold, possibly the leading hydrologist in the past century, inspired later research by scores of scientists, who determined that these natural features also maintain water quality and create wildlife habitat, especially for fish.

In Leopold's wake, many other projects have revived the benefits of natural river and stream channels. For example, a 2001 U.S. Forest Service handbook on stream corridor restoration catalogues techniques to reconstruct a waterway's "profile" to create optimal habitat for fish, plants, insects, birds, and mammals. In assessing conditions for restoration projects, the handbook emphasizes the importance—and suggests careful measurement—of such factors as bank slope, the ratio of the stream length compared to the length of its valley, and even the size of pebbles and other materials in the streambed (FISRWG 2001).

Natural channel reconstruction should include the following steps (adapted from FISRWG 2001, 8-28–8-31):

Cleanup of the waterfront, which began in the late 1970s, continues to this day. Trash piled upwards of 20 feet high along the banks is being removed along with the multitude of items in the riverway itself. Over the years, the Bronx River Working Group has worked tirelessly to reclaim sections of the river and replant them with greenery. With funds secured from federal, state, and local sources, the Working Group has a grand vision for the restoration of the Bronx River. Included in this vision are greenways and parkways along both sides of the river, hiking and biking trails, construction and restoration of wetlands, and projects to contain the overflow of sewage and stormwater. At the heart of this cleanup project is community involvement. Special events such as the Bronx River Golden Ball, where a 36-inch golden orb symbolizing the "sun, energy and spirit of the river" is floated down the river, serve to unite the community and draw attention to the wide variety of areas the river traverses.

Benefits to River and Community. These efforts have increased public awareness of the ecological value of Bronx River habitats in supporting commercially and recreationally important fish species. Also, the river is recognized as a valuable natural resource that is central to the well-being of local communities.

For more information . . .

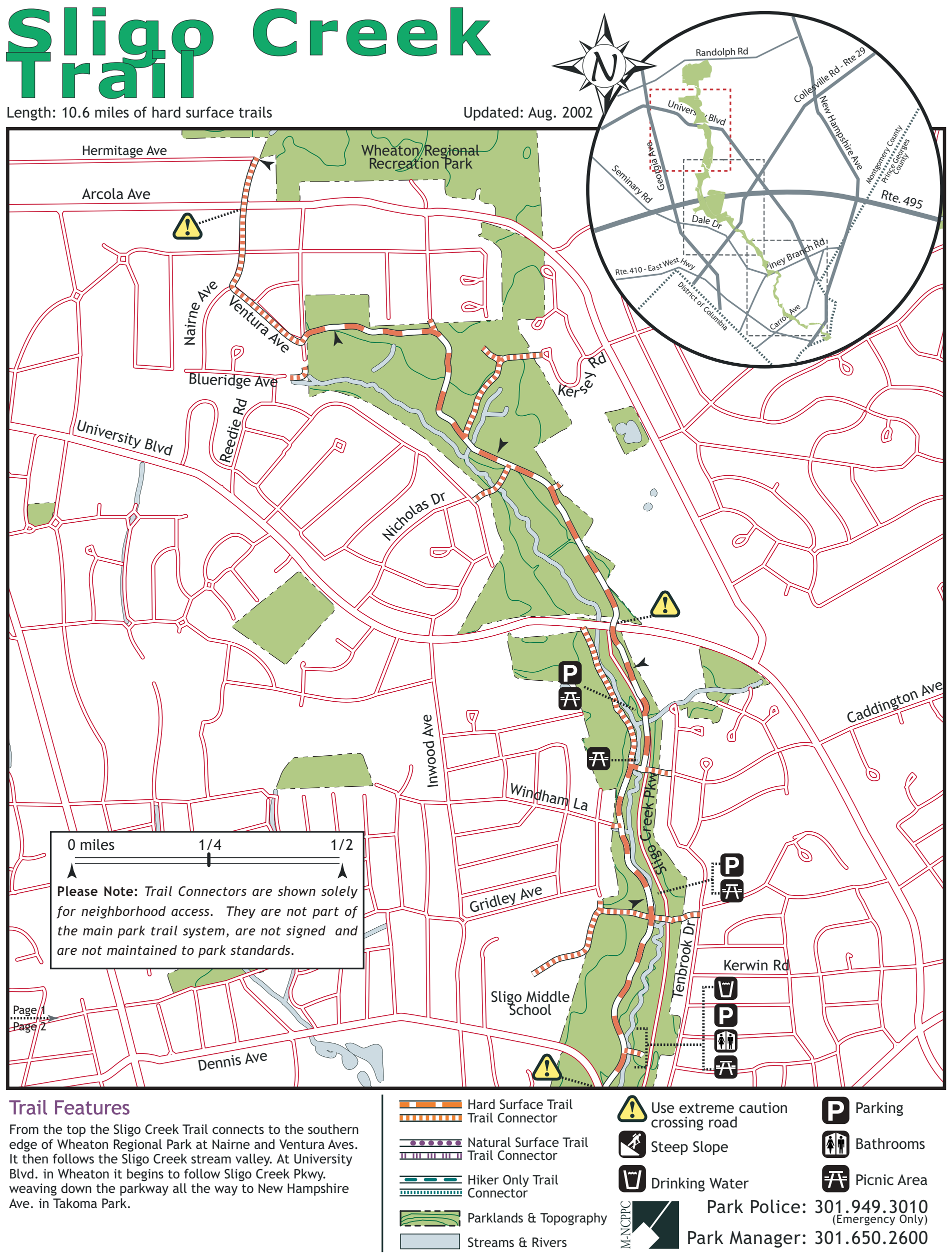
- See the Bronx River Alliance web site, www.bronxriver.org
- The Bioengineering Group, Inc. 2000. "Bronx River Preliminary Restoration Plan." [Accessed February 26, 2004.] Available at www.bioengineering.com/tbg_website.htm.
- Clean Water Action Plan. 2000. "The Bronx River Watershed: Community Cooperation in Urban Watershed Restoration." *Watershed Success Stories: Applying the Principles and Spirit of the Clean Water Action Plan, 1998-2000.* [Accessed February 26, 2004.] Available at www.cleanwater.gov/success/bronx.html
- "A River Rises," *New York Times*, December 3, 2000, Section 14, pp. 1, 26.

- *Study physical aspects of the watershed*. Reconstruction should emulate the channel's natural width and depth, hydrology, size of bed sediments, and riparian vegetation.
- *Reference the reaches.* Find another stable and ecologically healthy reach of the same waterway to use as a reference point for the dimensions of natural channel design. Ensure that the information captured includes the chemical, physical, and biological make-up of the healthy reach—not just the habitat structure, but also the mix of creatures in it.
- *Determine the size and placement of bed materials such as sand, pebbles, river stones, boulders, and tree stumps.* These will create habitat and "armor" the waterway against erosion.
- *Analyze hydrology.* Natural channel designs must be able to handle flood control. Analyze flows and adjacent land uses to help select the channel location, alignment, width, depth, and floodplain size.

In Montgomery County, Maryland, near Washington, D.C, the 13.3-square-mile Sligo Creek watershed, in poor condition before 1990, has benefitted from a reconstruction effort. More than 60 percent of the watershed was paved or impervious surface. The creek was polluted by combined sewer overflows (CSOs) during storms. As a result, only a few fish species—none of them native—survived in Sligo Creek.

From 1991 to 1994, Sligo Creek received one of the nation's most extensive watershedwide restorations—one that combined many techniques described in this section. The creek and its tributaries were improved by separating storm and sanitary sewers to eliminate CSOs and through revegetation, bank stabilization, and reconfiguration of in-stream flows. Upstream, three connected ponds were built to detain runoff for up to 36 hours, which

FIGURE 3-6. SLIGO CREEK TRAIL (NORTHERN PORTION)



Source: www.fosc.org/Maps/SligoTrail.pdf allowed pollutants and sediments to settle out. The downstream channel was completely rebuilt with 19 native shrub species reintroduced to the riparian zone. Volunteers then reintroduced native fish by the bucketful. By 1996, fish species had increased from three to 16, including native and pollution-sensitive fish. Fish deformities, lesions, and tumors dropped 75 percent. New greenway trails provide access to this revitalized resource (Thompson 1996).

Daylighting Creeks

Creeks channeled into underground culvert pipes destroy a healthy natural environment. Small streams are highly efficient in scrubbing pollution from runoff and auto emissions and thus are critical to the health of the entire watershed (Peterson et al. 2001). Piped creeks lose this capacity to clean runoff. They can dump polluted water into rivers at high velocity, also causing erosion. Culverts often create bottlenecks in stormwater conveyance systems that lead to flooding. Piped creeks also have no value for wildlife.

Creeks that have been encased in pipes or hidden beneath decks can be "daylighted." A daylighted creek is one whose channel has been excavated and restored. Daylighting seeks to restore creeks to their original channel or to thread them in a new, open channel between buildings, parking lots, and ballfields. Stormwater pipes also can be daylighted or replaced with naturalized swales, constructed wetlands, or rehabilitated estuaries (Pinkham 2000).

California, for example, which has lost 95 percent of its riparian habitat since presettlement times, is now reclaiming hundreds of culverted and piped streams. One of the first was Berkeley's Strawberry Creek. In 1984, a 200-foot-section of Strawberry Creek buried beneath an abandoned rail yard was re-exposed. As an 80-year-old culvert was dug out, the rehabilitated channel was modeled on the width, depth, and meander pattern of a healthier creek section several blocks upstream. Banks were replanted with native willows, cottonwoods, pines, manzanitas, and other species that require little maintenance or irrigation once established. The creek became the centerpiece for a four-acre, $580,000 city park. Daylighting represented less than 10 percent of that cost (Pinkham 2000).

Strawberry Creek has been an ecological, social, and economic success. While the native riparian vegetation thrives, Strawberry Creek has withstood numerous major storms that would have overwhelmed the culvert. Hundreds of people visit the park and its natural areas daily. Neighborhood property values have risen, and nearby buildings have been redeveloped. The Strawberry Creek project's success has led to several spin-offs of other creeks in Berkeley.

In Pittsburgh, the daylighting of Nine Mile Run has created an attractive and ecologically diverse new setting on the Monongahela River. For 60 years, Nine Mile Run was buried under a growing 20-million-ton slag heap that covered 238 acres at the stream's confluence with the Monongahela. In 2001 and 2002, this slag heap was regraded to create a platform for a new residential community called Summerset at Frick Park. The regrading of the slag (an inert byproduct of steel production) also uncovered Nine Mile Run, which is now undergoing an $8 million restoration.

More than 200,000 tons of topsoil have been layered over the regraded slag to sustain newly naturalized landscapes. These will be connected to Frick Park, a 455-acre forest preserve, and to new riverfront trails. Nine Mile Run is also becoming a major amenity for Summerset, which represents a $210 million investment into a formerly underused riverfront site (Bonci 2001, 2002; Ermann 2003).

The daylighting of Nine Mile Run along the Monongahela River in Pittsburgh has created an attractive and ecologically diverse setting. Here, people take a guided stream tour.

Nine Mile Run Greenway Project

In-Stream Habitat Structures

Within the river channel, in-stream habitat structures include rocks, gravel beds, snags (downed trees), roots and other naturally rough spots in the stream channel, and fabricated structures like dams and weirs. These can be manipulated to change the river dynamics—in other words, to speed or slow the flow of water, create rapids and pools, and reintroduce riverbends into a waterway that has been straightened. In general, dams should be avoided as they can severely alter natural flows, raise water temperatures, trap beneficial sediment and other materials, and create impassable barriers to fish (American Rivers 2003a).

