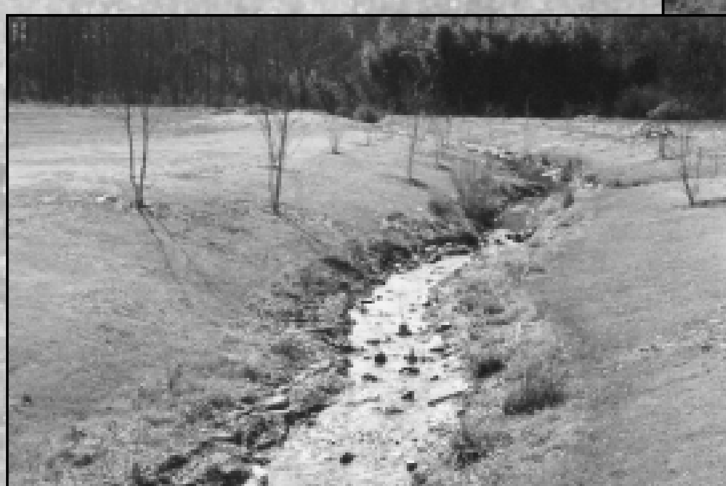
DAYLIGHTING

new life for buried streams



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DAYLIGHTING: NEW LIFE FOR BURIED STREAMS

by Richard Pinkham

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INTRODUCTION

What is Daylighting?

The modern era has not been kind to streams. As humankind has enlarged agricultural areas, built roads, and clustered into cities large and small, we have polluted streams, diverted them, straightened them, confined them in concrete channels, put them into pipes, filled their associated wetlands, and otherwise used and abused them, often beyond recognition.

These habits are beginning to change. Laws and programs in many nations are producing measurable improvements in water quality. Policy makers, engineers, and builders increasingly recognize the value of maintaining natural drainage patterns and stream channels in new development. And in some places, people are regrading and revegetating mangled stream channels to restore their functions and beauty.

"Daylighting" is perhaps the most radical expression of this change in attitudes and approaches to surface waters. The term describes projects that deliberately expose some or all of the flow of a previously covered river, creek, or stormwater drainage. Daylighting projects liberate waterways that were buried in culverts or pipes, covered by decks, or otherwise removed from view. Daylighting re-establishes a waterway in its old channel where feasible, or in a new channel threaded between the buildings, streets, parking lots, and playing fields now present on the land. Some daylighting projects recreate wetlands, ponds, or estuaries.

The phenomenon is relatively new. The daylighting of Strawberry Creek at a park in Berkeley, California took place in 1984. While other projects, such as in Napa, California and Urbana, Illinois re-exposed creeks in the 1970s, the Strawberry Creek project is widely considered the archetype of daylighting. It inspired many other projects. Its designer, Douglas Wolfe, now deceased, may be the source of the term, perhaps coining it to help describe that project to the community (Schemmerling 1998/99). In the past decade daylighting activity has steadily increased across the United States, and is even more widespread in parts of Europe. In just the city of Zürich, Switzerland, over nine miles of brooks and storm drains have been brought back to the surface since 1988.

All told, this report documents 18 projects that have daylighted over 14,000 feet of waterways in the continental United States. Another five completed projects in the United States are listed, but could not be researched and presented in this report due to time constraints. The report describes or lists another 23 projects that are in various stages of consideration. Additional completed and proposed projects probably exist; the author received many leads that could not be pursued and confirmed in time for publication here.

Removal of the culvert at Strawberry Creek in Berkeley, California in 1984. Courtesy of Wolfe Mason Associates.

Benefits of Daylighting

Why would anyone go to the trouble of digging up a culvert and recreating a surface waterway? As the case studies in this report show, daylighting projects can:

- relieve choke points and flooding problems caused by under-capacity culverts;
- increase hydraulic capacity over that provided by a culvert, by recreating a floodplain;
- reduce runoff velocities—thus helping prevent erosion—as a result of natural channel meandering and the roughness of the stream bottom and banks;
- replace deteriorating culverts with an open drainage system that can be more easily monitored and repaired;
- cost less, or only marginally more, than replacing a culvert;
- divert urban runoff from combined sewer systems before it mixes with sewage, reducing combined sewer overflows and burdens on treatment plants;
- improve water quality by exposing water to air, sunlight, vegetation, and soil, all of which help transform, bind up, or otherwise neutralize pollutants;
- recreate aquatic habitat and improve fish passage;
- recreate valuable riparian habitat and corridors for

wildlife movement;
- provide recreational amenities, such as a challenging new water hazard on a golf course, a place for children to play, or a streamside bench for people to relax upon;
- create or link urban greenways and paths for pedestrians and bicyclists;
- serve as an "outdoor laboratory" for local schools;
- beautify neighborhoods, perhaps serving as a focal point of a new park or neighborhood revitalization project;
- allow businesses to cut costs and increase profits while benefiting neighborhoods and the environment;
- increase property values;
- benefit nearby businesses by creating a new amenity that attracts people to the area;
- create jobs or job-training opportunities in building and maintaining the stream or park;
- build civic spirit and relationships as local residents, businesses, and governments come together to create the project;
- reconnect people to nature through the look, feel, and smell of open water and riparian vegetation, and through contact with aquatic and streamside creatures;
- give people a sense of "setting right something we messed up."

Daylighting Challenges

In recent decades, restorationists have renaturalized and revitalized many miles of badly degraded surface streams. Daylighting is in many ways a subset of the burgeoning field of stream restoration.[1] Whether a stream is already at the surface or is being uncovered, many of the same principles and procedures apply. However, daylighting can involve additional dimensions of complexity:

- Surface stream restorations may or may not require excavation and grading to correct channel alignments and geometries, but pulling up a culvert and creating a new channel where none exists usually does involve a significant amount of earthmoving. It may be necessary to haul away the spoils. These operations add expense.
- Finding the old channel—usually the best place to recreate the stream—can be difficult. It often involves historic research, examination of soils, and looking at the channel characteristics upstream and downstream.
- Existing surface waterways in need of restoration may already have at least a little buffer around them; daylighting projects are more likely to be squeezed for space. The less space, the less chance of creating a natural channel geometry and properly vegetated riparian corridor.
- Additional hydraulic issues may be involved. For instance, it may be necessary to build up hydraulic head to put a daylighted section of stream back into a pipe at its downstream end. Daylighting projects must be carefully engineered into the overall urban stormwater management system.
- Surface stream restorations are sometimes politically easier because the problems are apparent or easily pointed out. With buried waterways, people may be unaware that a culvert carrying a historic stream is under their feet, or that the stream's absence means degraded water quality, lost habitat, and so on.
- Since there's "nothing" there now, daylighting projects may require extra community education and outreach to help people visualize the potential. Moreover, creating an open channel often raises fears: kids will fall in and drown, vermin will breed, the channel will flood, adjacent property owners will face additional environmental regulations. Addressing these concerns is often a big task for daylighting proponents.

At the same time, daylighting projects can generate a level of excitement and dedication that comes from "bringing back" something that once seemed completely lost. In spite of the potential obstacles, interest in daylighting is rapidly increasing in the United States and many other countries.

Content and Purposes of This Report

This report seeks to:

- show the range of daylighting projects that have been completed or are under serious consideration;
- illustrate how some projects have been designed, facilitated, and funded; and
- identify some of the challenges encountered and lessons learned.

This review should be useful to individuals and organizations contemplating daylighting projects in their own cities and towns.

This is not a how-to manual. The case studies, findings, and recommendations presented here are meant to provide useful insights that can help those at the early stages of potential daylighting projects. Watershed and site conditions and local politics are different for every daylighting project. This report can only indicate some of the relevant considerations.

Daylighting involves many technical issues. To begin developing an understanding of important principles of hydrology,

[1]Mcdonald (1995) provides a brief history of the urban stream restoration movement; Riley (1998) provides a detailed review.

hydraulics, ecological process, and project design, the reader can refer to texts and videos in the fields of stream morphology, stream restoration generally, and urban stream restoration in particular. See “Selected Resources” at the back of this report for some recommendations; a glossary of technical terms is also provided. Of course, any report or book is a poor substitute for relevant training and experience. Rocky Mountain Institute strongly advises daylighting proponents to seek competent technical assistance, especially during the design and construction phases. The references section of this report includes contact information for many competent firms and consultants.

Between the introduction and the back matter, the reader will find the meat of this report, organized into the following chapters. “Findings” includes a table summarizing key information about most of the completed projects, describes the range of circumstances and motivations for daylighting projects, and lists many issues and questions that daylighting proponents should address. “Recommendations” briefly suggests some generic actions that will help ensure success in developing and carrying out projects. These two chapters attempt to distill much of the information that follows about actual projects. However, readers considering new projects are encouraged to carefully review the next several chapters. Reading about specific situations and experiences from actual projects will spark ideas and questions that the earlier summary material may not.

“Detailed Case Studies” presents descriptions of 13 completed projects. Each case study includes a very brief summary and a highlights table, followed by sections presenting background, actions taken, results, economics/funding, and challenges and lessons. Sources are cited at the end of each case study. “Additional Completed Projects” provides basic descriptions of five additional projects and lists five others, while “Proposed Projects” briefly describes or lists numerous projects under consideration at the time this report was prepared. “The International Experience” describes daylighting activities in Canada and Europe. “Conclusions” makes a few final comments.

This report had its genesis in late 1997, when the New England regional office (Region 1) of the U.S. Environmental Protection Agency contracted with Rocky Mountain Institute for assistance in developing demonstration daylighting projects in the Boston area. The EPA is nurturing such projects as part of the Clean Charles 2005 initiative, a watershed management program for the Charles River. Regional Administrator John DeVillars established the daylighting demonstration program in order to spark interst and encourage additional environmental restoration projects in the Boston region.

Rocky Mountain Institute facilitated a site-selection process with a committee of representatives of local, state, and federal agencies and nonprofits, and helped initiate design projects for a small number of selected sites. To inform site selection and design for the Boston projects, the EPA asked Rocky Mountain Institute to prepare a background paper presenting case studies of daylighting projects from across the United States.

Rocky Mountain Institute and the EPA recognized that the information gathered for that effort would be useful to others beyond Boston. This report is an expanded and revised version of the April 1998 background paper.

The author made a substantial effort to find and include as many completed and proposed daylighting projects in the United States as possible. Leads to projects abroad were investigated as well, to determine the objectives and level of daylighting activity in other lands. Research methods included:

- A literature review in early 1998. This turned up very few entries with the word “daylighting” or its variants in mainstream water resources, engineering, and landscape architecture databases, so abstracts found by searches for multiple variants of “urban stream restoration” were also examined.
- Inquiries in early 1998 and mid-1999 to a half-dozen internet mailing lists concerned with topics in hydrology, urban drainage, sewerage, and ecological restoration.
- Extensive phone networking with colleagues. Also, each case study source was asked what other projects he or she knew of.