In-stream habitat structures alone do not substitute for good riparian and upland management. Yet in-stream habitat structures can improve water quality and provide shelter and breeding areas that encourage insects and fish to thrive. In turn, insects and fish attract birds like dippers, herons, and kingfishers, and mammals such as beavers, raccoons, and river otters.

When restoration is required, the design process should follow several basic steps (adapted from FISRWG 2001, 8-71–8-76):

1. *Diagnose problems in advance*. Survey the stream or river to determine habitat and water-quality problems related to hydrology.

2. *Design a habitat improvement plan*. The plan should include in-stream habitat structures, bank restoration through bioengineering, and revegetation. Identify goals for wildlife population increases.

3. *Plan layout*. Each structure must be carefully located, avoiding conflicts with bridges and riparian vegetation. Customize placement for the hydrology and morphology of each individual waterway.

4. *Select types of structures*. The most commonly used structures are weirs, dikes, boulders, and bank covers (also called lunkers, these resemble a child's set of jacks).

5. *Size the structures*. Structures should produce aquatic habitats at a wide range of flows. Generally structures should be low enough so they are almost submerged during high waters.

6. *Investigate hydraulic effects*. Structures should not contribute to flooding by creating barriers to water conveyance.

7. *Consider effects on sediment transport*. Model the effects of structures on erosion and sedimentation.

8. *Select materials*. Materials may include stone, fencing wire, posts, and felled trees. Use natural materials when possible, especially stone or trees from the site.

9. *Monitor and evaluate results*. Track changes in wildlife populations, water temperature and quality, and percentage of area covered with native plants, including tree canopy.

10. *Plan to maintain in-stream structures*. Incorporate a management plan with funding into the design.

In Redmond, Washington, the Sammamish River lost much of its riparian vegetation when it was engineered into a deep trapezoidal channel in the 1960s. In the 1990s, a stretch of river was refurbished through downtown. The project combined bioengineering, in-stream habitat construction, and weed removal. The floodplain was enlarged by 50 feet through sculpted riverbank "benches" planted with native vegetation.

Behind City Hall, the river's meanders and curves have been revived by adding boulders, root wads, and gravel bars to the once-uniform channel. The restored riverfront has become the centerpiece of a new 16-mile trail that connects to a regional greenway system. Salmon, steelhead, native trout, and upland riparian species have returned to the river and its banks (Holt 2002).

Dam Removal

Dams block fish migration, disrupt water flow, change water temperature, and generally wreak havoc on the food chain in rivers. They limit public access to rivers and harm the natural and aesthetic quality of their settings.

(Left) Before trail construction, the west bank of the Sammamish River was cut off visually and overrun with invasive non-native species. (Right) The constructed trail recreated river meanders and provides river access to cyclists, joggers, equestrians, and walkers.

Parametrix

Removing dams can be a particularly effective way to restore rivers.

Efforts to remove unneeded, unsafe, or obsolete dams have been gaining momentum. Of the 75,000 dams identified in a U.S. Army Corps of Engineers inventory, about 66,000 are on rivers. Studies indicate that about 1 percent of these dams are obsolete or unsafe and might be considered for removal. Many communities have low-head dams that no longer serve a purpose, but block fish migration and cause hazards for boating and other recreation. As operating licenses expire and more dams become obsolete, the opportunities to remove dams will increase. By 2020, about 85 percent of all dams will exceed their life expectancy of 50 years.

In recent years, more than 465 dams have been removed across the country. Removing dams where the benefits of removal outweigh the benefits of repair or replacement is the most effective way to restore rivers, save taxpayer money, revitalize riverside communities, and improve public safety.

Removing dams can dramatically regenerate river ecosystems, often in a matter of months. In Hampden, Maine, a dam built to power a grist mill had blocked fish migration along the Souadabscook River since the eighteenth century. Within months of the dam's removal in October 1998, Atlantic salmon established upstream spawning areas for the first time in 200 years. Brook trout, American shad, smelt, and alewife also quickly repopulated the river.

Dam removal also saves money. In 1988, West Bend, Wisconsin, was faced with removing or replacing the deteriorated Woolen Mills Dam from the Milwaukee River. The city spent $86,000 to remove the dam instead of an estimated $3.3 million to replace it (American Rivers et al. 1999).

When it was built in 1837, the Edwards Dam destroyed thriving commercial fisheries along the Kennebec River in Maine. As the first dam from the sea on the Kennebec, the Edwards Dam was literally a cork that, if unplugged, would allow miles of the river to be restored as a natural ecosystem and as prime habitat for migratory fish.

When removal of the Edwards Dam began in July 1999, it signaled a turning point for the Kennebec—and for rivers nationwide. Removal of the dam improved water quality and fish passage while creating new public open space bounded by a free-flowing river.

The most important environmental benefit has been the reopening to sea-run fish of a significant stretch of spawning ground north of the Hudson River. At least 10 migratory fish species, including Atlantic sturgeon, American shad, and Atlantic salmon, are now found in this newly accessible 17-mile stretch of river. During the spring following dam removal, oceanmigrating fish were caught in the river above Augusta for the first time since 1837 (American Rivers et al. 1999).

Downtown Augusta also experienced an economic resurgence following dam removal. Working cooperatively with the state, the city formed the Capital Riverfront Improvement District (CRID) to protect the scenic character of the river, provide public access, and bring additional economic development to a one-square-mile historic riverfront district. Since 1999, the CRID has attracted nearly $10 million in public and private investment, including the award-winning conversion of historic City Hall, vacant for 15 years, into 28 apartments for seniors. The CRID also has raised $3 million for the first phase of an eventual $8 million riverfront park. The park will recycle a remaining brick building from the Edwards Mill as an interpretive center. It will also interpret nine areas of natural and cultural history.

In 2002, the city dedicated the first two miles of a riverfront rail-to-trail conversion through downtown. Already popular, the trail will soon be extended another seven miles toward an eventual 20-mile loop covering both sides of the river and connecting Augusta to neighboring communities (Bridgeo 2003).

Vegetation Management

Native vegetation helps filter runoff, controls flooding, and reduces or eliminates erosion. Native plants provide shelter and food for wildlife. Canopy trees shading creeks help lower the water temperature and therefore create more favorable conditions for native fish.

Nine Mile Run Greenway Project

REVEGETATION TECHNIQUES

The following techniques can be combined to revegetate conditions that suit a particular stretch of river (Riley 1998):

- Create the conditions for native plants to "reinvade" a site. For example, remove invasive species through weeding programs, dredging, or controlled burns. Remove levees or regrade to allow for natural reseeding.
- Layer dead brush, trees, or tree stumps to stabilize the bank and capture sediment that will become a growing medium for native plant communities. Plant live cuttings from native species such as willows and dogwoods that regenerate readily. These "pioneer" species stabilize banks and create habitat for other riparian vegetation.
- Transplant native vegetation from areas being altered by development.
- Plant nursery-grown natives to emulate the number, density, and relationships of plant species within a riparian community.
- Preserve and enhance existing vegetation, including snags and dead trees, through purchase, conservation easements, floodplain zoning, and ecological management.
- In extremely urban situations with a narrow floodplain and channel, use hybrid engineering methods such as riprap and gabion walls that are packed with soil and planted.

Weeds and other nonnative plants generally provide little or no habitat compared to natives. They can create monocultures with no ecological diversity. The most visible example may be the exotic phragmites reeds that choke and provide many urban wetlands almost no wildlife habitat.

Along the river's edge and in the floodplain, native vegetation can be reestablished through a number of methods. Effective riparian restoration provides wildlife habitat, improves water quality, and anchors soil to control erosion and flooding. Yet even the best projects will not replicate a natural, presettlement river. Replanting "pure" native landscapes next to urban areas may be difficult because native plant communities may not survive urban runoff and pollution. In urban areas, native planting schemes must be installed in specially prepared environments and adapted to the site's water levels, contaminated soils, and levels of runoff.

Revegetation requires a complex process of analysis, planning, design, installation, monitoring, and maintenance. It should be undertaken by an experienced team that includes aquatic and plant ecologists, civil engineers, and landscape architects. The team should first identify, survey, and inventory a stream reference corridor—a healthy riparian habitat with similar hydrology, ecosystems, and climate. Often this corridor will be located on a different reach of the same waterway. Studying the stream reference corridor creates benchmarks for plant density, diversity, and placement.

Once study is complete, revegetation projects can pursue several different strategies. Some begin with canopy tree planting; others with understory plantings; others with grasses and other nonwoody plants that allow a natural succession into mature woodland.

Weed removal and control is equally important. Weeds may be removed by hand pulling (a good volunteer project), cutting, burning, or selective use of herbicides (Pinkham 2000).

Sally Petrella, Friends of the Rouge River

Revegetation requires analysis, planning, design, implementation, monitoring, and maintenance. Here volunteers work along the banks of the Rouge River in Detroit.

With proper planning, design, and leadership, volunteers can play a key role in revegetation efforts. In the Twin Cities region, Great River Greening gets citizens involved in reclaiming their riverfronts. Since 1995, the organization has trained 460 volunteer "restoration leaders" who have directed another 10,700 volunteers to plant more than 35,000 native trees and shrubs and 16,500 prairie grasses and wildflowers in Mississippi River valleys (Karasov 2002).

In Salinas, California, a group called Return of the Natives built six greenhouses that produced 30,000 native plants. Local schoolchildren seeded, cared for, and replanted native grasses, shrubs, and trees along Natividad Creek, which was also restored through natural channel design (Return of the Natives 2003).

In Murray City, Utah, residents and government officials are restoring habitat along the channelized Jordan River through replanting, hydrological engineering, and natural lands preservation. Under this pragmatic approach, the city is restoring natural riparian areas where possible while also identifying areas too disturbed to be restored.

Stream banks have been replanted with native grass, shrubs, and trees. Two newly constructed wetland ponds treat urban runoff before discharging it into the river. Dried wetlands were recharged with returned irrigation water. At the upper end of the wetland, sediment basins filter out phosphates and nitrates from stormwater before releasing into wetlands. Some 350 acres have been preserved as natural habitat.

Since the project began in 1990, water-quality testing has shown decreasing concentrations of arsenic, zinc, total suspended sediment, dissolved oxygen, nitrate, and phosphorous. Native birds are returning to the river, along with species not found in Murray City before, including orioles and cinnamon teals. Water-dependent plants are flourishing in the wetland ponds, and wildflowers line the river (U.S. EPA 2002e).

Design Principle 4: Use nonstructural alternatives to manage water resources

For years our rivers and tributaries suffered from their own version of the Four Horsemen of the Apocalypse. These were the infamous "Four Ds." Rivers and creeks were ditched, dammed, and diverted, while associated wetlands were drained. This "hard" engineering approach harmed water quality, caused flooding, and destroyed wildlife habitat. Indeed, despite billions of dollars spent for structural and nonstructural flood control measures, flood damages continue to escalate in part because of intensified floodplain development and engineered river corridors.

A Sustainable Future

In recent years, newer and "softer" approaches have emerged that offer flood protection combined with the benefits of restoring natural river functions. In a landmark report, *National Flood Programs in Review 2000*, the Association of State Floodplain Managers called for a fundamental shift in national policies and programs. ASFPM (2000, i) envisions "a sustainable future—one in which floodplains throughout the nation are used only in ways that protect their integrity as enduring ecological systems."

The organization recommends policy changes at the national, state, and local levels that would promote sustainable natural systems, including purchasing permanent easements, preserving open space, restoring habitat, and adapting watershed-based planning and management (ASFPM 2002).

ASFPM notes that current floodplain management systems are costly and often allow development that fails to evaluate or mitigate damage to other properties. "We continue to intensify development within floodplains," the organization observes in a policy statement, "and do it in a manner where flood prone or marginally protected structures are suddenly prone to damages because of the actions of others in the floodplain" (ASFPM 2003).

In response to this problem, ASFPM developed its No Adverse Impact policy, which states that "the action of one property owner should not adversely impact the rights of other property owners" (ASFPM 2003). The policy aims to counteract the belief, held by many local governments, that hard-engineered federal flood-control approaches are acceptable, not realizing that those approaches may cause more flooding and damage. No

The Napa River Flood Protection Plan is restoring the river's natural characteristics and moving buildings and people out of harm's way in Napa, California.

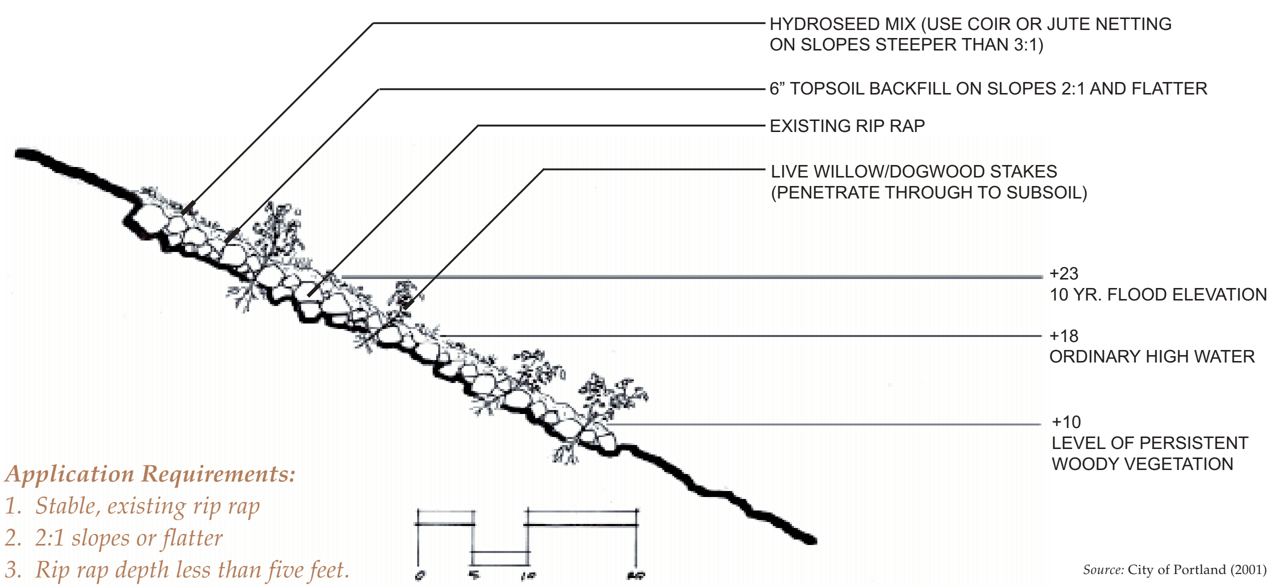
Chris Malan

Adverse Impact promotes responsible floodplain development through community-based decision making.

California's Napa River is one of the largest rivers to undergo reconstruction guided by nonstructural engineering principles. Although the Napa is the state's last major undammed river, it did not escape from dikes, levees, and channelization, which only increased flooding. In the last 40 years, property damage from six major floods totaled $542 million. Hundreds of acres of wildlife habitat were destroyed.

In 1998, Napa County residents approved a tax increase to remove much of the Napa River's flood control system. The Napa River Flood Protection Plan is restoring the river's natural characteristics by freeing it as much as possible from artificial controls. To move buildings and people out of harm's way, the Napa Flood and Conservation District bought 50 parcels from which buildings have been removed, with plans to remove structures on another 45 properties. Businesses and residents are being moved within

FIGURE 3-7. PLANTING EXISTING RIP RAP



Application Requirements:

1. *Stable, existing rip rap*
2. *2:1 slopes or flatter*
3. *Rip rap depth less than five feet.*

Source: City of Portland (2001)

the town of Napa. A major bridge has been replaced by a longer bridge with footings removed from the floodplain. Another similar bridge replacement is scheduled.

Levees have been removed to allow the river to recapture 400 acres of natural floodplain. Floodwalls and other structures are being removed, bridges altered, and levees pulled back to give the river room to expand during floods. Trees and other vegetation have been restored to the riverbank. Marshy terraces and wetlands will replace cement terraces. No reseeding is needed since tides on this estuary are reestablishing native wetland plantings. On the river's edge, programs to replant native oaks and buckeyes are underway.

Through downtown, the district has pursued a compromise approach. One riverbank remains engineered with a floodwall. The opposite bank is being naturalized and widened by several hundred feet. Redevelopment on this riverfront is being encouraged with design guidelines for suitable setbacks, limited impervious surfaces, and native plantings.

Developers are also being encouraged to embrace the river by providing visual and physical access. As pelicans and other native shorebirds return to the area, residents are excited about seeing the renewal of the Pacific Flyway's vast ecological richness (American Rivers 2003b; Malan 2002).

Few projects approach the comprehensive scope of the Napa River effort, but all rivers can benefit from nonstructural solutions used there.

Clark County, Washington, Department of Public Works

Clark County, Washington, is implementing bank protection techniques sensitive to fish and wildlife habitat and long-term bank stability.

Bioengineering

One alternative to hard engineering—bioengineering (also known as soft engineering)—has gained acceptance among civil engineers and public works departments. Bioengineering uses plants to stabilize watershed slopes, a practice that may date as far back as ancient Roman times (Riley 1998).

While held to the same performance standards as hard engineering, bioengineering uses plants and other natural materials to simulate natural forces that, in turn, control floods, maintain water quality, provide access to recreation, reduce erosion, and create wildlife habitat.

Bioengineering minimizes structures like levees in favor of natural floodplain storage through riparian and wetlands restoration. Instead of riprap, concrete, or steel walls, a bioengineering approach uses naturalized bank slopes, broad floodplains, riverbends, and floodplain forests and wetlands to stabilize riverbanks and prevent erosion. Wetlands can be enhanced or created to filter stormwater and reduce flooding. Natural riverbanks often feature gently sloped banks with access for boating and fishing.

Bioengineering minimizes structures like levees in favor of natural floodplain storage through riparian and wetlands restoration.

Successful bioengineering requires the cooperation of an interdisclipilinary team that includes engineers, ecologists, hydrologists, planners, landscape architects, landscape contractors, and an engaged public. Bioengineering must begin with planning at the watershed level. Elements such as the percentage of impervious surface and nonpoint pollution sources should be analyzed, cataloged, and addressed. Once study has been completed, bioengineering projects can be scheduled throughout the watershed, much as public improvements are staged for urban infrastructure through an annual capital improvements budget. Areas receiving attention first might be those with the greatest potential to engage public interest and support, such as public parks, urban waterfronts, and the edges of schoolyards. Or priorities may be based on the need to control floods or to halt and repair erosion.

Bioengineering reverses the degradation of creeks, streams, and rivers. For example, unstable or eroded banks can be bioengineered to simulate the slope, vegetation, appearance, and ecological function of a natural bank. Bioengineering is generally less expensive to construct than hard engineering, which can cost $1,400 per linear foot for a technique like steel sheet piling (Hartig et al. 2001). An Ontario study found consistently lower costs for bioengineering compared to riprap or concrete walls (Patterson 2000).

Long-term maintenance costs of soft engineering can also be lower because over time these "living structures" mature and stabilize, rather than deteriorate. For example, a stable, naturalized riverfront—unlike a channelized river with floodwalls and other hard features—will need almost no bank repairs, will suffer less damage from flooding, and will not collect sediments that must be dredged (Wenk 2002).

Biotechnical engineering presents a hybrid approach to bioengineering. In biotechnical engineering, native plants are interspersed with an engineered erosion-control system, such as geotextile fabrics. Plantings are not expected to hold the soil, but they do provide habitat. For example, riprap can be naturalized by interplanting live stakes of willows or other native species at an angle on the slope. Within a year, live staking can provide shade, habitat, and erosion control (Sotir and Nunnally 1995).

Streambank repairs at Black Ash Creek in Collingwood, Ontario, offer a striking example of the durability of soft engineering. In 1993, one bank of the creek was repaired using bioengineering, specifically a planted cribwall. In 1995, the opposite bank was armored with concrete. Four years later the bioengineered bank matured into a stable, vegetated environment, while the concrete wall was failing (Grillmayer 2000).

Bioengineering approaches and specific techniques should be considered carefully in ultra-urban settings where some structural components such as stone or rock may be necessary due to current velocities, channel alterations for navigation, and adjacent infrastructure, such as bridges (Schueler 2003).

The Willamette River is encased by a seawall as it runs through Portland, Oregon. Efforts to "soften" the seawall and other hardscape features are included in the Willamette Riverbank Design Notebook.

Amy Souers

Bioengineering Techniques

Bioengineering systems comprise bundled plant materials, including brush, branches, and live cuttings, that are layered on banks to reduce or eliminate erosion. Bioengineering generally seeks to reestablish native riparian plantings that stabilize banks. Benefits include slowing and filtering stormwater, anchoring soils, and providing wildlife habitat.

The following techniques can be combined as appropriate within the same riverbank (adapted from Riley 1998, 374–84):

- *Fascines* are oblong bundles of cuttings planted on angle to stabilize a slope and slow runoff as it enters a stream. Bundles are staked in rows parallel to the waterline. The cuttings (often native cottonwoods, dogwoods, and willows) will sprout and fill in to cover the bank.
- *Brush layers* are live cuttings laid on terraces that will take root in the banks.
- *Brush mats* consist of live cuttings held in place by a staked mat.
- *Branch packing* involves stuffing clusters of live stakes to stabilize gullies.
- *Live plant materials* can be used in conjunction with synthetic geotextile mats or natural cotton, jute, sisal, and coir mats that will biodegrade.

Bioengineering works best in concert with channel designs that restore natural floodplains and bank grades. Yet urban riverfronts are more difficult to restore with nonstructural alternatives because virtually no urban rivers flow through their original floodplains. Tributaries and creeks, on the other hand, generally are easier to adapt for nonstructural alternatives, including bioengineering and natural floodplain design.

Throughout the United States, efforts are underway to add natural features to urban rivers, even in extreme circumstances. For example, the Willamette River is encased in a huge seawall as it flows through Portland, Oregon. Most of the former natural floodplain is now built up as downtown Portland.

Reconstructing the river's natural features in this highly altered environment is impossible. Yet the city's *Willamette Riverbank Design Notebook* suggests numerous strategies to "soften" the seawall and other hardscape features (City of Portland 2001). Given to property owners who submit plans for waterfront development to a design review board, the *Notebook* provides alternative designs intended to improve conditions for fish (including endangered stocks of Pacific salmon), other wildlife, and people.