Daylighting is doable. It is happening across the United States. It takes careful consideration, design, and implementation. Rocky Mountain Institute hopes that the ideas, information, and recommendations in this report will help others contemplating daylighting projects to ask good questions and take the right steps to develop sound projects and achieve their desired objectives.

Findings

The case studies in this report offer many lessons to prospective daylighters. They show that:

- Daylighting projects have been completed in a wide variety of situations.
- Many motivations may exist to daylight a waterway, and the chosen objectives will determine much about a project.
- The challenges can be numerous, including technical, institutional, and social issues. They must be met carefully, but with a can-do attitude.
- Daylighting projects can be expensive, but many have been completed at relatively low cost. Good design, donations of services and materials, and volunteer labor can keep costs low if projects are expertly facilitated. Potential partners and funding sources vary greatly depending on location and type of project.
- Certain implementation strategies are common to most successful projects, particularly the use of technical consultants experienced in stream restoration, and an emphasis on public education and participation.

The following table summarizes key information for each of the completed projects described in this report. The remainder of the chapter discusses each of the first four topics noted above in turn. The “Recommendations” chapter addresses the fifth.

Completed Projects Summary

Location/ *Waterway*	**Watershed**[1]	**Flow rates**[2]	**Length daylighted**[3]	**Year daylighted**	**Project costs**[4]	**Primary objectives**	**Notable features**
Detailed Case Studies:							
Arcata, CA *Jolly Giant Creek*	1.7 square miles; rural and urban	5 cfs average annual flow 128 cfs average annual peak flow 250 cfs 100-year peak flow	160 feet of new channel day-lighted, plus 570 feet of surface chan-nel restored	1991, 1995, and 1997	$120,000, plus considerable donated mater-ials, in-kind services, and volunteer labor	Creation of "outdoor classroom"; stream restoration; park development	Linking of multiple daylighting and restoration projects
Berkeley, CA *Strawberry Creek*	2.0 square miles; urban and university campus	2-6 cfs average seasonal low flow 800-1000 cfs 100-year peak flow	200 feet of new channel	1984	~$50,000 for daylighting (of $580,000 total park cost)	Create park and an urban creek amenity	Early, model daylighting project; completed with limited budget
Berkeley, CA *Codornices Creek*	1.5 square miles; urban	2-8 cfs average seasonal low flow 800-1000 cfs 100-year peak flow	400 feet of new channel	1994	$33,000 plus in-kind donations and considerable volunteer labor	Restore creek for salmonid and human use; motivate upstream and downstream restoration	Successful low-budget project
Berkeley, CA *Blackberry Creek*	0.3 square miles; urban	15 cfs 1.5-year peak flow (bankfull flow) 220 cfs 100-year peak flow	250 feet of new channel	1995	$144,000 plus donations and additional park-related costs	Create educational site; improve community park; relieve flooding problems	Curricular use of the new creek
DeKalb County, GA *Shoal Creek Tributary*	~0.15 square miles; medium density residential	1.5 cfs seasonal low flow 225 cfs 100-year peak (very rough estimate)	200 feet of culvert removed	1994	$14,500 plus unallocated staff time	Remove hazardous collapsed culvert; restore stream	Successful low-budget project; less costly than culvert replacement

Completed Projects Summary

Location/ *Waterway*	**Watershed**[1]	**Flow rates**[2]	**Length daylighted**[3]	**Year daylighted**	**Project costs**[4]	**Primary objectives**	**Notable features**
Barrington, IL *Kilgoblin Wetland*	1.2 square miles; urban and suburban	Unavailable; has perennial flow	300 feet of culvert removed	1995	$55,000	Improve downstream water quality	Daylighting storm sewers to create a wetland
Urbana, IL *Embarass Creek*	<1 square mile; suburban	Small stream; ephemeral in dry summers	~4,000 feet of new channel	Early 1970s	Unavailable	Create stream amenity for new park	Deactivated farm field drainage tiles to surface the creek
Rowley, MA *West Ox Pasture Brook*	0.35 square miles; low-density suburban	Unavailable; small perennial stream	85 feet of culvert removed	1989	$1,200, plus donated materials and time	Stream restoration and riparian habitat creation	Backyard daylighting; cost savings for a homeowner
Kalamazoo, MI *Arcadia Creek*	7.4 square miles; urban	<5 cfs seasonal low flow 1,015 cfs 100-year peak flow	1,550 feet of new channel (5 city blocks)	1995	$7.5 million	Flood relief; creation of downtown amenity	Daylighting in a central business district; use of a confined channel; part of a major redevelopment project
St. Paul, MN *Phalen Creek*	2.4 square miles; high-density residential and industrial	~2 cfs (continual controlled flow)	~2,100 feet of surface channel and ponds created	1987	Unavailable	Create stream amenity for park	Partial-flow daylighting
Roscoe, NY *Darbee Brook*	~1.5 square miles; agricultural and residential	~0.5 cfs seasonal low flow 30-40 cfs annual peak flow	330 feet of culvert removed 160 feet of new channel	1996	$9,000, plus undetermined earthmoving costs and donated services, materials, and labor	Replace deteriorating culvert; improve school playing fields; allow fish passage	Trade-offs to achieve a win-win project for school, state regulators, and fishing groups; less costly than culvert replacement
Port Angeles, WA *Valley Creek*	4.2 square miles; forested and urban	15 cfs average base flow 120 cfs 2-year peak flow 545 cfs 100-year peak flow	490 feet of culvert removed	1997	$1 million, including park amenities; includes value of considerable donated time and materials	Reduce costs for an important local business, retain jobs, create habitat and recreational amenity	Restored a coastal estuary; high return on investment for a business

Completed Projects Summary

Location/ *Waterway*	**Watershed[1]**	**Flow rates[2]**	**Length daylighted[3]**	**Year daylighted**	**Project costs[4]**	**Primary objectives**	**Notable features**
Maple Valley, WA *Jenkins Creek*	*Phase 1:* 1.6 square miles; rural and mid-density suburban *Phase 2:* 0.6 square miles; rural and low-density suburban	*Phase 1:* 3.3 cfs mean annual flow 39 cfs average annual peak flow 55 cfs 100-year peak flow *Phase 2:* 1.7 cfs mean annual flow 6.8 cfs average annual peak flow 24 cfs 100-year peak flow Both have low summer flows—ephemeral some years	*Phase 1:* 800 feet of new channel *Phase 2:* 700 feet of new channel	*Phase 1:* 1994 *Phase 2:* 1998	*Phase 1:* $645,000, including purchase of an easement *Phase 2:* $400,000	Improve upstream salmonid passage and spawning and rearing habitat	Daylighting on golf course and daylighting of a parking lot; design for fish passage and habitat
Additional Completed Projects:							
El Cerrito, CA *Baxter Creek*	0.25 square miles; residential	Unavailable; small perennial stream	250 feet of new channel	1996	Unavailable	Storm drain renovation; create open stream in neighborhood park	Repair of a poorly engineered project; daylighting on a steep slope
Barrington, IL *Flint Creek*	~4 square miles; semi-rural	Unavailable; average flows 6' wide by 1' deep, low to moderate velocities	250 feet of culvert removed	1999	$60,000	Stream bank restoration; reduce municipal maintenance costs	Special use zoning permit used to require daylighting on private property
Hutchinson, KS *Cow Creek*	1.5 square miles, plus 6.8 sq. miles divertible to a levy in storm events	<30 cfs design flow >700 cfs 100-year peak flow	800 feet of new channel	1997	$1.25 million for stream and new park; $4 million total	Speed a large bridge replacement project; create a downtown park	Use of confined channel through an urban park

Completed Projects Summary

Location/ *Waterway*	**Watershed**[1]	**Flow rates**[2]	**Length daylighted**[3]	**Year daylighted**	**Project costs**[4]	**Primary objectives**	**Notable features**
McLean, VA *Pimmit Run tributary*	0.03 square miles (17 acres); forested	Ephemeral creek <10 gpm (0.02 cfs) seasonal low flow >7 cfs flow in large storms	50-100 feet (exact length unavailable)	mid-1990s	Unavailable	Storm runoff control; create amenity	Residential-scale "micro-daylighting"; partial-flow daylighting
Omak, WA *Omak Creek*	140 square miles; range land and commercial forestry	1 cfs seasonal low flow 30 cfs bankfull flow 900 cfs 100-year peak flow	1,500 feet of culvert removed	1998	$788,000, including special arch culvert logging deck	Improve fish passage and stream function; repair flood damage and reopen lumber mill	Fast-track design and permitting; adaptive construc-tion management; incremental intro-duction of flows

[1]Watershed size is an important measure for stream restoration efforts. There is a strong correlation between the size of a contributing watershed and the geometry of the bankfull channel for streams within a given region or area. Comparisons between streams in different parts of the country on the basis of watershed size should be made cautiously.

[2]Flow rates are another key variable for design and a basic comparative indicator of the size of streams. However, note that consistent measures of flow were not available for all projects.

[3]For some projects, the available measure was the length of culvert removed. For others, the length of the new channel was the available figure. Generally, a new channel measurement will be longer than a removed culvert measurement because of the sinuosity of a restored channel, but this is not always the case. Some new channel measurements here may have been done on a straight line basis, without including the channel's sinuosity. Also, in rare conditions a daylighted channel may "cut corners" off the path taken by the culvert it replaces.

[4]Cost comparisons should be made carefully because the various projects used different levels of in-kind contributions, donations, and volunteer labor. Some of these additional factors are indicated. The figures do not include purchases of land or easements unless otherwise indicated. These figures are not inflated to a consistent economic year. This would be false precision given the just-mentioned variations in what the figures include.

Situations

Daylighting projects have been carried out in all kinds of situations: from small ephemeral creeks to true rivers, in watersheds tiny and large, on rural farmland and in the central business districts of cities. The daylighted waterways detailed in this report range in size from an unnamed tributary of Pimmit Run in McLean, Virginia, which drains a watershed of 0.03 square miles (17 acres) and sometimes dries up in summer, to Omak Creek, which drains a watershed of 140 square miles in the state of Washington and flows at 900 cubic feet per second in a once-in-100-years flood event.

The previous land uses at daylighting sites have been many. Waterways have been liberated on:

- vacant land;
- former railyards;
- school properties;
- open space and playing fields at parks;
- farm fields;
- golf courses;
- parking lots;
- extended "bridges" and parking decks;
- brownfield sites;
- former and active lumber mills;
- residential backyards;
- commercial properties in downtowns.