The *Notebook* suggests several techniques to add native plantings to the seawall. One calls for the installation of a "timber grid," a latticework that extends beneath the waterline on the seawall and supports aquatic plant species. The grid creates new habitat by providing cover for young fish. Other strategies include attaching root wads to timber pier pilings and creating "floating planters" for native upper-shore plants. These relatively low-tech methods may cost tens of thousands of dollars rather than the millions required for large-scale engineering. Property owners who implement the *Notebook*'s ideas benefit from streamlined review and may have a better chance of complying with the Endangered Species Act (Fishman 2002).

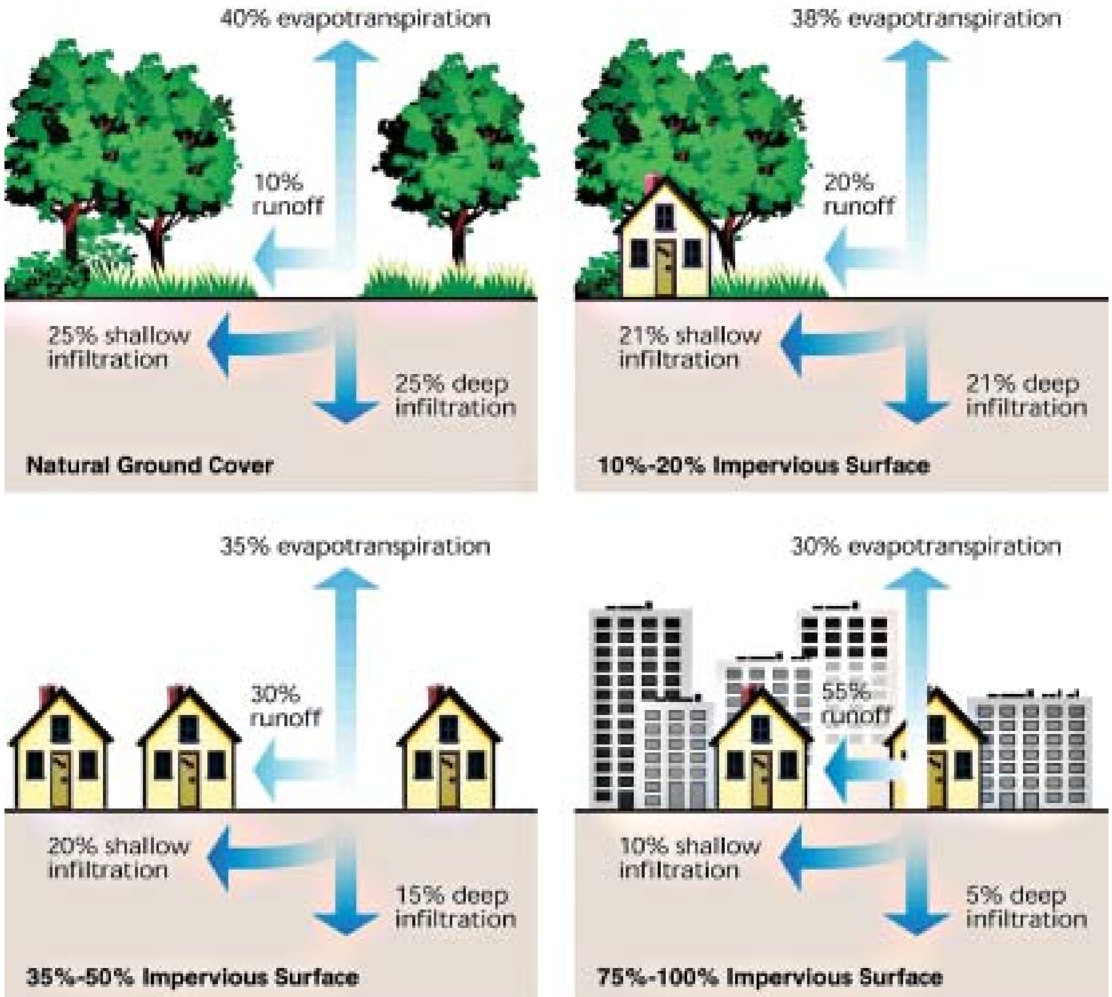
Throughout the United States, efforts are underway to add natural features to urban rivers, even in extreme circumstances.

Design Principle 5: Reduce hardscapes

Hardscapes are roads, parking lots, sidewalks, driveways, paved paths, rooftops, and other impervious surfaces that prevent rainwater from filtering through soil and replenishing rivers and streams as groundwater. Groundwater—the water that moves through the subsurface soil and rocks—generally supplies about half of all stream flows. During droughts, the percentage can rise much higher (Alley et al. 1999).

The impervious surfaces of hardscapes degrade urban rivers because they do not absorb stormwater. In fact, they significantly increase the volume, velocity, and temperature of rainwater runoff. Paved surfaces also

FIGURE 3-10. RELATIONSHIP BETWEEN IMPERVIOUS COVER AND SURFACE RUNOFF



Source: FIRSRWG (2001)

Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.

contribute to pollution when stormwater washes surface oils, fertilizers, heavy metals, bacteria, and other contaminants into rivers and streams.

Watershed experts generally divide impervious surfaces into two categories: habitats for people, such as buildings and sidewalks, and habitats for cars, such as roads, parking lots, and driveways. In suburban areas with big-box stores and sprawl, parking lots and other car habitats represent most paving. In urban areas with structured parking and multilevel garages, human and car habitats are about equal as hardscape factors (Brown 2002). A third category is impaired pervious surfaces, or urban soils such as suburban lawns, which are natural surfaces that have become compacted through human action (Lehner et al. 2001).

Imperviousness is one of the most useful measures of the impacts of land development. Research studies conducted in many geographic areas, concentrating on many variables and employing a wide range of methods, have reached a similar conclusion: at a relatively low level of imperviousness—around 10 percent of cover in a watershed—streams become ecologically stressed. Stream stability is reduced, habitat is lost, water quality degrades, and biological diversity decreases. Imperviousness of 25 percent significantly impairs the stream. At 40 percent, it becomes damaged, and at 60 percent, a stream is severely damaged (Schueler 1995a; Center for Watershed Protection 2003a).

At 35 percent watershed imperviousness, the runoff rate can be 55 percent higher than predevelopment volumes. Depending on the percentage of watershed impervious cover, the annual volume of stormwater runoff can increase by two to 16 times its predevelopment rate, while the groundwater recharge rate (the amount soaking into the ground) reduces by equivalent proportions (Schueler 1995a; Center for Watershed Protection 2003).

Facts bear out that we have indeed paved over much of our metropolitan areas. Total imperviousness in medium-density, single-family residential areas typically ranges from 25 percent to nearly 60 percent (Schueler 1995c). Total imperviousness at strip malls or other commercial sites can approach 100 percent (Lehner et al. 2001).

The problems of erosion and pollution are related. Runoff from hard surfaces is loaded with concentrations of contaminants such as gasoline, antifreeze, and oils that collect on paved surfaces. Runoff also causes spikes of flows into streams. The resulting increased volume and velocity of water erodes streambeds and banks. This produces excessive sediment, the leading pollutant impairing the nation's rivers. Channel erosion constitutes as much as 75 percent of sediment in urban streams, particularly during periods of urbanization when the channel is still enlarging (FISRWG 2001).

As a partial but significant solution, riverfront designs should minimize the total impervious area and use permeable materials wherever possible, including on trail surfaces. Hard surfaces should be interspersed with softscapes where rain and snowmelt can collect and infiltrate into the soil.

As a partial but significant solution, riverfront designs should minimize the total impervious area and use permeable materials wherever possible, including on trail surfaces.

Benefits of Reducing Hardscapes

Reducing hardscapes and installing natural landscapes can help restore natural watershed functions, filter pollutants, and prevent erosion of banks and channelization of streambeds. In older, industrial, or derelict riverfront areas, the replacement of hardscape with soft, permeable surfaces, such as native grasses, shrubs, and trees, will improve both the ecological and aesthetic environment.

When hardscapes are unavoidable, planners should minimize their extent. Reducing hardscapes in new development can save money for local governments, developers, and homeowners. Infrastructure—roads, sidewalks, sewer lines, curbs and gutters, and parking spaces—is expensive to build and maintain.

Remove Buildings

Removing buildings from the floodplain helps restore more natural river functions. From 1990 to 1992, the city of Boulder, Colorado, spent $3 million to lower the floodplain in a flood-hazard area downtown along Boulder Creek. The city bought 13 structures, relocated residents from 132 apartments, and then removed the buildings and regraded a 10-acre area next to the creek. By lowering the floodplain two to three feet, the project allows floodwater to spread out, which also protects a downstream section of the creek from higher velocities and deeper flows. The floodplain now includes a park, playing fields for a high school, and a greenway corridor (Taylor 2002).

Remove Paving

Even small urban spaces can be converted to reduce impervious cover and create wildlife habitat and places for people. In downtown Jonesborough, Tennessee, an unused town park and its paved parking lots have been transformed since 1992 through a landscape restoration. Spearheaded by the

BETTER SITE DESIGN FOR SUBURBAN DEVELOPMENT

A collection of planning practices known as "better site design" can conserve natural areas, reduce watershed pollution, save money, and increase property values. Better site design is an approach fundamentally different from typical subdivision design for residential and commercial development. These practices seek to accomplish three goals: reduce impervious cover, conserve more natural lands, and use porous areas for effective stormwater treatment.

In 1996, the Center for Watershed Protection convened a national site-planning roundtable, which created 22 model development principles. The following 16 principles, based on the roundtable's work, are adapted with permission from CWP (2003b). They are intended to help local governments to modify their ordinances rather than to serve as national design standards.

Residential Streets and Parking Lots

1. Design residential streets to minimize pavement width. Design streets to support travel lanes, parking, and emergency, maintenance, and service vehicles. Base street widths on actual traffic volume.

2. Reduce the total length of residential streets with alternative street layouts that increase the number of homes per street.

3. Reduce residential street widths to the minimum needed for the travel-way, sidewalk, and vegetated swales. Locate utilities and storm drains within the right-of-way pavement section.

4. Reduce residential street cul-de-sacs to the minimum radius needed for emergency and maintenance vehicles. Include landscaped areas to reduce impervious cover.

5. Where density, topography, soils, and slope permit, use vegetated open channels (swales) in the street right-of-way to convey and treat stormwater runoff.

6. Review local parking ratios to see if they can be reduced.

7. Reduce parking requirements where mass transit is available or spaces can be shared.

(continued)

International Storytelling Center, the project converted a valley with steep walls into a three-acre terraced park that accommodates 12,000 people for an annual storytelling festival. The restoration removed two parking lots—one on top of a hill, and the other in the floodplain. Slopes were regraded and reforested with native trees; the top terrace next to Main Street features an "urban" park with a plaza and fountain. A ditch that ran straight down from the top of the site was rebuilt into a stream with rocks and plants. Water now meanders through swales and biofiltration ponds (Franklin and Franklin 2002).

Reduce Paving in New Development

Smart growth planning and design reduces the square footage of parking and other paved or hard surfaces. Reconfiguring streets, parking lots, and driveways to reduce unnecessary pavement turns more of a site over to soil and plants that filter rainwater. Cluster developments, as opposed to

BETTER SITE DESIGN FOR SUBURBAN DEVELOPMENT *(continued)*

8. Reduce overall parking lot imperviousness by providing compact-car spaces, minimizing stall dimensions, and using efficient parking lanes and porous materials for spillover parking.
9. Provide economic incentives for parking garages and shared parking.
10. Provide stormwater treatment for parking lot runoff with naturalized retention ponds, swales, and other features that can be integrated into landscaped areas like medians and traffic islands.

Lot Development

1. Protect the watershed by advocating for open-space design subdivisions with smaller lot sizes that will minimize total impervious area, reduce construction costs, conserve natural areas, and provide recreation space.
2. Relax side-yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.
3. Promote more flexible design standards for residential subdivision sidewalks. Consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.
4. Reduce overall imperviousness by promoting alternative driveway surfaces and shared driveways to two or more homes.
5. Specify how community open space will be managed and designate a sustainable legal entity to be responsible for managing natural and recreational open space.
6. Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas, and avoid routing rooftop runoff to roadways or the stormwater system.

Source: Center for Watershed Protection (2003b)

standard cul-de-sac layouts, reduce site imperviousness 10 to 50 percent (Schueler 1995c).

Zoning ordinances that allow fewer parking spaces for commercial and residential development make sense for sites near public transportation, or when existing parking can be shared with other new development. Narrower roads—even four-foot reductions from the standard 26-foot width—create much less runoff.

On commercial and municipal sites, developers can reduce paving with alternative parking designs. Businesses with parking demands at different times, such as a medical practice and a restaurant, can share the same parking lot. Other alternatives include planning lot capacity for average rather than peak parking demands, placing parking beneath commercial buildings, and constructing multistory parking garages (Lehner et al. 2001).

Portland, Oregon, has reduced its parking lot standards. City regulations formerly required 24-foot-wide aisles and 9-by-19-foot stalls, with some smaller

SMART SITE PRACTICES FOR REDEVELOPMENT AND INFILL PROJECTS

Urban redevelopment and infill projects can help revitalize city centers and provide opportunities for environmentally friendly growth. Because of the potential impact of such projects on urban rivers and streams, however, planners should consider the site location and other factors such as stormwater runoff, water quality, air quality, and natural habitat, along with building and zoning codes and regulations.

The Center for Watershed Protection convened the Redevelopment Roundtable, a group of national and local stakeholders, to develop Smart Site Practices for redevelopment and infill sites. The group issued the following 11 practices, which are adapted with permission from the *Redevelopment Roundtable Consensus Agreement: Smart Site Practices for Redevelopment and Infill Projects* (CWP 2001b):

Practice 1: Redevelopment and infill planning should include environmental site assessments that protect existing natural resources and identify opportunities for restoration where feasible.
Brownfield and other legislation generally requires that infill and redevelopment sites be subjected to a site history, surface soil and water testing, and clean-up. Bank loans also often carry such requirements. Even when not required by law or loan terms, developers should prepare a thorough environmental site assessment. To address environmental constraints and highlight opportunities for restoration and reclamation at a site, this assessment should include a base map that outlines existing buildings, transportation networks, utilities, floodplains, wetlands, streams, and other natural features.

Practice 2: Design sites to use impervious cover efficiently and to minimize stormwater runoff. Where possible, the amount of impervious cover should be reduced or kept the same. In situations where impervious cover does increase, sites should be designed to improve the quality of stormwater runoff at the site or in the local watershed.
Impervious cover has a direct impact on annual runoff volume and increases pollutant loads, flooding frequency, and stream channel degradation. Some impacts can be mitigated by reducing or using existing impervious cover efficiently, and by managing stormwater runoff on site.

Practice 3: Plan and design sites to preserve naturally vegetated areas and to encourage revegetation and soil restoration. Sites should use native or noninvasive plants where feasible.
Natural urban areas often are found in small fragments that suffer from poor quality soils, invasive plant species, dumping, and extensive alteration by past development. Collecting and mapping natural features, preserving areas in a consolidated manner, and evaluating the site for potential stormwater management, revegetation, and recreational benefits can provide environmental, aesthetic, and economic benefits.

Practice 4: Establish plans to guarantee long-term management and maintenance of all vegetated areas.
Long-term management, financing, and maintenance plans ensure that vegetated areas continue to function and that the public can enjoy them. Conservation easements, land trust donations, and innovative partnerships can help landowners guarantee that intensively used vegetated urban areas are well maintained.

Practice 5: Manage rooftop runoff through storage, reuse, and/or redirection to pervious surfaces for stormwater management and other environmental benefits.
Reducing urban rooftop runoff can reduce pollutant loads, flooding, channel erosion, and other impacts on streams and rivers. Stormwater management techniques such as green roofs, rain barrels, and downspout disconnection, as well as the design, slope, and architecture of rooftops, can reduce the volume of rooftop runoff.

(continued)

SMART SITE PRACTICES FOR REDEVELOPMENT AND INFILL PROJECTS *(continued)*

Practice 6: Parking lots, especially surface lots, should be minimized and designed to reduce, store, and treat stormwater runoff. Where site limitations or other constraints prevent full management of parking lot runoff, designers should target high-use areas first.

Parking lots are one of the greatest sources of stormwater runoff. Some runoff management techniques include making parking lots incrementally smaller, providing landscaping that substantially contributes to runoff management, and treating the quality of stormwater runoff.

Practice 7: Use a combination of "better site design" techniques with infill projects to minimize stormwater runoff and maximize vegetated areas.

Many single-lot or small multilot infill projects contribute to "impervious creep" through new structures, sidewalks, and paved areas. Better site design benchmarks are applicable to infill development that entails single-lot or small multilot infill (one to three lots) or larger infill subdivisions (10 to 30 lots). Although infill development typically occurs on smaller lot sizes (10,000 square feet or less), it is often still possible to cluster lots to provide more open space and reduce impervious cover.

Practice 8: Use proper storage, handling, and site design techniques to avoid the contact of pollutants with stormwater runoff.

Pollutants can be controlled on-site through source control measures, such as proper handling and storage of pollutants in outdoor areas, and site design practices, including loading docks designed to contain pollutants. Source control measures usually are the simplest and most cost-effective way to reduce stormwater pollution at many commercial sites.

Practice 9: Design the streetscapes to minimize, capture, and reuse stormwater runoff. Where possible, provide planting spaces to promote the growth of healthy street trees while capturing and treating stormwater runoff. In arid climates, xeriscapes should be used to achieve similar benefits.

The streetscape, or area between the street, sidewalk, and other structures, provides opportunities to manage stormwater runoff while providing many other environmental and aesthetic benefits.

Practice 10: Design courtyards, plazas, and amenity open space to store, filter, or treat rainfall.

Much of the open space in redevelopment and infill projects consists of hard surfaces that are impervious to rainfall. Using creative site plans, these courtyards, plazas, and other hard surfaces can be designed to store, filter, and treat rainfall through alternative pavers, bioretention areas, and planting boxes, among other examples.

Practice 11: Design sites to maximize transportation choices so as to reduce pollution and improve air and water quality.

Redevelopment and infill sites should be designed to increase nonautomotive connections between adjacent land uses, parks, and public spaces. Bike paths and pedestrian walkways offer residents alternative modes of transportation that can improve environmental quality. Sites should also provide links to mass transit and offer commuter amenities such as bus shelters and bike racks.

Source: Center for Watershed Protection (2001b)


Low Impact Development Center, Inc.

Permeable paving surfaces can reduce erosion and help recharge groundwater.

stalls for compact cars. While SUVs are big, they actually are shorter and narrower than the vehicles driven when the standards were written decades ago. In 2002, the city unveiled standards for "hybrid" spaces that fit most vehicles. Developers now have the option of building narrower, 20-foot-wide aisles and smaller, 8.5-by-16-foot stalls. Developers like the code because it reduces construction costs. An added incentive is lower fees. Portland charges commercial and multifamily developers a stormwater management fee based on square footage of impervious surfaces. In 2005, the city will begin discounting this fee for reduced paving. The city intends to begin the discount in 2005, retroactive to a year to be determined (Liptan 2002, 2003).

Alternative Pavers

Alternative paving surfaces—also called alternative pavers—are permeable or semipermeable surfaces that allow varying degrees of water infiltration. Alternative paving materials are an important component of low-impact development that can achieve stormwater management conditions close to nature. They can be used to infiltrate rainwater on site and reduce runoff leaving the site, which in turn help decrease downstream flooding, the frequency of combined sewer overflow events, and the temperature of stream water.

Studies by William James at the University of Guelph, for example, found that pavers made of interlocking concrete blocks can significantly reduce the surface runoff loads of such contaminants as nitrite, nitrate, phosphate, phosphorous, metals, and ammonium. They also reduced runoff temperatures by two to four degrees Celsius compared to asphalt paving. The Low Impact Development Center (2003) summarizes the benefits of alternative pavers: they "can eliminate problems with standing water, provide for groundwater recharge, control erosion of streambeds and riverbanks, facilitate pollutant removal, and provide for a more aesthetically pleasing site." In some cases, they can eliminate the need for underground sewer pipes and conventional stormwater retention and detention systems.

Alternative pavers can replace asphalt and concrete in parking lots, fire access roads, driveways, and walkways.

Alternative pavers can replace asphalt and concrete in parking lots, fire access roads, driveways, and walkways. Paving blocks are one type of alternative paver: these blocks are cement or plastic grids with voids that can be filled with gravel or grass and used for parking and driveways. Gravel, cobbles, brick, or natural stone arranged in a loose configuration can also be used to construct driveways. Wood mulch is appropriate for walking paths. Traffic volume and type, access for the handicapped, and climate considerations like soil and snow removal may limit the use of some of these alternatives. For example, alternative pavers are best used for overflow parking but not in high-traffic parking areas. Similarly, paths that use mulch or similar pavers may require more maintenance, especially in frequently inundated areas.

Permeable Paving

Permeable paving is a sustainable-design solution that takes advantage of a site's natural features (such as a slope) to allow stormwater to infiltrate through the paved surface and recharge groundwater, thus reducing erosion and eliminating the need for conventional and costly stormwater drainage systems.

Twelve years ago, the Morris Arboretum near Philadelphia created a permeable parking lot for 80 cars. The surface is constructed of a special permeable asphalt that, because it lacks fine particles, resembles peanut brittle. This permeable surface allows water to flow to a recharge basin beneath the parking lot. The basin is lined with filter fabric and filled with ostrich-egg-size stones that allow water to percolate through, preventing the clogging that thwarts some porous-paving systems. Pollutants such as oil and antifreeze are removed by being filtered through the soil mantle.

Stormwater soaks into the ground and seeps into Papermill Run, a 20-foot-wide urban stream on the property (Franklin and Franklin 2002).

Permeable paving will not work in every situation, but must be matched to a site's geology, soil structure, and hydrology. Heavy clay soil, for example, does not allow water to infiltrate unless the clay level is punctured. These paving surfaces also require careful, continuous maintenance (Low Impact Development Center 2003).