Daylighting projects usually liberate a stream from a culvert; for example, a metal or concrete pipe or arch culvert, or a concrete box culvert. But culverting is not the only way people have "disappeared" streams. Hutchinson, Kansas, and Providence, Rhode Island once covered over portions of local waterways with wide bridges and parking decks. In Urbana, Illinois (and no doubt in many other locations in America's farmlands), a stream disappeared from the surface when farmers laced the fields around it with drainage tiles—pipes that provide a new path of least resistance to lower the water table and dry up an area.

Most daylighting projects restore the full flow of a waterway to the open air. This is not always the case, however. Projects in St. Paul, Minnesota; Olympia, Washington; and McLean, Virginia daylight some or all of a stream's base flow, but for various reasons keep large storm flows in existing or new culverts.

Most commonly, daylighting projects restore brooks, streams, and rivers. But some projects create ponds or wetlands, often in combination with flowing waterways. One project recreated an estuary in Port Angeles, Washington. And while this report focuses on daylighting of perennial or occasionally ephemeral waterways, stormwater culverts that run with water only during wet weather can also be daylighted. For instance, the city of Portland, Oregon recently replaced storm culverts with vegetated drainage swales around playing fields in Custer Park and on the grounds of the Parkrose Middle School (Liptan 1999).

Finally, daylighting projects vary greatly in the degree to which they renaturalize a waterway. Most daylighting projects restore an earthen bottom to the waterway, and rely mainly on vegetation and woody materials to stabilize channel and stream bank soils. They use rocks as naturally as possible, and other hard reinforcements very sparingly. Other projects have confined newly reopened streams more rigidly. In Providence, Rhode Island, the daylighted river banks are reinforced with granite blocks, not vegetation. Projects in Kalamazoo, Michigan, and Hutchinson, Kansas hold their creeks within concrete-walled and concrete-bottomed channels. All of these are projects in downtown locations with severely constrained corridors.[1] While they may not provide some of the values of naturalized channels, they represent important improvements over previous conditions.

Several points should be made here. Clearly, not every hidden waterway can or should be daylighted. Among the "doable" projects, not every one can be highly naturalized. That said, good design can create more opportunities for naturalization than might commonly be thought. As Wendi Goldsmith of The Bioengineering Group, Inc. says of restoration projects generally, "There are projects out there, including ones that cost a lot of money, where no one has really plumbed the depths of what is possible" (Goldsmith 1999). Daylighting proponents should seek expert assistance to determine what is feasible given the available corridor and funding.

It is also worth noting that the most important "daylighting situation" is to prevent streams from being buried in the first place. A number of communities have stream protection ordinances that discourage culverting of open waterways. Passage of a culverting moratorium to allow time for development of such an ordinance in Berkeley, California prevented culverting of a stretch of Strawberry Creek just downstream from the 1984 Strawberry Creek daylighting project (Schemmerling 1998/99).

As the case studies show, daylighting opportunities can come up in many ways. Unfortunately, most urban dwellers have no idea that streams run underneath their feet. When project possibilities arise, they may be surprised and unprepared to consider the value or viability of the project. One way communities can raise public consciousness, encourage dialogue, and move toward long-term plans for urban waterway restoration is to develop "disappeared stream maps" that show the paths of buried streams and the locations of remnant open sec-

[1]Some might question whether projects like these, which do not renaturalize a waterway's channel and banks, qualify as daylighting projects. This report is inclusive and takes exposure—the most obvious sense of the word daylighting—as the root of its definition of daylighting: "projects that deliberately expose some or all of the flow of a previously covered river, creek, or stormwater drainage."

tions. The Oakland Museum of California has prepared such a map for communities on the east side of the San Francisco Bay. Portland Metro, a regional planning agency for Portland, Oregon and surrounding communities, has done the same. These maps assist in a wide variety of watershed education, protection, and restoration efforts. As Chris Richard of the Oakland Museum says, "local agencies are finding out they are great tools for opening the eyes of the citizenry to the fact they live in watersheds" (Richard 1999).

Daylighting is often a good, low-cost solution for collapsed culverts. This 1994 project near Atlanta, Georgia replaced a deteriorating metal pipe with an open, naturalized channel. Courtesy of DeKalb County Parks Department.

Motivations and Objectives

There are many potential reasons to daylight a culverted stream or storm drain. Often the benefits are interrelated, but several general types of motivations exist.

The functional values of opened waterways are important benefits. Exposure to sunlight, air, and soil allows growth of aquatic and riparian vegetation that can *improve water quality* by taking up organic and inorganic pollutants. The California Urban Creeks Council's Carole Schemmerling says that a frequent objective of Bay Area daylighting projects is to benefit bay shore estuary marshes, which should be dedicated nursery habitat rather than de facto treatment zones. Daylighted, open waterways often have *greater hydraulic capacity* than culverts. They can slow and infiltrate runoff, benefiting downstream residents by preventing flooding or erosion. Or they can speed its passage in comparison to culverts that may have choked flows and flooded upstream areas. Daylighting is also sometimes a way to *remove water from combined sewer systems*, as in the proposed Ravenna Creek project. This can free up wastewater system capacity—an objective achieved by the extensive daylighting program in Zürich, Switzerland.

Daylighting projects often happen because they *save money*. For instance, when a culvert collapses, it may be less expensive to replace it with an open waterway than to reinstall a new culvert, as demonstrated by projects in DeKalb County, Georgia and Roscoe, New York. A project in Port Angeles, Washington cut operational costs substantially for a local business. Open waterways are also *easier to monitor* for damage than are buried culverts.

Creating habitat is another motivation for daylighting projects. Projects in the state of Washington included restoration of salmon passage and habitat as primary objectives. Other projects have noted creation of wildlife corridors in the urban landscape as a goal. The *educational value* of bringing aquatic and riparian ecosystems closer to students, whether grade school or university level, is an important related benefit. Likewise, daylighting can inform adults about the value of natural systems.

Many projects include *new recreational and leisure opportunities* as key benefits. These may range from a challenging new water hazard on a private golf course to places for city kids to splash. The aesthetic and amenity value of water is quite high. At the local level, a creek can be a valuable attraction, even a focal point, in a public park. At a regional level, restored creeks can define a network of urban greenways and paths. Establishing such networks creates functional and habitat values as well. But it's important to not underestimate the intangible benefits, which often increase the more urban the site. People familiar with the Strawberry Creek project note that its local impact is out of proportion to its small size—the opportunity to hear the soothing sound of running water is a huge draw for people in the highly built-up environs.

Daylighting projects can *revitalize surrounding neighborhoods* by providing new amenities. The investment in the stream can motivate investments in nearby properties and businesses, which may see an increase in walk-ins as people come to enjoy the re-opened stream. Some daylighting projects—for instance Strawberry Creek in Berkeley, California and Arcadia Creek in Kalamazoo, Michigan—have *increased local property values*. As Ann Riley of the Waterways Restoration Institute says, "Stream restoration is neighborhood restoration" ("Urban Stream Restoration" 1998). Planning and implementing daylighting projects can bring communities, businesses, and governments together. Building and maintaining them can provide *job-training opportunities*, as shown by programs on daylighting sites in Berkeley.

Reconnecting people to nature is a frequent theme of daylighting proponents. In Vancouver, British Columbia, planner Alan Duncan says surveys show people are interested in daylighting and creek restoration because they see restoring salmon as an important regional goal. They want to take their kids to streams right in the city to see salmon spawning. Being able to do this, they feel, is part of living in and being connected to the Pacific Coast rainforest ecosystem (Duncan 1998). "Setting right something we messed up" is another similar theme. This hope is a strong underpinning of continued public support for the proposed but beleaguered Ravenna Creek project in Seattle.

Whatever the motivations for daylighting, it is important to clearly define the specific objectives of each project. These, along with the particular physical situation, will determine the configuration of the project. Hydraulic performance and bank stability are always the bottom line—no one can afford to have a project blow out. But is the project mainly being done to re-establish an attractive stream channel for this area of the city? Aesthetics will then be emphasized. What about supporting fish? Then designers must attend carefully to maintaining proper flows, velocities, and temperatures. Species will matter; for instance, migratory salmon require certain flows at specific times, while resident species may have different requirements.

Of course, desires and physical possibilities may sometimes not match. Proponents must be realistic about what is possible. The more urban the site, the more constrained will be the design opportunities. This may have to translate into lowered expectations. The more general the objectives, the higher the chances of measurable success (Johnson 1998). For instance, it is easier to meet a goal of improving water quality than to establish fish habitat, and easier to host warmwater fish than to reintroduce trout or salmon.

Challenges

Objectives in mind, what next? Restoration proponents must be prepared for any number of challenges. Daylighting is never straightforward technically, institutionally, or socially. Persistence and a can-do attitude are essential to getting a project implemented. The list below includes just a few of the obstacles that may come up, drawn from the case studies in this report and discussions with practitioners of urban stream restoration, to provide an initial "heads-up" list for those considering daylighting projects.

Social

Early challenges may be social and psychological in nature. These issues can persist throughout project implementation and follow-up. Landscape architect Gary Mason says the biggest problem can be summed up in one word: fear. Water in pipes doesn't seem to scare people; water in open channels often does. Contributing to fear, but sometimes separate from it, is unfamiliarity.

- Local public works departments may worry about hydraulic performance, or object to real or imagined maintenance needs.
- Neighbors may believe the new channel could be a hazard to their children.
- Nearby residents and businesses may express concerns that the project will attract homeless people or drug dealers, become a trash-filled eyesore, support rats or mosquitoes, or otherwise impact the quality of the neighborhood.
- Expectations in the community may conflict. For instance, affected and adjacent property owners may have different desires for access and security than other potential users.
- Construction may be locally disruptive.
- Users and viewers of the new creek may expect instant, exotic landscaping. The values of native vegetation are not familiar to many, nor are the successional stages that newly established vegetation must go through. Early years will present a scruffy look that some may object to.

Institutional

Daylighting projects can raise various issues relating to ownership, maintenance, and liability. They may also present difficulties in coordinating multiple agencies and in permitting.

- Who will own the new waterway is sometimes an issue. Where private property is involved, should a public agency buy the affected property outright, or secure a right-of-way? What will the property owner accept?
- Who will be responsible for maintaining the project? A buried pipe is typically the responsibility of the relevant public works agency. When something is opened, responsibility may revert to the adjoining owners, as would be the case for an open stream.
- An open channel may raise liability issues. Increased exposure to damage claims for water problems or to personal injury claims is possible. This may result in increased insurance premiums for owners of the site and those adjacent to it.
- Creating a surface waterway may also expose owners of the site or adjacent properties to additional environmental regulations and planning procedures (wetlands regulations, setback requirements, etc.), reducing their ability to develop their properties further. This has been a big issue for the proposed Ravenna Creek project.
- It can be challenging to work with multiple private organizations and public agencies that may not understand daylighting, and may not be responsive to public desires.
- These projects need leaders, including governmental ones. Daylighting is often driven by a local citizens'

group, but frequently sponsorship by a public agency that will take on the project as its own is essential. Establishing a lead agency is sometimes difficult. Should it be a public property owner like the city parks department or a school district? The sanitation authority? A regional planning commission?