Design Principle 6: Manage stormwater on site and use nonstructural approaches

Ecologically designed riverfronts capture, store, and infiltrate or otherwise naturally treat and release stormwater. Systems with natural processes, such as wetlands and bioswales (small linear wetlands planted with riparian and water-tolerant trees), can provide wildlife habitat and aesthetic value as well. These natural systems can often replace stormwater pipes and other engineered structures, most of which send high volumes of untreated stormwater directly into rivers and streams.

Stormwater infrastructure that relies on drains, sewers, and hard engineering also sweeps large volumes of urban contaminants from roads and parking lots into rivers. These pollutants—oil, grease, combustion

COMBINED SEWER OVERFLOWS

Most urban communities have an aging sewage infrastructure that leaks, spills, and overflows into rivers and streams. The riverfront also is usually the final point of discharge of treated wastewater. These sources of river pollution affect the aesthetics and the use of the riverfront for recreation and relaxation, and they create negative public perceptions.

Combined sewer overflows (CSOs) remain a major challenge for urban water quality. Combined sewer systems convey stormwater, sewage, and industrial waste through the same system. Remnants of older urban infrastructure, combined sewer systems serve about 40 million people in 772 U.S. communities, mostly in the Northeast, Great Lakes, and Pacific Northwest regions. During heavy rainfall, these communities often experience CSOs that spill raw sewage into rivers. About 43 percent of all CSOs spill into rivers, and 38 percent into streams. Some 12 percent flows, into canals and ditches, and the rest goes into oceans, estuaries, and bays (5 percent), and lakes and ponds (2 percent) (U.S. EPA 2001b, 2002b).

CSOs occur during and after storms, when the volume of stormwater entering a combined sewer system overwhelms collector pipes and sewage treatment plants. As a result, industrial wastes and sewage combine with storm runoff and flow directly into streams and rivers. Nationally, more than one trillion gallons of untreated sewage and stormwater overflow into streams and rivers every year. (U.S. EPA 2001b). In response, the U.S. Environmental Protection Agency has developed the Combined Sewer Overflow Control Policy.

CSOs pose a challenge for cities with a stormwater problem: should the riverfront zone, the last place to treat sewage before it enters the river, become the location for a sewage treatment plant, or should city officials reserve this area for other purposes such as recreation?

In Portland, Oregon, CSOs are the primary stormwater issue. Portland needs $1 billion to build tunnels, tanks, and pump stations to meet state water-quality standards by 2011. By mid-2003, Portland was constructing giant tunnels on the West Side to keep the combined sewer overflow from discharging into the Willamette River. The city has begun designing tunnels for the city's East Side (Liptan 2002, 2003). Portland is also aggressively promoting on-site and nonstructural stormwater approaches to minimize the amount of stormwater flowing into sewers.

byproducts, metals, herbicides, pesticides, pet wastes, and many others—can be toxic to aquatic organisms, and expensive to remove to meet water-quality and drinking-water standards.

In contrast, well-designed stormwater management alternatives—including green roofs, stormwater planters, and biofiltration basins, either individually or in combination—can treat almost all stormwater on site, except during an event like a 100-year storm (Liptan 2002).

Site-design measures such as natural drainages instead of storm pipes and culverts help delay the timing and reduce the peaks of stormwater runoff. Detention measures, such as constructed wetlands, ponds, and rainwater cisterns, as well as reforesting and preserving buffer zones, also filter stormwater before it enters stream and river channels (Riley 1998).

Nonstructural approaches can save money. These approaches can range from simple measures, such as providing inexpensive rain barrels for homeowners to catch downspout drainage for use in their gardens, to more complicated systems that store and treat water for part of a watershed.

The most successful stormwater practices are based on site conditions—the climate, soils, hydrology, degree of impervious materials, and how the buildings and the landscape work together. Stormwater strategies may also depend on the intensity and setting of new development. For example, infill and other urban development may not have enough land to construct wetlands for stormwater treatment. In such cases, stormwater control structures can be retrofitted to provide water treatment—in other words, the infrastructure both removes contaminants and controls water flow (Lehner et al. 2001).

Natural Stormwater Management

Naturalizing techniques can supplement infrastructure to cleanse and control stormwater, resulting in substantial savings for developers and local governments. These include detention ponds, bioretention ponds and swales, cisterns, stormwater planters, and infiltration ponds.

Bioretention ponds. Bioretention ponds capture runoff in constructed wetlands and allow water to infiltrate slowly into the ground. Placed two to six inches below grade, bioretention areas use layers of soil, sand, and mulch with native plants that filter pollutants and slow and cool the water. Bioretention areas can fit into small spaces such as parking-lot islands and infill sites. With no concentrated release point, they do not cause erosion.

The most successful stormwater practices are based on site conditions—the climate, soils, hydrology, degree of impervious materials, and how the buildings and the landscape work together.

North Carolina State University researchers are studying the effectiveness of bioretention ponds in preventing water pollution and the alteration of stream channels. In North Carolina, Carpenter Village has installed two dry ponds, each 800 square feet and six feet deep, in two pocket parks at the top and bottom of a hill. These bioretention areas have been filled with topsoil, native plants, and trees. Installed as permanent features, they share the open space with a path and benches. Researchers will monitor how the ponds, designed to drain within 24 hours, reduce the volume and velocity of stormwater (White 2002).

Smaller versions of bioretention areas are called rain gardens. They are designed to infiltrate water within four to six hours. Rain gardens remove pollutants at the rate of 60 to 80 percent for nutrients and 93 to 99 percent for heavy metals. Each lot at Somerset, a New Urbanist community in Maryland, features a rain garden of 300 to 400 square feet. Sited at topographic low points, the gardens are planted by the developer and maintained by homeowners. The developer estimates that substituting rain gardens for more conventional detention basins will reduce infrastructure and other costs by $300,000 (Russell 2000).

Infiltration basins and trenches. Infiltration basins resemble dry detention ponds but have no outlet, forcing water to infiltrate through the bottom of the basin. Infiltration trenches, generally filled with rocks and gravel, create a reservoir for water that will be infiltrated to surrounding soil. French drains, another widely used infiltration technique, are small infiltration trenches at the bottom of gutter downspouts. These allow water to infiltrate on site rather than passing into the storm sewer system (Lehner et al. 2001).

Although less natural than bioretention ponds or swales, infiltration basins can still provide water-quality benefits. These basins temporarily store runoff until water percolates slowly into the soil. Infiltration basins reduce peak flow and recreate to some extent the natural pattern of water infiltration. They can handle up to 98 percent of stormwater and remove significant amounts of pollutants. They can cool stormwater significantly, to 55 degrees, as it infiltrates into the ground, and they thus reduce the damaging effects of heated stormwater on aquatic environments.

Successful projects require soil that is capable of infiltration. One study suggests such soil can contain no more than 30 percent clay. Yet other studies of infiltration basins suggest a high rate of failure, mostly due to clogging from sediments carried in by runoff. To prevent clogging, experts recommend a pretreatment settling pond or other sediment-removal device (MacElroy and Winterbottom 2000).

Biofiltration channels and swales. Biofiltration uses plants—generally grasses and wetland plants—to filter and treat stormwater runoff conveyed though open channels or swales. Whether natural or constructed, such wetland areas absorb excess nutrients and metals and help break down microbes. By slowing the flow of stormwater, biofiltration also allows contaminants to settle out.

Tom Lipton

The Oregon Museum of Science and Industry uses 2,300 linear feet of small wetlands to treat stormwater in its 768-car parking lot.

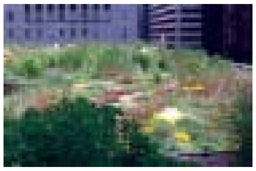
An award-winning example is a stormwater treatment project at the Oregon Museum of Science and Industry (OMSI) in Portland, which restored natural processes to a former industrial site along the Willamette River. OMSI's 10-acre, 768-car parking lot incorporates about 2,300 lineal feet of bioswales—small linear wetlands planted with riparian and water-tolerant trees—instead of traditional landscaped islands. Unlike a rain garden, which allows water to infiltrate by holding it stationary, a bioswale allows infiltration as water moves along its length.

Unlike a rain garden, which allows water to infiltrate by holding it stationary, a bioswale allows infiltration as water moves along its length.

Curb cuts channel stormwater runoff into the bioswales, where check dams slow the water's speed to allow sediment to drop out while water infiltrates into the soil. Plants also filter out oils and other pollutants. Designed to fit a small space while also conforming as much as possible to standard design, construction, and maintenance for parking lots and storm drains, the bioswales are a pragmatic, aesthetically striking, and cost-effective solution. The bioswales cost $78,000 less to construct and require no more maintenance than conventional storm drain systems (Liptan 2003).

The OMSI project won a 1996 award in a stormwater design competition sponsored by public agencies in the Portland metropolitan area (Jerrick 1998). The example worked so well for the developer, the city, and the environment that the city now requires all new parking lots to follow OMSI's model. There are two complementary codes. The first is a planning code created 20 years ago and modified in 2002 that requires developers to install landscape areas to filter stormwater equivalent to 10 percent of the interior area of a parking lot. The second is a public works water-quality code that requires developers to use landscaping in parking lots as filters for stormwater management, rather than piped and engineered systems.

Combined with the new Portland code (mentioned above) that allows for narrower aisles and smaller stalls in parking lots, the city has experienced no net loss of parking spaces while it has improved on-site stormwater management and water quality in aesthetically pleasing ways (Liptan 2002, 2003).



City of Chicago

This green roof rests on top of Chicago's City Hall.

Also in Portland, the Water Pollution Control Laboratory harvests rainwater directly from the lab's gutterless roof. Scuppers that extend from the roof shoot rainwater in a trajectory into a wide, rock-lined bioswale several feet from the edge of the building. Planted with ornamental wetlands grasses and other plants, the bioswale offers an artistic approach to stormwater management (Thompson 1999).

Green Roofs. Rooftop gardens are another solution that minimizes runoff volume by absorbing stormwater. Widely used in Europe, so-called green roofs are beginning to sprout in American cities. Green roofs are a lighter modern variant on sod roofs and can capture 15 to 90 percent of stormwater, depending on soil, rooftop cover, and weather conditions (Low Impact Development Center 2003).

Green roofs also can improve water quality by filtering pollutants such as nitrogen, which breaks down in soil and is absorbed by plants. Green roofs provide extra insulation that can reduce energy costs for heating and cooling, and can extend the roof's life span by preventing exposure to ultraviolet rays. Considering the savings associated with deferred maintenance and reduced energy consumption, green roofs compare in cost to conventional roofs (Low Impact Development Center 2003).

They also soften and beautify urban skylines with flowers and shrubs that draw birds and butterflies, which, beyond their aesthetic and ecological value, can raise property values. They can even produce vegetables and fruit.

Green roofs are not merely container gardens. They completely cover roofs with lightweight planting material and have an additional layer impenetrable to roots, sharp objects, and water seepage. Because urban rooftops in many regions can have a desert-like microclimate, they often do best with drought- and heat-tolerant plants with shallow roots. Designed and installed properly, with the help of engineers who specialize in green roofs, they pose little risk of collapse or water damage.

Considering the savings associated with deferred maintenance and reduced energy consumption, green roofs compare in cost to conventional roofs.

Green roofs come in two general types. An *extensive* garden—basically a meadow planted on a thin layer of planting medium—requires little or no irrigation or maintenance and usually is not accessible to the public. An *intensive* rooftop garden is landscaped with trees, water structures, walkways, and other elements of a traditional garden that may need frequent irrigation. Some green roofs rely on a simple plant palette, such as native grasses.

In 2001, the North American Premier Automotive Group, a division of Ford Motor Company, installed a 45,000-square-foot roof garden on one wing of its new 300,000-square-foot headquarters in Irvine, California.

The garden atop the one-story building features drought-tolerant groundcover plants. Ford hopes the roof will produce oxygen, create a habitat for bees and butterflies, reduce stormwater runoff, extend the roof's life, and help reduce interior heat. Although the rooftop is not being monitored formally, the property manager reports that air conditioning costs are lower compared to other buildings (Borghese 2003; Roofscapes, Inc. 2003).

Spanning 20,300 square feet atop an 11-story building, the green roof of Chicago City Hall includes walkways and 20,000 plants covering a range of landscape environments from native meadows to trees and shrubs. Completed in 2001, the design ranges from 3.5-inch-deep extensive areas to 24-inch-deep intensive areas. Rooftop weather-station monitoring indicates the gardens have lowered surface temperatures. For example, on one August afternoon in 2001, the air temperature was in the 90s. The roof garden registered between 91 and 119 degrees Fahrenheit, at least 50 degrees cooler than the black tar roof on the adjacent Cook County building. The green roof saves $3,600 per year in energy costs (City of Chicago 2003).

Cisterns. Cisterns are a less common but promising detention measure. A "green" house at Carpenter Village, a New Urbanist development in North Carolina, features two underground cisterns that supply irrigation water. The yard contains two in-ground pump tanks connected to gutters. Downspouts direct rainwater to the cisterns, which hold up to 1,250 gallons each. The cisterns work by pressure, pumping out water for irrigation, car washing, and other exterior uses. For $4,000 to install the system, the cisterns provide effective stormwater treatment. Ninety percent of rainwater is treated and reused on site; the cisterns also recharge the groundwater because the retained water is reapplied during a dry time (White 2002).

A system like this one requires substantial planning. A water budget must be developed and followed. Tanks must be big enough to store two to three months of rainwater for dry times. But the design has great promise. Rainwater collection systems like this might be used to irrigate larger sites and even whole developments.

Stormwater planters. Stormwater planters are a low-cost alternative for stormwater treatment and water conservation. Installed at-grade or raised, stormwater planters filter rainwater that has been drained from downspouts connected to gutters. In Portland, Oregon, planters varying from 5-by-10 feet to 10-by-50 feet are filled with several feet of soil and plants. Portland State University uses planters to store water that is pumped into buildings for use in toilets. Through filtering and evaporation, stormwater planters can manage nearly 100 percent of roof runoff (Liptan 2002).

Design Principle 7: Balance recreational and public access goals with river protection

Riverfront communities should provide facilities for as many recreational uses as possible while balancing some conflicting uses (for example, between power boats and birdwatching platforms) and managing possible overuse of the river corridor.

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Thanks to the Clean Water Act and other initiatives, Americans have returned to urban riverfronts and other waterways in large numbers. In 2000, more than 34 million Americans over age 16 went canoeing, rafting, or kayaking (Outdoor Recreation Coalition of America 2001). That same year, some 71 million people went bicycling, many on riverfront trails and greenways, which now exist in 500 communities. Some 35 million American anglers spend $38 billion on fishing every year. Another 14 million hunters spend $20 billion a year pursuing migratory waterfowl that rely on rivers and others bodies of water (U.S. EPA Office of Water 2000).

Cities and towns have also done much to encourage Americans to return to urban riverfronts over the past two decades. Following the economically successful (if ecologically sterile) example of the San Antonio Riverwalk, communities like Estes Park and Pueblo in Colorado developed their own riverwalks that linked parks, natural areas, festival areas, and shopping. In recent years, major new riverfront parks have been introduced in Denver; Louisville, Kentucky; and San Jose, California. These combine public gathering spaces and trails with natural flood control and naturalized infiltration swales.

Environment/User Conflicts

The popularity of urban riverfronts can create conflicts between users and the environment. A 10-foot-wide greenway trail, for example, introduces one acre of paving per mile into a floodplain (Searns 2002). Many greenways have proven so popular they are being widened or augmented with separate hiking or equestrian trails. While these accessory trails often feature a porous surface such as crushed stone, they still may usurp wildlife habitat.

Motorized boating presents a more direct threat to habitat. Eighty-five percent of the 29 million gallons of oil dumped into America's waterways each year comes from the two-stroke engines used in many boats and personal watercraft (PWCs), often known by the brand names Waverunner or Jet Ski. Even small spills measured at parts per trillion are toxic to fish and aquatic plants (Committee on Oil in the Sea 2003).

PWCs also create noise pollution and pose safety challenges. Only 10 percent of the motorized boats registered in the United States are PWCs, yet they account for 30 percent of accidents, of which 80 percent are collisions. In recent years, some communities have banned or restricted PWCs. In 1995, San Juan County, Washington, which includes the San Juan Islands, became the first jurisdiction to ban PWCs outright. San Francisco County enforces a 1,200-foot setback from shorelines for PWCs, except for limited access to boat ramps. The National Park Service has restricted or banned PWCs on portions of the Colorado, Missouri, and Rio Grande Rivers (Smith 2002).

Powerboats and marinas also present user conflicts and environmental concerns. No-wake zones help canoeists and anglers coexist with powerboats. Yet, some communities have rejected proposed marinas because of concerns about disturbing wildlife habitat and threatening endangered marine mammals.

Human health issues are another access challenge. Some 300,000 miles of rivers and streams do not meet state water-quality guidelines. Even with advances since the Clean Water Act, many urban rivers are not clean enough for swimming or to produce edible fish. The EPA and other regulatory agencies are struggling to control such pollution sources as urban runoff and combined sewer overflows (U.S. EPA Office of Water 2000).

Supporting Access and the Environment

Greenways and river trails combine recreational access with environmental enhancements and can often be incorporated into other infrastructure projects. For example, near the resort community of Glenwood Springs, Colorado, the widening of I-70 through Glenwood Canyon in the 1980s was accompanied by construction of a 16-mile trail, whitewater boat ramps, and large-scale native revegetation. River access was improved through new highway exits convenient to Colorado River parks.

While providing access, properly designed greenways also protect the floodplain and provide wildlife migration corridors between otherwise isolated "patches" of native habitat (Smith and Hellmund 1993).

Louisville Waterfront Development Corporation

Louisville and Jefferson County, Kentucky, worked together to create a greenway master plan that brings citizens in touch with the waterfront.

GREENWAY AND RIVERWALK PLANNING IN PUEBLO

A prairie steel town in southeastern Colorado, Pueblo had the Rust Belt blues 20 years ago. Pueblo's unemployment rate soared above 20 percent after the city's biggest steel mill laid off 5,000 employees before heading into bankruptcy. Then the city slowly climbed back. Pueblo diversified its economy by recruiting 40 companies in the high-tech manufacturing and warehousing industries, adding nearly 9,000 jobs. From 1984 to 1995, the city's population grew from 107,000 to 137,000 and median household income jumped more than 60 percent (McNulty 2000).

In October 2000, Pueblo threw a three-day riverfront party to celebrate a crowning touch in its renewal campaign. Live music, beach volleyball, and a raft race and regatta marked the dedication of the $24-million Historic Arkansas Riverwalk of Pueblo (HARP). The 26-acre riverwalk features waterfalls, public art, natural areas, and a water taxi system that links Pueblo's historic, business, and commercial districts. In addition to providing new park and recreation opportunities for residents, HARP is expected to generate $9 million a year in tourism revenues (Munch 2002). In 2000, Partners for Livable Communities cited the riverwalk as a feature that made Pueblo one of the nation's four most livable cities.

Pueblo launched its downtown riverwalk planning in 1991. The key challenge was to daylight one-third of a mile of the Arkansas River that had been diverted into two eight-foot-wide pipes and an underground culvert. The plan called for redirecting the river into a new channel in the historic riverbed without reintroducing a flood risk. At the west end of the proposed channel, the city wanted to beautify and naturalize Lake Elizabeth, an eyesore the city leased to the local power company as a cooling pond.

Initial funding for the project hinged on a 1995 vote for a $12.85 million bond issue. To help Pueblo voters grasp the project's scope, local architects made a $9,000 scale model that was displayed in Pueblo at the state fair, where 500,000 people viewed it. The bond issue was approved by a narrow margin and has since been augmented by $7 million in private and foundation grants and another $3 million in state and federal funds.

HARP now unifies downtown as the city's focal point and links city hall with civic, cultural, and educational institutions such as the Sangre de Cristo Arts Center, El Pueblo Museum, and the new Buell Children's Museum. Some 6,500 feet of walkways and bike paths connect people with water features. Water taxis and observation boats ply 2,760 linear feet of the channel. At the west end, Lake Elizabeth hosts an outdoor education and nature study area with wetlands and native-plant landscaping. The riverwalk also includes benches and fountains made from local stone by Colorado sculptor and landscape architect Richard Hansen (Brandes 2002). In 2003, the Riverwalk attracted the first mixed-use project to its banks .

Greenways and river trails provide a "green infrastructure" by incorporating flood control, river buffer zones for filtering stormwater, and transportation. In Boulder, Colorado, where a 60-mile greenway system links neighborhoods to schools, jobs, and shopping, about 12 percent of the population commutes by bike, or about 12 times the national average.

After a major flood, Louisville, Kentucky, in 1946 created the Metropolitan Sewer District (MSD) to build dams and levees, channel streams, manage sewers, and build wastewater plants. In the 1990s, MSD officials admitted that many of its engineering measures were ineffective. The river still flooded, and surging stormwater brought pollution into the river and its tributaries.

Regional support for protecting the river led to passage of an innovative 1997 floodplain ordinance that protects 12 percent of Jefferson County as floodplain. As part of the process of reclaiming the Ohio River and its tributaries, the MSD also created a 1999 greenway master plan to bring citizens in touch with the waterfront (Louisville and Jefferson County 1999). Several trails have been built. Plans include connecting Beargrass Creek, now one of the city's most polluted urban streams, to a new $90-million, 120-acre Waterfront Park, under construction in three phases since 1991. Waterfront Park was planned in conjunction with 1 million square feet of new riverfront housing, commercial development, and a minor league baseball stadium (Calkins 2001). The park is located entirely within the 100-year floodplain. The first 50-acre phase withstood a 1998 flood with no major damage (Croce 2002; Flink 2002). Since then the master plan for Waterfront Park has been updated to dovetail with Jefferson County's greenway master plan.

These riverfront and tributary improvements have enhanced nearby property values. In the Louisville region, real estate with visual and physical access to the new greenways and riverfront parks commands a 5 percent premium (Searns 2002).

Ecologically Sensitive Design and Construction

Greenways and riverfront parks can be designed to minimize or mitigate effects on the natural environment. For example, greenway planning can reclaim other floodplain lands to make up for lands consumed by trails. Rather than closely following rivers, trails can weave in and out of waterfront access points, steering visitors away from sensitive wetlands and meadows or easily eroded banks (Searns 2002).

To avoid natural areas as well as privately owned land, 12 miles of new trails being built along the Anacostia River in Washington, D.C., will crisscross the river on a series of new biker-pedestrian bridges. The bridges will reduce the amount of paved trail on land while allowing visitors to enjoy a more intimate, yet low-impact, experience of the river and its marshes (Bunster-Ossa 2002).