- All relevant agencies need to be on board. Reluctance from key local agencies can harm the prospects for securing grants and permits.
- Multiple permits will probably be necessary, perhaps from all levels of government: federal, state, and local. The U.S. Army Corps of Engineers regulates almost any alteration to surface waters. Most states have one or more environmental programs that must examine the project. Local planning, construction, or hydraulic modification permits may be required as well.

Technical

Daylighting projects can present a number of technical challenges. The more urban the project's location, the more issues will come up. And the more constrained the potential project corridor, the more difficult it will be to solve problems. This should not discourage project proponents unduly. The case studies demonstrate that daylighting projects are feasible, even in some highly urban situations. But one must have open eyes and realistic expectations. Alan Johnson, a fisheries biologist experienced in urban stream restoration, says it requires a different paradigm from restoration work in rural or natural areas. One can't expect to duplicate pre-development conditions, and techniques appropriate in the woods may not be appropriate in the city (Johnson 1998). Compromises will have to be made.

It is important to try to anticipate all the issues that could potentially arise for a particular project. Below are some of the technical questions that may come up.[2] Daylighting proponents should expect to call on expert technical assistance to identify and solve potential problems. Also note that a solution to one challenge may conflict with solutions for another.

Site and Situation

- What's underneath the site? Will buried utilities have to be avoided or moved? Might the project compromise access to utilities? Will the utilities compromise the project?
- What kinds of soils are there? Are soils contaminated from previous land uses or dumping?
- Where is the water table? Will the channel lose or gain water? Is either a problem? Is the ground water clean or contaminated? Is impervious lining of the channel necessary?
- Does the project require usurping other valuable land uses, such as parking spaces or recreation fields? Can these uses be moved or replaced elsewhere?
- Can the loss of existing desirable features of the site—mature trees, for instance—be minimized?
- What safety features are necessary? Fences, railings, shallow slopes? Grates over culvert outfalls and inlets?
- Will streamside paths be part of the project? What route should they take? Are picnic areas, bridges, or other features desired, and where should they be placed?
- Is disabled access required or desired, and how can it be provided?

Inputs from the Watershed

- Will sedimentation be a problem? Can and should some sediments be trapped and periodically removed? Can the channel be designed to flush sediments downstream, and is that OK? All streams move sediment. The design objective is usually to achieve equilibrium—the condition in which the amount of sediment leaving the stream reach in question equals the amount entering it.
- What other pollutants will the new stream have to handle? Urban streams typically receive considerable amounts of nutrients and many kinds of organic and inorganic pollutants in stormwater. Are biofiltration strategies upslope of the channel necessary to produce suitable water quality in the channel for supporting fish or other objectives? Can riparian vegetation remove enough of the pollutants?
- Will the new stream carry or collect trash? What strategies can minimize this problem?

Channel Design

- Can the original meanders be re-established? Can they be found or approximated from aerial photos, measures of the stream sinuosity upstream or down, or by examining soil types along the likely path of the old stream?
- What should the channel geometry be? Relationships between gradient and discharge (flow volume per unit time) must be carefully examined to determine the appropriate channel cross sections and sinuosity. Often these parameters are substantially different for current watershed conditions than before development. How

[2] Most daylighting projects produce new stream channels, so this list focuses on the issues raised in creating new channels. Daylighting projects may also be designed to produce ponds, wetlands, or estuaries. Such projects may raise other issues not noted here.

should this affect placement of the channel? In short, what is the "urban equilibrium" condition given current or projected development?

- What fixed points will constrain channel design? For instance, culverts or bridges for roads and driveways may have to be accepted.
- What additional demands will be placed on design of the channel? Fish habitat requirements are a common consideration.
- Will in-channel structures be used to adjust depth, direction, or velocity? It's necessary to work with the flow rather than against it. As Gary Mason says, "You have to know what the water wants to do. If you're not totally respectful of the water, it'll come back and bite you" (Mason 1998/99).
- How will any structures be anchored in the streambed?

Stream Bank and Floodplain

- How much of a floodplain is needed? What is feasible given surrounding land uses?
- What techniques will be used to stabilize the stream banks? Can bioengineering measures be appropriately anchored in the banks?
- Which native species will be best for revegetation? Can cuttings or saplings harvested from other sites be used to cut costs?
- What kinds of plantings are compatible with the site circumstances? For instance, narrow corridors may not allow for tree species that form a large diameter canopy at maturity.

Project Logistics

- What is the appropriate season for construction and revegetation? How can the project logistics be arranged so that all essential operations are carried out within the available window of opportunity (including time to handle surprises)?
- Will temporary diversion of water flows be necessary? How will it be accomplished?
- How much excavation is required? Will demolition of parking lots or other structures be necessary? Can fill and spoils be used onsite to reduce hauling costs?
- How long will the restoration take to stabilize? What follow-up work will be necessary as the site matures? Establishing the new channel hydraulics happens quickly, but full ecological function requires time for slopes to stabilize and a canopy to develop.
- What routine maintenance tasks must be handled?

Costs and Funding

Daylighting projects involve many potentially pricey activities and materials: technical studies and design work, acquisition of properties or easements, excavation and rough grading, hauling of fill, materials for the streambed and in-channel structures, landscaping materials, hand labor for final grading and revegetation, and more. According to Gary Mason, designer and coordinator of several daylighting projects, $1,000 per linear foot is a good rule of thumb for the full costs of these projects at market rates.

Actual costs for most projects often come out less. Lack of full funding mothers such inventions as use of volunteer labor, in-kind contributions, and donations of services and materials. The Codornices Creek project in Berkeley, California, among others, shows daylighting can be done on a shoestring. However, it takes lots of public-spirited people and extremely competent coordination to pull this off.

It's worthwhile to brainstorm potential sources of support: a local heavy equipment firm owned by an angler, a design firm that might reduce its fees to work on a novel project, nurseries that might give plant stock in return for publicity, highway or construction projects that could provide or accept fill, donate woody plant cuttings, or salvage root wads bound for a fire or dump. Potential volunteer or low-cost labor sources are also many: local conservation corps, schools, community organizations, and project neighbors. A project in Roscoe, New York even made use of prison inmate work crews.

Daylighting proponents can secure cash funding in a number of ways. Case studies and discussions with experienced practitioners indicate that potential funding sources include:

- City parks budgets.
- School districts (for projects on school property).
- Redevelopment authorities, special districts, or economic development projects. A large project in Kalamazoo, Michigan, implemented daylighting and other downtown revitalization through an authority funded by bonds based on tax-increment financing.
- Public works budgets. Daylighting may be rolled into larger projects to improve stormwater management, roads, sewers, or other public services. If daylighting displaces some other action, like replacing an old storm drain, funds that would have gone to the conventional action may be applied instead to daylighting.
- Stormwater utilities funded by specific fees for water management. For example, the Jenkins Creek project outside of Seattle was funded by revenues from a "surface water charge" collected by the King County Surface Water Management Division.
- Other infrastructure agencies. State highway departments may support projects that involve improvements

to bridges, reduce road flooding, or provide other transportation benefits. Several projects have tapped funds established by the federal Intermodal Surface Transportation Efficiency Act.

- Gifts from individuals. These can be secured in many ways. In Port Angeles, Washington, restorationists are paying for amenities around a daylighting site by asking citizens to sponsor benches, lamp posts, and even individual bricks in a path. People can have names put on the features they "buy."
- Local businesses. They may believe the project will bring people to the area, or may simply support it as good neighbors.
- Businesses may also be property owners on daylighting sites. They may find daylighting is cheaper than replacing a deteriorating culvert, or governments can require them to daylight and restore a stream as a condition of approval for rezoning, redevelopment, or other actions that trigger government review.
- Local or national fishing and other sporting organizations, equipment manufacturers, and magazines.
- Foundations and philanthropists, ranging from local sources to large national organizations like the National Fish and Wildlife Foundation. Often a funder will be interested in a particular angle of a project, such as fishery restoration or urban park creation.
- State environmental programs. California's Department of Water Resources has an Urban Stream Restoration Program. Such a focused program is no doubt rare, but other states may have programs on habitat, water quality, riverways, wetlands, fish and game, or other concerns that could include daylighting projects within their scope. Besides programs paid from a state's general fund, many states have funds for land acquisition or special projects from dedicated bond issues, vanity license plate fees, and lotteries.
- Clean Water Act funds; e.g., Section 319 grants.
- The U.S. Fish and Wildlife Service Challenge Cost-Share program and Partners for Wildlife program.
- Community Development Block Grants.
- Funds from the Federal Emergency Management Agency for flood relief and for flood prevention measures such as removal of choke points at undersized culverts.
- Many other sources. Daylighting proponents should think of every benefit a project offers, and then brainstorm lists of every possible agency, foundation, business, and community group that might have an interest in supporting each benefit.

RECOMMENDATIONS

Here is some advice on project implementation condensed from the case studies and discussions with people experienced with daylighting projects.

Start It Up

- Start small. Small projects give a community a feel for the value created and can generate support for doing more later.
- Begin to pursue funding early on. Try to leverage small grants into more funding.
- Do a thorough historical analysis of the site. What's underneath will affect project costs from excavation effort to soil amendments.

Reach Out

- Get the community involved right away. Make sure residents understand what is involved, and be sure this is something they want. Outreach is very important. How it is done can determine the community reaction. Make the process very inclusive. Most of the neighbors can, and must, buy in. Design and construction get a lot of emphasis, but working with the community is a big part of the total effort involved.The Urban Creek Council's Carole Schemmerling advises, "Get as much information out there as possible in whatever ways you can do it. Tell people: here are the benefits, here are problems people perceive might occur, and here is the reality of other, completed projects. They have to have the pros and cons, and every situation is different."
- Work hard to develop a constituency for the project. Fostering supportive neighbors and users pays off politically and economically (in the form of volunteer labor and site stewards).
- Get schools involved. Schemmerling again: "Kids will be in the creek right away anyway, and involving them creates an incentive to do it right."Get lots of press coverage. Organize tours, host receptions, and so on. Get the word out and solicit ideas and concerns. Handle the concerns early.
- Enlist community help in planning and maintaining the project. Hold a community design "charrette"—an intensive workshop to develop objectives and design ideas. Organize planting and clean-up days. To stem vandalism, seek to involve kids and youths: they are less likely to pull the new willows for sword fights if they planted them.