A successful riverway trail system may increase public support for river protection, tributary restoration, and trails. Well-designed trail systems attract users—especially those who live nearby—and encourage social use, which, in turn, can minimize vandalism and other crime. A study of Seattle's

KEYS TO BUILDING PUBLIC SUPPORT FOR GREENWAYS AND RIVER IMPROVEMENTS

- Identify allies in positions of authority. Meet individually with elected officials, city staff, and business executives.
- Build grassroots support among interest groups that benefit directly, such as cyclist organizations and kayak clubs.
- Build support among nonusers, including business groups that recognize the economic benefits of greenway development and taxpayers who may not use greenways but can be helped to understand the value of funding them.
- Contact landowners and tenants whose properties may be directly affected by the greenway. They can become powerful allies—or vociferous opponents.
- Contact utility companies who may control river rights-of-way and be concerned about possible vandalism, trespassing, or other public-safety issues. Explain how they may be able to reduce their own costs and win public relations benefits by, for example, combining storm conveyance with greenways, or converting high-maintenance ornamental landscapes to naturalized landscapes.
- Create a pilot project such as a trail section with interpretive signs that demonstrates the value of greenways to all community members.

Source: Adapted from Flink and Searns (1993, 49–63)

Burke-Gilman Trail found no difference in crime rates when the trail area was compared to the rest of the city. Property values for homes near the trail enjoyed a 6 percent premium (Little 1995).

Water Trails: A Growing Movement

A water trail is a stretch of river, shoreline, or ocean that has been designated to provide educational, scenic, and challenging nature-based experiences to recreational boaters. For communities across the country, water trails are a valuable tool for promoting a healthy economy and a high quality of life while preserving natural systems and cultural heritage. Water trail projects can inspire individuals, unify communities, provide hands-on experience for recreation and city planners, and serve as outdoor classrooms for students and educators.

Inaugurated in 1998, a 24-mile stretch of the Susquehanna River between Halifax and Harrisburg became Pennsylvania's first water trail. It incorporated four access sites and 10 river islands for day use and primitive camping. The trail is managed by a partnership of the Pennsylvania Fish and Boat Commission, Pennsylvania Department of Conservation and Natural Resources, the Pennsylvania Game Commission, the city of Harrisburg, and the Alliance for the Chesapeake Bay. Volunteer groups have already adopted islands and access sites. Members serve as trail stewards and are responsible for maintaining the trail, monitoring resource impacts, and analyzing public use. Today this trail is a part of the 51-mile Middle Susquehanna River Water Trail, which is one of Pennsylvania's 16 state-designated water trails (Pennsylvania Fish and Boat Commission 2003).

Design Principle 8:
Incorporate information about a river's natural resources and cultural history

Ecological interpretation and education are important along urban rivers because so many natural systems and references have been erased. The river's history and function may not be obvious to the public. An informed public that understands river ecology as well as the potential for regeneration will support efforts to improve and protect its river. Citizens also need to know how to use their river safely and should be informed about water-quality issues and hazards to swimming and boat navigation.

Riverfront wayfinding and other sign systems explain the river's unique characteristics and the region's natural assets. People of all ages, income levels, and ethnic backgrounds should be invited to participate in riverfront interpretation and activities. Public art initiatives, concerts, open-air movies, or other cultural events can draw people to explore the riverfront. So can sporting events, outdoor recreation activities, and festivals. Outreach efforts can include hiring river guides and interpretive experts from varied ethnic and economic backgrounds, interpreting riverfront cultural sites to various groups within the local population, and scheduling special activities and programs for community schools (Wilkinson 2000).

Interpretive Signs

Signs should contain clear and succinct information that tells stories or provides information about the river in language easily grasped by the layperson. Signs can be as simple as stenciled "Drains to creek" messages, such as those painted near stormwater drains in Sioux Falls, South Dakota, where stencils are designed through an art contest. The stencils alert residents that dumping motor oil or other wastes harms their own watershed.

Riverfront wayfinding systems should incorporate multiple languages and communication alternatives for people with disabilities. Trails and access points can feature universally accessible designs that avoid ungainly sepa-

CASE STUDY

SAMMAMISH RIVER *Redmond, Washington*

River Issues. The Sammamish River in Redmond, Washington, is typical of many urban and suburban streams. The river lost much of its riparian area and native vegetation when the U.S. Army Corps of Engineers straightened and reconstructed the river into a deep trapezoidal channel in the 1960s. Straitjacketing the river destroyed habitat and dealt a blow to its once-abundant salmon.

Parametrix

Sammamish River, Redmond, Washington

What Has Been Accomplished. Rather than rely upon the Army Corps' traditional approach to controlling the river, project planners seek to let the river be a river. Using a multidisciplinary approach, groups have come together to revitalize Redmond's Waterfront. Among the groups involved are the project designers, Parametrix, the city of Redmond, King County, public agencies, and the citizens of Redmond.

Chinook salmon already have benefited from a pilot project on a 300-foot long stretch of riverbank. Additionally, since restoration of portions of the riparian corridor there has been a marked increase in species diversity and wildlife quantity. Among the animals benefiting are waterfowl, perching birds, and raptors including bald eagles. With the success of the pilot project, an additional 600-foot section was designed in 1998, with construction completed on the west bank in 2000. Current projects include restoring the east bank of the 600-foot section, which began in the summer of 2002, and restoration of an additional 600-foot section upstream.

rate ramps (PLAE, Inc. and USDA Forest Service 1993). Native-plant scent gardens and sound recordings can explain elements of the river to visually impaired visitors.

Signs and graphics are most effective when they use a consistent design with the same typography, graphics, colors, styles, sizes, materials, and construction techniques. While signs need to catch a visitor's eye, they should also blend into the landscape; they will blend in more effectively if they are constructed from natural materials found locally and employ colors that complement nearby geology and plant life.

Near Joliet, Illinois, at the Midewin National Tallgrass Prairie, two rivers and two prairie creeks are being interpreted through low signs incorporated into landforms. Designed to be durable and resistant to vandalism, the signs do not impede the sweeping prairie view. They are constructed from native dolomite limestone quarried from the nearby Des Plaines River. The stone is etched with information as well as images of the site's natural and cultural history, including prairie grasses, Native American motifs, symbols of farming, and images from the site's use as the Joliet Arsenal during and after World War II (OZ Architecture and USDA Forest Service 2000).

Behind city hall, engineers have recreated the river's meanders and curves, and added boulders, root wads, and gravel bars to the once-uniform channel. To the west of city hall, the bank was graded into a series of earth benches. The top of the bank was moved back from the river about 50 feet at its maximum point. These benches were planted with native vegetation and provide the potential for different habitat zones. They also are helping to maintain the river's flood-flow capacity.

Tying these restoration projects together is Redmond's new riverwalk, a thoroughfare for joggers, bikers, and shoppers. The Sammamish River Trail links the communities of the Sammamish Valley with the King County trail system. The county hired JGM-Landscape Architects to develop a master plan that includes trails, fishing opportunities, planting buffers, and wildlife habitat enhancement. Currently underway is a water conservation demonstration garden where local residents can learn low-water use and environmentally friendly gardening techniques as part of public stewardship of the river's ecology.

Benefits to the River and Community. Development of the master plan for the Sammamish River Trail includes a commitment to creating a more natural waterway that is accommodating to people and wildlife, and that includes systems of flood control.

For more information . . .

- See the Parametrix web site, www.parametrix.com, and the JGM-Landscape Architects web site, www.jgm-inc.com/sammamish.htm

Public Art and Special Events

Other forms of public art, sometimes quite whimsical, can attract private support and public funding to river improvement projects.

In 1999, an alliance of community interest groups in and around New York City organized the first journey of the Golden Ball. Paddling alongside or walking the shore, residents followed a floating 36-inch golden orb down the Bronx River to a festival at Starlight Park. Since then, the event has grown significantly. In September 2002, the Bronx River Alliance—composed of more than 65 community organizations and agencies—coordinated the fourth annual journey, which drew media attention to this polluted waterway, the city's only freshwater river (Wichert 2002). The event is aimed at building support for water-quality improvements, debris removal, and habitat restoration. The Alliance has also used more traditional approaches to bring attention to the river. For example, it has organized canoe trips and nature walks for residents from low-income neighborhoods that line the river.

In the Pacific Northwest, a group of artists spent two-and-a-half years creating the Soul Salmon project to celebrate the region's most famous wild fish and its habitat. The project

Benjamin Swett Partnership

The New York City Bronx River Golden Ball Festival has helped build support for water-quality improvements, debris removal, and habitat restoration on the city's only freshwater river.

distributed eight-foot-long fiberglass salmon to dozens of artists, who then decorated the salmon for display at special events in Puget Sound communities over six months. Maps and other information about regional ecosystems were available at the events, whose aim, the organizers stated, was to "inspire local salmon culture and generate charity to save native salmon" (Soul Salmon 2002). After the event's completion in April 2002, an auction of 11 Soul Salmon raised $43,000 for daylighting a creek buried under a shopping mall.

Interpretive Programs

Along 72 miles of river in the Mississippi National River and Recreation Area in Minnesota, the National Park Service (NPS) hosts a pair of innovative interpretation programs, Big River Journey and the Birding Boat. Both bring people out on the river—many for the first time—in 300-passenger paddlewheel boats that NPS leases from local tour operators.

In the past several years, Big River Journey has hosted river trips for 4,500 public school students, whose curriculum requires study of the Mississippi. The boat contains learning stations where students explore such topics as aquatic insects, water quality, geology, ecosystems, river birds, history, and stewardship.

At a cost of $7.50 per student, with financial assistance available, the students are accompanied by ecologists, birders, and experts from the Science Museum of Minnesota. Xcel Energy plant managers have also joined the tour to explain a successful program of hosting peregrine falcon nests on 450-foot-tall smokestacks near the river.

The Birding Boat is open to both students and the general public. Each year in season, about 5,000 people take 90-minute paddle-wheel boat rides to explore Mississippi bird life with expert birders.

The Mississippi National River and Recreation Area also employs the Park Service's only authorized "singing ranger," Charlie Maguire, who serenades visitors with songs that celebrate river history. Maguire's performances have helped some cities rediscover waterfront spaces. For example, in South Saint Paul, a concert in a neighborhood park situated on Mississippi River bluffs led the city to improve the park's wiring and move special events to this venue. Concertgoers now enjoy a spectacular view of several miles of river (Maguire 2002).

CONCLUSION

When William Least Heat-Moon crossed America by 5,000 miles of waterways to research his book *River-Horse* (1999), he found an amazing diversity of river types and systems. Some rivers appeared largely natural, perhaps as natural as when explorers first laid eyes on them. Other rivers had become little more than concrete barge channels linking reservoirs or systems of locks.

This is the political reality faced by today's riverfront planner. Cities and industries located within river floodplains cannot be dislodged, nor should they be. Agencies and utilities that control the flow and use of water will be reluctant to cede their power, although they can be encouraged to take a broader view of river management that includes wildlife and recreation. As a result, riverfront planners may not be able to apply every principle described in this chapter to every project. In some cases, compromises may leave doors open for future river improvements.

For several generations, we abused and nearly destroyed our rivers. Now, slowly, we are learning to appreciate, restore, and live *with* them in the best possible sense.