Collaborate

- Work diligently with affected landowners. Note their concerns and adjust designs to allay fears and produce value for them.
- Link the project into a larger-area development scheme or master plan. This is especially helpful in more urban areas, where the expense and politics of right-of-way acquisition necessitate broad support. Also, a larger project with multiple benefits may be easier to fund than a more narrowly-focused one.
- Take a watershed approach. Look upstream and downstream for potential allies, like people affected by flooding or erosion problems that daylighting may help address. Don't take no for an answer. Work with local agencies and politicians to help them recognize the value being created.
- Obtain the enthusiastic support of one or more influential politicians. This can make everything else come much more easily.

Seek Assistance

- Design the channel carefully, with competent technical help. The last thing daylighting proponents need is to have a project blow out, so it's imperative to get the hydraulics right.
- Look for solutions that reduce technical or construction complexities. For example, find ways to do appropriate parts of the restoration work using volunteers and the local conservation corps. This cuts costs, creates jobs, and connects local people to the local environment.
- Use technical and construction contractors who understand stream restoration well. Engineers who haven't done this sort of work may not fully appreciate the differences between the hydraulics of rigid channels and living streams, or the biologic and aesthetic issues. Earthmoving contractors must have a feel for what the designers want, and an ability to make field adjustments as required by the supervising engineer or designer.
- Pull together a competent team. It takes many types of expertise to pull off projects like these.
- Find a qualified generalist to pull it all together—someone with broad enough training or experience to understand the approaches, language, and data of all the various experts participating in the project, and with the requisite intuition to envision the desired outcome and steer the project toward it. Plan the logistics of construction carefully, especially if the seasonal

window for earthmoving and planting is narrow due to wet weather or other conditions. Have everyone lined up to go.

Follow-up

- Prepare for strong follow-up. Most daylighting projects need continued planting and maintenance in their early years. It may be necessary to try many different plantings to see which work best with the site's soils, hydrology, etc. Plant and replant what can survive until a vegetative canopy gets established.
- Develop a budget for the first two to three years of follow-up. Ideally this should be incorporated into the overall project budget and funded before construction begins. This budget should include monitoring and evaluation of channel and bank stability and revegetation dynamics; training and supervision of volunteers and any paid maintenance personnel; tools; and an allowance for additional plants and other materials.
- Educate neighbors and users about the beauty and value of native species. People often expect more conventional landscaping.
- Educate them as well about the successional stages of the restoration. Landscape architect Gary Mason notes that a project will go from infancy to adolescence to maturity, with a different look and feel at each stage. The project will look like a mess as it's being done, then in the first years, shrubs and weeds will predominate. These are necessary for stabilizing the soil, and are part of the evolution toward a vegetative canopy, but they may prevent people from seeing or accessing the creek for a time.
- Document everything! Says Carole Schemmerling, "There is nothing so powerful as pictures of the culvert coming out, of the first fish, the first crayfish, the first bird's nest along the new stream."
- Take plenty of time. Be in it for the long haul. Successful daylighting projects are an incremental learning process.

Make the most of milestone events! Here, proponents of the Valley Creek estuary daylighting project in Port Angeles, Washington hold a publicity event as they receive significant funds for the project. Courtesy of Port of Port Angeles.

Detailed Case Studies

The projects detailed here present daylighting under diverse geographic, hydrologic, institutional, technical, and economic conditions. Readers hoping to gain ideas or perspectives to apply to new projects can scan the summary paragraphs and summary boxes[1] for situations similar to their own. However, even very different situations may provide relevant insights. For instance, reading about projects with very different watershed or flow conditions might still spark ideas about potential funding sources. A close review of these case studies will reveal the many intricacies of implementing daylighting projects, as well as varied situations, objectives, and benefits. The projects are presented alphabetically by state and municipality, and chronologically by project date where more than one project has taken place in a municipality.

Arcata, California

Jolly Giant Creek

Approximately 160 feet of Jolly Giant Creek in central Arcata were daylighted in the early and mid-1990s, and about 340 feet of open but highly urbanized channel restored. The project began as an environmental education project at the adjacent high school, was taken up by a regional development and advocacy agency, and was eventually funded by the state. The stream corridor, once neglected land, is now a major pedestrian thoroughfare and passive recreation area.

Watershed:	1.7 square miles; rural and urban
Flow rates:	5 cfs average annual flow 128 cfs average annual peak flow 250 cfs 100-year peak flow
Length daylighted:	160 feet of new channel daylighted, plus 570 feet of surface channel restored
Year daylighted:	1991, 1995, and 1997
Project costs:	$120,000, plus considerable donated materials, in-kind services, and volunteer labor
Primary objectives:	Creation of "outdoor classroom;" stream restoration; park development
Notable features:	Linking of multiple daylighting and restoration projects

Background

Roughly 15,000 people living on the northern California coast just north of Eureka call Arcata home. The city hosts Humboldt State University, and once had a strong logging industry. It is an environmentally progressive community with a majority Green Party city council, a community forest logged sustainably for city revenue, and one of the country's first constructed wetland tertiary sewage-treatment facilities.

Jolly Giant Creek rises in the community forest and flows six miles to the Pacific, passing through the university campus and Arcata's downtown on its way. Much of the creek from the campus to downtown was culverted and channelized as the area developed, then neglected after the lumber mills located there shut down in the 1960s and 1970s.

Just downstream of the university lies Arcata High School. In 1990, biology teacher Lewis Armin-Hoiland proposed daylighting a section of the creek that crossed underneath a corner of the school district property. The area had previously been used as a dump. In 1990 it was a tangle of briars and berry vines. Armin-Hoiland's objective was to create an outdoor ecology laboratory for the high school. Lacking the information needed to obtain a Nationwide 26 permit from the U.S. Army Corps of Engineers and a California Department of Fish and Game "1603" stream-alteration permit, he approached the university for help. An aquatic ecosystems restoration class in the fisheries department took up the call. Various teams examined the creek's ecology, hydrology, and use, and designed concepts for daylighting and restoring the stream where it passed the high school.

Two students, master's candidate Melissa Bukosky and undergraduate Tom Hagberg, continued to work on the project after the class ended. They gathered more hydrologic data, developed flood frequency tables, engineered a channel design, researched revegetation options, and wrote a project plan. This work helped secure the necessary permits. Meanwhile, Armin-Hoiland approached the Natural Resources Services Division of the Redwood Community Action Agency (RCAA), a private nonprofit regional development organization, for assistance in funding the project. RCAA obtained a $25,000 grant from the California Department of Water Resources Urban Streams Restoration Program, and hired Bukosky to act as a liaison with the stream construction team in the fall of 1991.

After this project was completed, additional projects began to take shape downstream at two defunct lumber mill properties. The city of Arcata had previously acquired these properties for the eventual development of Shay Park, named after the Shay railroad engine, a local historic icon. Early parks and recreation department plans emphasized basketball courts, baseball

[1]Be sure to see the interpretive comments at the end of the overall project summary table in the "Findings" chapter.

diamonds, and a new railroad museum. According to Bukosky, the plans were not "creek-friendly." As a result, the local neighborhood rebelled. Concerned citizens formed the Friends of Jolly Giant and began a campaign of presentations, input at city meetings, letter-writing, and other activities to convince the city to let the neighborhood plan its park as a natural landscape with passive recreational opportunities. The parks department came around, and environmental restoration projects that included daylighting began on the mill sites in 1995.

Actions

In the first project, at the high school site, construction crews removed approximately 100 feet of culvert and installed a sedimentation basin where the creek emerges onto the high school property from a culvert under Highway 101, a four-lane freeway. This basin is an earthen trapezoidal channel roughly 30 feet wide by 15 feet deep by 80 feet long. It is designed for easy access by a city backhoe. It settles much of the sediment carried from the creek headwaters and construction activities upstream.

Next comes a curved pond roughly 75 feet long and one-third of an acre in size. The pond bottom slopes gradually at the edge to provide shallows for emergent aquatic vegetation, then slopes more steeply toward a deeper center designed as a fish refuge. Here sunken root wads provide cover.

Downstream from the pond runs 75 feet of new stream channel. Logs and root wads are incorporated into the banks to create fish habitat and to direct flow. Willow plantings stabilize the banks.

The new channel finally gives way to about 100 feet of recovering natural stream channel—not the channel the culvert previously dumped into, but an older channel found during site analysis to be largely dewatered but still maintaining some riparian vegetation. This channel runs diagonally across the bottom of the six-acre site, an area bounded by a high school soccer field, road, railroad, and bluff. Crews revegetated about three-quarters of this area with riparian plants and trees.

When the mill site projects began in 1995, Jolly Giant Creek ran on the surface through much of its passage by the mills, but had long since been channelized (in places with 10-foot-deep vertical side walls), diverted into log ponds, culverted in some sections, and otherwise manipulated. Concrete slabs covered much of both sites. With state funding, RCAA and the city removed the slabs and culverts, excavated wood waste and other debris, recontoured a floodplain, and established a new stream channel geometry. At the downstream-most mill site, they left the old channel in place for high water overflow, and created a new base flow channel. In addition, they used fill excavated from both sites to create a berm around the lower site to provide stormwater detention. A small culvert under the adjacent railroad track regulates storm flows, creating a seasonal wetland and wet-weather detention pond that holds up to 2.5 acre feet (about 800,000 gallons). These projects restored a total of over 400 feet of Jolly Giant Creek at the two mill sites, including over 60 feet formerly in culvert. Crews completed construction activities at the upper mill site in 1995, and finished the lower mill site project in 1996-97.

Results

The Jolly Giant daylighting and associated channel restoration work has created a valuable new public space in the city of Arcata, and an attractive asset for the neighborhood. Formalization of previous footpaths into bona fide, handicapped-accessible trails and removal of derelict structures has made the area less of a hangout for troubled youths and drug dealers, and has increased pedestrian traffic and use by school biology classes. The area is now largely "self-policing." New bridges across the stream have also increased safety. The corridor receives increased use as a pedestrian thoroughfare, especially by students on their way to and from the high school and the university.

The projects also provide the outdoor classroom envisioned by Armin-Hoiland. Many students have been involved in restoration and monitoring throughout their high school years, and thanks to this experience choose to pursue college studies in biology and other sciences. Besides specific curricular benefits, Bukosky believes that the restored stream allows volunteers and students to reconnect with nature and learn stewardship skills. The value of this, she says, should not be underestimated.

Environmentally, the projects have been very successful. The sites are revegetating well (providing, incidentally, an excellent example of vegetative succession and maturation as one moves upstream from the 1996-97 restoration at the lower mill site to the 1995 project at the upper mill to the 1991 daylighting project, where a canopy of alder, willow, and maple and an overstory of redwood trees topping 40 feet are now established). Monitoring by high school and university classes has shown improvements in water quality and aquatic biodiversity. Resident cutthroat trout are thriving in the restored reaches. Observers have found spawning redds in the old recovering channel on the restoration site at the school property, and recent electrofishing studies found juvenile coho salmon and steelhead. The restored creek provides settling of sediments (the sedimentation basin has been dredged several times since its creation), radically improved channel and floodplain geometries, improved flood control and stormwater detention, habitat-creating structures, erosion control, and riparian and wetland vegetation that shades the stream and takes up nutrients and pollutants. All have contributed to the stream's improved physical and biological performance.

Finally, the efforts have helped shaped city policy. The city is now actively pursuing acquisitions and easements along local streams, and is initiating projects to restore hydrologic and ecological functions of its riparian corridors. It has also prepared a new drainage master plan. The city even hosted a western regional urban stream restoration conference in 1996, and was flattered when attendance topped 300. Now that the Arcata government is taking the lead, the RCAA can devote some of its attention to other worthy projects.

Economics/Funding

Funding for these projects came primarily from the California Department of Water Resources Urban Stream Restoration Program, first in a $25,000 grant for the initial daylighting project, and then a $50,000 grant for work at the upstream mill site, both to the RCAA. Restoration at the downstream mill was funded by a total of $45,000 received by the RCAA from the Department of Water Resources restoration program and the U.S. Fish and Wildlife Service Challenge Cost-Share Program. These monies primarily paid for earthmoving services and materials.

While the necessary funding to complete these projects was not insignificant, naturalizing the area was undoubtedly cheaper than establishing active recreation facilities such as playing fields and courts. Moreover, available funds were highly leveraged by extensive donations of time and materials. The city of Arcata contributed in-kind as much as $40,000 worth of equipment, materials, and staff time. Jay Franke, a heavy-equipment contractor who does restoration work in Redwood National Park and whose family owned the mill sites, donated equipment, materials, time, and expertise. The National Tree Trust provided many trees for free. Students and RCAA staff did the planning and design work. Thousands of hours of school and neighborhood volunteer labor have gone into revegetation efforts. Students have carried out assessment and monitoring efforts.

Challenges and Lessons

Bukosky reports that the biggest challenge in these projects was establishing the channel geometry in a floodplain now constrained by surrounding development. While average annual flow is 5 cubic feet per second (cfs), average annual peak flow is 128 cfs, and the 100-year event is 250 cfs. Because of urban land uses upstream, Jolly Giant Creek comes up very quickly with each rainstorm, and a one-inch storm creates a bankfull runoff event. Besides establishing the bankfull and low-flow channel geometries, the designers had to establish an upper floodplain where none existed before. Bukosky points out that projects like this involve three significant restorations: channel, floodplain, and vegetation.

The first daylighting project was perhaps the easiest to carry out, as the earthwork there did not require the major effort to remove concrete slabs and other debris at the mill sites. Trucking chunks of concrete up to 18 inches thick was very costly, and finding a disposal site for the spoils was not easy. Project coordinators used some of the excavated materials to construct the stormwater detention berm at the downstream mill. They sent the concrete rubble to a project that was building dikes for wetland ponds near Humboldt Bay.

Project participants did not find obtaining the necessary U.S. Army Corps of Engineers and state permits too trying—the agencies were supportive of the concept. More difficult was the effort to get the city to change its park design. A strong local constituency for the natural park concept eventually led the city to be supportive.

Vandalism—graffiti, destruction of plants, signs, and fences, and movement of stream features—is still a nuisance, though kept in check by neighborhood and school watchfulness. At one time, project workers mortared in rocks placed along the outside of stream bends to prevent removal. But wet mortar doesn't last well, so more recent work relies on rocks too large for individuals to move.

Sources: Bukosky 1998/99; Pinkham 1998.

San Francisco Bay Area Projects: An Introduction

California's San Francisco Bay Area features the highest concentration of daylighting activity in the country. Three projects are described in the following pages; others are covered later in this report.

Daylighting began in the Bay Area when the city of Napa removed a cover over a channelized portion of Napa Creek in the 1970s. While this project did not renaturalize the stream, it may have been the first North American project to re-expose a previously hidden stream. Berkeley completed the path-breaking Strawberry Creek project in 1984. Additional daylighting projects followed in Berkeley and El Cerrito. These daylighting projects are just a few of the many stream-restoration actions taken in the Bay Area over the last two decades, and more are on the way.

All this daylighting activity both grew from and spawned a plethora of local "Friends of the (name of a local creek)" groups as well as the Urban Creeks Council, an umbrella organization. Local firms like Wolfe Mason Associates have built expertise in stream restoration, and the Waterways Restoration Institute, a nationally active nonprofit river-restoration design, training, and advocacy group, makes its home here. As the case studies show, collaboration between local governments, institutions, businesses, nonprofits, and citizen groups has been a key to the success of Bay Area daylighting projects.

A common feature of these projects is their location in densely developed urban and suburban watersheds. This creates a number of challenges for the designers: identifying the proper geometries for restored channels, securing the confidence of project neighbors, and dealing with the problems of older urban infrastructure. Designers of these projects have used historical aerial photographs, measurements of less disturbed upstream reaches of the creeks, and other techniques to determine meander patterns and channel cross-sections. They have pushed hard for significant public involvement in developing the creek- and park-restoration plans. That involvement continues beyond the planning stage—volunteers have been very active in landscaping, planting, and maintaining many of the projects.

Daylighting offers significant urban infrastructure benefits in the Bay Area. Many culverted streams in this region have required expensive repairs because of earthquake damage, which often goes undetected for long periods. Daylighting also allows an increase in storm flow capacity—all these projects are designed to carry a 100-year event, while most local storm drains have far less capacity. These projects have weathered even the torrential rains of the 1998 El Niño without erosion. On the problematic side, several of these projects experience occasional low-level sewage contamination from old, leaking sewer lines upslope. This is not a show-stopper for potential projects. In fact, landscape architect Gary Mason likes to turn problems like this into opportunities, advising concerned officials and citizens that an open channel allows and encourages monitoring to identify such problems, and provokes action to correct them. The city of Berkeley now has a comprehensive sewer upgrading program that addresses contamination sources.

Most daylighting projects need continued planting and maintenance in their early years. Bay Area projects have benefited from a variety of maintenance arrangements. At some, city maintenance crews remove debris in the fall to prepare for winter rainstorms. Participants in a local job-training program maintain two of the projects. Local citizens look after others, and the Urban Creeks Council and Waterways Restoration Institute hold two or more expertly supervised volunteer work days each year, usually for weeding in the spring and planting in the fall.

At the turn of the 20th century, prominent landscape architects and urban planners like Frederick Law Olmsted, Charles Mulford Robinson, and Werner Hegemann envisioned preservation of riparian corridors throughout the rapidly developing Bay Area. Most of the area's creeks have since been culverted. In a small yet important way, these daylighting efforts tap into the earlier vision and revitalize the ecology of local streams and the relation of the region's people to them (Owens-Viani 1999a).

Berkeley, California

Strawberry Creek

One of the first daylighting projects in the United States, Strawberry Creek now anchors a popular urban park in a mixed-density residential neighborhood of Berkeley. Four acres of abandoned railyard was transformed in 1984 into Strawberry Creek Park, featuring playing courts, landscaped hillocks, grassy meadows, native trees, and 200 feet of babbling brook. The successful restoration sparked other local daylighting efforts and is considered a model daylighting project.

Watershed:	2.0 square miles; urban and university campus
Flow rates:	2-6 cfs average seasonal low flow
	800-1000 cfs 100-year peak flow
Length daylighted:	200 feet of new channel
Year daylighted:	1984
Project costs:	~$50,000 for daylighting (of $580,000 total park cost)
Primary objectives:	Create park and an urban creek amenity
Notable features:	Early, model daylighting project; completed with limited budget

Background

In 1974, the Santa Fe Railroad abandoned a railyard and the land reverted to the city of Berkeley. The land in the flat bayside area of west Berkeley lay neglected until 1982. At that time Douglas Wolfe, one of the city's staff landscape architects, began promoting a park project with a visionary plan to daylight Strawberry Creek as its centerpiece. City officials were unsympathetic, fearing the exposed creek would be a safety and flood hazard and a litter-filled eyesore. As landscape architect Gary Mason, a member of the city's design team and Wolfe's eventual business partner, puts it: "They wanted to know why we would bother to dig up a perfectly good culvert." But citizens rallied behind the daylighting component of what was to be called Strawberry Creek Park—supporters launched a vigorous leafleting campaign, attracting up to 75 people at a time to various public meetings—and the Berkeley Parks Commission eventually voted unanimously in favor of it.

Actions

Project design and construction occurred in 1983 and 1984. The designers did not have modern watershed analysis and fluvial geomorphology tools at their disposal, but paid careful attention to determining the proper channel geometry for the "new" creek. They looked upstream several blocks, to where Strawberry Creek still flowed free on the University of California campus, to analyze channel width, depth, and meander pattern. After digging out the turn-of-the-century culvert, restorers also examined soil types to help find and re-establish the original meanders of the creek.

Crews used fill from the dig to create hillocks in upland portions of the park, where they also built in swales to gently carry runoff to the newly opened creek. Broken-up concrete slabs from the site's previous uses now serve as steps down to the water, boulders in the creek bed, and rip-rap protecting the stream bank. (Reuse of this material in a streambed might not be allowed by state regulators today.) About two hundred feet of restored creek now cross the four-acre park.

Restorers used native trees and groundcover both along the creek and in the uplands. The willows, cottonwoods, pines, oaks, manzanitas, poppies, snowberries, and other species used require minimal maintenance or irrigation.

The city of Berkeley put in place an innovative program to maintain the creek and the park. When parks department staff complained the project had created a new burden, parks and marina superintendent Bill Montgomery sought and funded a proposal from a local job-training program to maintain the facility. The program has since grown into an $80,000-per-year contract between the city and Berkeley Youth Alternatives to maintain four parks. Creek-related work occurs at two of the parks—Strawberry Creek Park and the Thousand Oaks School Park (the location of the Blackberry Creek daylighting project, described below)—and represents a small portion of the budget. At any one time, about a dozen high school students from low-income families are enrolled and paid to pick up garbage, weed, prune plantings, and otherwise maintain the parks. (The city parks department still handles mowing.) The youths work every day after school and half days on Saturday, and receive some tutoring as well as income and job training. The city gains financially by not having to hire and pay benefits for adult parks staff. According to Carole Schemmerling of the Urban Creeks Council, things were "a bit rocky" at first in properly training and supervising the youths for the creek-related tasks, but the work goes smoothly now.

Results

By all accounts, the Strawberry Creek restoration has been a stellar success. Strawberry Creek Park draws dozens to hundreds of people a day, many for the opportunity the creek presents urban dwellers, children, and adults alike to see, hear, smell, and feel flowing water and to enjoy the birds and aquatic creatures.

Property values in the neighborhood have increased. Once a high-crime area and drug-dealing hotspot, the area now has a family-oriented feel. An old brick warehouse adjacent to the park hosts several professional offices and a bakery. Senior

Strawberry Creek Park was an abandoned railyard prior to daylighting of the creek in 1984. Courtesy of Wolfe Mason Associates.

housing, an adult school, and a daycare center are nearby.

This project galvanized the community, leading to several other daylighting and channel-restoration projects in Berkeley and surrounding communities. On Strawberry Creek itself, the city is now examining the potential of daylighting a three-block section upstream in the heart of downtown Berkeley (see the "Proposed Projects" chapter). Strawberry Creek Park has won many awards, including a Design Merit Award from the American Society of Landscape Architects in 1995.

Economics/Funding

The entire park project was completed within its $580,000 budget (1984 dollars) from city funds. Creek restoration amounted to less than 10 percent of the cost, and a substantial part of the restoration budget was the cost of a pedestrian bridge over the creek. Grading costs were low because much of the site work was required for the park, irrespective of the new creek. The budget included most of the restoration labor (unlike later Bay Area projects, which have sometimes used considerable donated labor). Despite pressures to do otherwise, Wolfe kept the creek work in the base bid structure instead of making it an "add alternate," assuring it would not be cut if bids for the overall park construction came in high.

Challenges and Lessons

According to Gary Mason, Strawberry Creek was an early example of a challenge that must be faced in nearly all daylighting projects: fear. It comes in many forms—city officials worrying about hydraulic performance or fretting over maintenance, and neighbors afraid the project will attract vermin or drown their children. Addressing such concerns is a key effort in any daylighting project. The Strawberry Creek daylighting experience, at least, shows the fears may be largely imaginary. The creek has survived many major storms—small surprise given it was designed (as all the Berkeley projects have been) to carry a 100-year event. This is more than can be said for most culverts in most American cities. And no one has ever gone to the hospital in Berkeley on account of an accident in the restored creek. This safety record, even with heavy use by children, helped make possible a school-site project on nearby Blackberry Creek (see below).

Currently the creek has no interpretive signage. Local school children hope to change that. A teacher at nearby St. Joseph the Worker School is seeking a grant to fund their efforts. Schemmerling reports that signage at local stream projects has historically been hard to finance. It can be expensive, and funders tend to think it is too prone to vandalism.

Among many other lessons, the Strawberry Creek story shows the importance of public support for a daylighting project. It also illustrates that imaginative use of materials can keep project costs down and create a unique aesthetic—a restoration that acknowledges the stream's historical encapsulation in concrete.

Sources: Landscape Architecture 1995; Mason 1998/99; Owens-Viani 1999b; Powell 1991; Schemmerling 1998/99.

A portion of the daylighted section of Strawberry Creek after construction. The vegetation has since grown into tall trees that now overhang and shade the stream. Courtesy of Wolfe Mason Associates.

Berkeley, California

Codornices Creek

Daylighting this 400-foot reach was just the beginning of the restoration of Codornices Creek. Proponents are now assembling more than a half-mile of surface channel restoration, additional daylighting, and trail-building efforts to link lower portions of this creek with the Bay Trail on the shore of San Francisco Bay. This project shows how daylighting can be done with a low cash budget when sufficient volunteer labor and expert technical oversight are available.

Watershed:	1.5 square miles; urban
Flow rates:	2-6 cfs average seasonal low flow 800-1000 cfs 100-year peak flow
Length daylighted:	400 feet of new channel
Year daylighted:	1994
Project costs:	$33,000 plus in-kind donationsand considerable volunteer labor
Primary objectives:	Restore creek for salmon and human use; motivate upstream and downstream restoration
Notable features:	Successful low-budget project

Background

Slated for a parking lot behind an expanding industrial warehouse, a vacant block of land between 8th and 9th streets on the border of the cities of Berkeley and Albany became the focus of creek restoration discussions in 1991. Both cities, the developer, the University of California (owner of an adjoining married-student housing complex), and three nonprofits (the Urban Creeks Council, the Waterways Restoration Institute, and Ecocity Builders) collaborated to bring about a daylighting project. Facilitation, grant-writing, design, and project coordination were provided by the landscape architecture firm Wolfe Mason Associates.

The project began contentiously. Neighbors and the Urban Creeks Council stopped the initial development proposal, using a Berkeley ordinance that prohibits major construction within 30 feet of a creek. The ordinance applied because a short portion of Codornices Creek in this block was still open. The Urban Creeks Council agreed to find restoration funding and help with permitting of a modified project if the developer would daylight the creek. They obtained a small state grant in 1992, and small contributions from the two cities, even though the project was on private property. Knowing that the limited funds would not go far, the council enlisted the help of Ecocity Builders, a Berkeley-based nonprofit that explores ecological city design and planning from both theoretical and practical, project-based perspectives. Ecocity's Richard Register arranged for low-cost services from a bulldozer operator, and committed to organizing volunteer labor.

Actions

Designers reconceived the building expansion, facing the building toward the creek-to-be. They relocated the parking lot out of view from the creek, and placed the new channel along the original meander path of the creek. In the fall of 1993, a bulldozer roughed out the new channel. Three-quarters of the way down to the planned level of the creek, the machine began to bog down in the wet sub-soil. With oversight from the Waterways Restoration Institute, work crews from the East Bay Conservation Corps and the Ecocity volunteers finished the digging, shaped the banks and a small floodplain, and began planting the site. The following year, 1994, the developer's crews completed the daylighting by breaking open the culvert and diverting its flow into the new channel.

Grading and planting efforts continued that year and into the next. In the first two years of construction, on work days and virtually every Saturday, up to a dozen volunteers would show up to shovel, rake, plant, and otherwise create the project. Altogether more than 375 people contributed to this effort.

Native shrubs and 22 fruit trees now provide shade, screen the site from surrounding streets and buildings, and line a path. The landscaping here is wilder and less park-like than the Strawberry Creek project. Volunteer work days continue to this day, now taking place every Sunday to avoid Saturday's noise from a nearby sports complex and for the enjoyment of wildlife that is more varied on quiet days. The efforts have shifted from landscaping to plant maintenance—weeding out undesired and non-native species and removing dead or dry materials that could pose a fire hazard.

Results

This project survived the severe 1998 El Niño storms in fine shape. The site is used by neighbors, children from a local day-care center, and employees of nearby businesses. Crayfish, damselflies, and other macroinvertebrates make their homes in the creek. In 1999 six mature steelhead were spotted upstream of the daylighted reach—probably the first time steelhead have reached this high on the creek in decades.

Native frogs have returned, as have garter snakes. A pair of mallards have made this stretch of creek their home since 1998, raising six young one year. Many bird species are now sighted on a regular or sporadic basis, including night herons, snowy and great egrets, towhees, doves, Anna's hummingbirds, vireos, warblers, goldfinches, house finches, sparrows, wrens, and a pair of Cooper's hawks. Pocket gophers live on the site but are stalked by domestic and feral cats, presumably along with some of the birds.

Daylighting of this section of Codornices Creek sparked restoration of an open but badly degraded section a few blocks downstream in 1997. Local creek advocates will restore another upstream concrete channelized section to natural conditions in 2000, in connection with a low-income housing development. In an even more exciting development, the cities of Berkeley and Albany and the University of California, in planning new university playing fields, have committed to improved fish passage, flood-hazard mitigation, and trail development for several blocks above and below the daylighted site. They will terminate one or more streets and bridge additional streets in order to remove the culverts at those street crossings. Funds from the federal Intermodal Surface Transportation Efficiency Act (ISTEA) and the California Coastal Conservancy will help support this work.

Volunteers working on the banks of the new Codornices Creek channel shortly after excavation. Courtesy of Wolfe Mason Associates.

Economics/Funding

This project was completed with a relatively small amount of direct funding. Each city pitched in $5,000, and the California Department of Water Resources Urban Stream Restoration Program provided a $23,000 grant. The developer paid for heavy equipment operators to do the final opening of the culvert in exchange for a several-thousand-dollar reduction in city permit fees negotiated by the Urban Creeks Council. The University of California agreed to accept partial relocation of the creek from the culvert on the developer's property to a new channel on land at its married-student housing complex. The project would not have been possible without thousands of hours of volunteer labor.

Challenges and Lessons

The state grant for this project was small in part because of the state's expectation that the university or the private landowner would chip in with funds. They did not, leaving proponents scrambling for resources. According to Gary Mason, creek advocates decided to risk doing a low-budget project, rather than let the original development project go ahead and lose indefinitely the chance to daylight the creek. Lacking funds to fully stabilize the creek banks the first winter, some erosion problems occurred. While the low-budget approach was less than optimal, this project shows that volunteer labor and in-kind contributions can be used to keep direct projects costs way down. However, the considerable experience of the project partners in designing and coordinating urban stream restorations was essential to pulling off a project with limited funds.

One technical challenge on this project was the need to lower a gas pipeline crossing the creek. Fortunately, Pacific Gas & Electric cooperated fully with the designers to do so.

Richard Register reports that homeless people do sometimes use the creek as a camping site. This problem is of course not unique to creek restoration projects, and is a much bigger issue than creek restorationists alone can address. At this daylighting site, typical dense willow growth in the early years and relatively low public use attracted homeless individuals. Now that the willows have grown tall (over 30 feet), volunteers are cutting lower branches and undergrowth to increase visibility and reduce hiding places. Volunteers also repair occasional vandalism and teach visitors about the creek restoration project and the plants and animals there.

Sources: Mason 1998/99; Register 1999; Schemmerling 1998/99.

Berkeley, California

Blackberry Creek

A 250-foot section of Blackberry Creek was taken out of a culvert underneath a schoolyard in 1995. The school uses the new creek in various curricula. Neighbors enjoy the running water and surrounding park in the schoolyard. Collaboration between many private and public organizations, state funding, and labor from a job-training program made the project possible.

Watershed:	0.3 square miles; urban
Flow rates:	15 cfs 1.5-year peak flow (bankfull flow) 220 cfs 100-year peak flow
Length daylighted:	250 feet of new channel
Year daylighted:	1995
Project costs:	$144,000, plus donationsand additional park-related costs
Primary objectives:	Create educational site; improve community park; relieve flooding problems
Notable features:	Curricular use of the new creek

Background

Blackberry Creek runs to the San Francisco Bay from the hills in the northern part of Berkeley. The creek flows through a dense single-family-home neighborhood in a narrow but relatively natural riparian corridor upstream from Thousand Oaks Elementary School. At that point it ducks into a culvert running under the school and, until recently, a portion of the schoolyard called the Grove. This culvert had a history of backing up in large storms, with the excess water flooding out onto nearby streets through its catch basins.

The Loma Prieta earthquake of 1989 damaged the Thousand Oaks School and other facilities in the Berkeley Unified School District. When this school's turn came for structural upgrades in 1992, a local PTA member proposed also improving its "school park" and broached the idea of daylighting Blackberry Creek there. The idea of providing an outdoor environmental education classroom and living lab for the school was a key selling point, as was the opportunity to address the flooding problem and provide a better park for the neighborhood.

The school district and the Thousand Oaks School PTA obtained a $144,000 grant from the California Department of Water Resources Urban Stream Restoration Program. Wolfe Mason Associates, a local landscape architecture firm, provided planning, facilitation, and design services. Collaborators included the Urban Creeks Council, the Waterways Restoration Institute, the school district architect, the City of Berkeley landscape architect, and local citizens. Key citizen supporters included a teacher at the school and some businesses along a retail strip one block away. With the money in hand, proponents then educated the neighborhood about the benefits of the project and soothed the usual fears over safety and appearance. They also obtained permits from the U.S. Army Corps of Engineers, the California Water Quality Control Board, the state fish and game department, and local authorities.

Actions

The Waterways Restoration Institute was able to measure upstream reaches of Blackberry Creek to help design the channel geometries for the unearthed reach. These upstream segments appeared to have adjusted to increased flows from development and had reached "urban equilibrium," neither eroding excessively nor silting up. Designers also asked people in the upstream neighborhoods questions like: "Where have you seen erosion occurring?" and "How high did the flood of 1955 get?" They measured water velocities and levels upstream during storm events. They examined original creek meanders in 1940s aerial photographs. All this information helped the designers cross-check and supplement the bankfull channel cross-section indicated for the size of the drainage area by documented relationships for streams in the eastern San Francisco Bay Area.

In September of 1995, a heavy equipment contractor dug out the 1950s-era culvert and roughed out banks and meanders for the new stream channel. Additional bank shaping and landscaping proceeded by hand labor, provided largely by an Americorps crew of the East Bay Conservation Corps with technical oversight from the Waterways Restoration Institute. Like dozens of other conservation corps across the country, this group provides job training to young adults, especially low-income and minority youths.

The restoration efforts created 250 feet of new channel. It drops two feet between the culverts upstream and downstream. To control velocities and orient the channel, the designers specified four shallow rock weirs, each anchored deeply in the streambed. Because the stream channel is 10 to 13 feet below the surrounding level of the land, the designs gave close attention to erosion control on the banks. Crews placed large rocks on the outside banks of each meander and stabilized other banks with a variety of bioengineering techniques: fascines, brush layering, pole cuttings, and natural or biodegradable erosion-control fabrics. Native dogwood was the species of choice for this project, instead of willow or cottonwood, as local citizens had expressed a preference for shorter vegetation.

Results

The Blackberry Creek site as it appeared in 1996. Crews daylighted and planted the site in late 1995. Courtesy of Wolfe Mason Associates.

The surrounding neighborhood now enjoys a restored 0.6-acre park with a lawn, creek, creekside path, and picnic area. The park has one of the most popular tot-lots in Berkeley, perhaps because families' older children can distract themselves in the stream while their younger siblings enjoy the playground. Thousand Oaks Elementary has become one of Berkeley's magnet schools, focusing on ecology. Students learn to identify and understand organisms in the restored creek and they investigate the connections of this reach to the larger watershed. Indeed, students learned a water-quality lesson shortly after crews landscaped the project. Nitrogen leaching from shredded bark and other local organic materials applied as mulch to the stream banks caused a brief algae bloom in the creek. The students worked with the project designers to remove the algae and restore balance to the stream.

Economics/Funding

A $144,000 grant from the California Department of Water Resources Urban Stream Restoration Program paid for planning, permitting, grading, hauling away fill, burying the excavated culvert on site, installing irrigation for the park, and conservation corps labor. The school district pitched in $8,000 for fencing at the top of a steep section of stream bank and above the headwalls for the upstream and downstream culvert openings. The city contributed $15,000 for concrete work, drainage, and sand for the playground, and paid for a staircase leading from the lawn down to the creek. Local businesses and residents donated a few thousand dollars for plants. The design firm reduced its usual fee. If all the funds and donations and foregone fes are totaled, the project probably cost about $200,000. A significant portion of this went toward the playground and park amenities, not just the stream restoration. Not counted in that figure are the many hours volunteers contributed to this project.

Challenges and Lessons

Project designer Gary Mason notes that during project planning, local residents expressed strong concerns about losing the "sure thing" of the older playground on the site. The state stream restoration grant would not pay for play equipment, and the old, substandard gear could not be reused. Eventually the neighborhood took on fundraising for the new playground. This illustrates that daylighting projects can raise concerns about the loss of features now present on a site, even when those features are in poor condition. Proponents would do well to address such concerns directly, and propose relocation or replacement wherever possible.

Designers had to work around a redwood tree that had grown up where the creek once ran. A local T'ai Chi meditation group considered this a sacred tree. Preserving the tree required some adjustments to the path of the restored creek.

Mason also says this project illustrates a common phenomenon: the scruffy adolescence of riparian landscaping. "It's really messy, and where's the creek?" is the most common complaint he hears. While lawns, walks, trees, and benches give a finished look to the upland, streamside vegetation must pass through a wild, shrubby, weedy stage before a more mature, familiar canopy develops. Restoration proponents should anticipate some complaints from neighbors and plan a strong campaign to educate the public about what to expect during the five-year establishment period.

Sources: Klesius 1999; Mason 1998/99; Mcdonald 1996; Schemmerling 1998/99; "Urban Stream Restoration" 1998.

Shoal Creek Tributary

The DeKalb County Parks Department removed a broken-up, hazardous culvert on a small stream in Longdale Park in 1994. Daylighting the stream was less costly than replacing the 200-foot culvert. The county used an existing Clean Water Act section 319 grant to fund the design time by a staff member, and applied its costs for this project as an in-kind match for the grant.

Watershed:	~0.15 square miles; medium density residential
Flow rates:	1.5 cfs seasonal low flow 225 cfs 100-year peak (very rough estimate)
Length daylighted:	200 feet culvert removed
Year daylighted:	1994
Project costs:	$14,500 plus unallocated staff time
Primary objectives:	Remove hazardous collapsed culvert; restore stream
Notable features:	Successful low-budget project; less costly than culvert replacement

Background

To maximize playing-field space when it created Longdale Park in 1984, DeKalb County culverted a 200-foot section of a small, unnamed tributary to Shoal Creek in the suburbs of Atlanta. Over the years the culvert deteriorated. By the early 1990s, sink holes had appeared in several places. Kudzu invaded, and the spot became a significant eyesore. Lacking funds to replace the culvert, the parks department fenced off the hazardous area.

It remained that way until Ginna Tiernan, a parks department employee who was responsible for developing stream-restoration projects, lobbied managers to remove the culvert and re-establish the stream. Noting that daylighting the creek would be cheaper than replacing the culvert, the parks department approved the proposal in 1994. Initial concerns about the loss of playing-field area subsided in light of the fact that demand for the field had declined and the county no longer programmed organized games at the site.

Actions

Lack of budget prevented Tiernan from undertaking quantitative studies of the stream's hydrology and channel geometries. Instead, she relied on visual assessment of upstream sections of the stream to design the new channel and the bank slopes. Also, the stream had been culverted in its original channel, so the project did not involve relocation. Based on the upstream geometries, Tiernan put a small amount of sinuosity into the new channel.

No formal permits were required for the project, as it involved a non-open section of stream. Also, the county's development department classified and approved the project as a maintenance activity rather than a new construction project.

County crews excavated the old culvert and constructed the new stream in December of 1994, during a low-flow period. They placed rocks along the toe of the banks to stabilize the channel and built small rock check dams in the channel to catch sediment during construction. Toward the end of the construction period, after removing accumulated sediment, they pushed down the rocks to make shallow weirs.

Partly as an experiment, Tiernan used two methods of bank stabilization. In some areas she specified jute erosion-control fabric, tree seedlings (river birch, tulip poplar, and red maple), and grass seed. In others she used sod and nursery trees. She did not use willows, due to concerns over possible community objections to dense vegetation along the stream through this previously open area.

This project became part of a larger stream-restoration effort in the park. Crews had previously regraded and revegetated an open but incised section of the tributary immediately upstream of the daylighting site.

Results

Tiernan says the stream channel is functioning well. Trees planted along the banks are flourishing, and many native grass, shrub, and tree species, including willows, have colonized the banks. Both experiments have performed well; Tiernan has not heard any complaints about the mix or density of the vegetation. The project demonstrated to the parks department that daylighting is a feasible and worthwhile endeavor. It has been cited and lauded by organizations promoting potential daylighting projects in the Atlanta area.

Economics/Funding

Tiernan's position, and thus her time to design and supervise the project, was partially supported by a U.S. Environmental Protection Agency grant under the Clean Water Act section 319(h) program. The county tracked and valued (at conservative, somewhat sub-market rates) its contributions to the project. These included $4,500 in erosion-control fabric, rock, straw, seed, and other materials; $5,000 in construction crew labor; and $5,000 in vehicle and heavy-equipment use. The county applied the $14,500 total expense as an in-kind contribution to the 40-percent local match required for several projects Tiernan completed as part of the 319(h) grant. The DeKalb County Roads and Drainage Department covered the material costs from a citizens' drainage-improvement fund. The county undertook the project in part because it believed the cost would be considerably less than the cost of replacing

A culverted creek in Longdale Park near Atlanta prior to daylighting. Kudzu vines crawl over fences around collapsed sections of culvert. Courtesy of DeKalb County Parks Department.

the culvert. The Environmental Protection Division of the Georgia Department of Natural Resources contributed some staff time to the project by administering the EPA 319 grant.

Challenges and Lessons

Tiernan reports that the park maintenance crews still mow too close to the stream's edge for an optimal riparian buffer. They may be getting pressure from the community to do so, given the stream's proximity to other park features. The biggest problem is kudzu, an invasive, exotic vine. "Kudzu is truly a horror here in the South," she says, "but it can be eradicated. It just takes a strong commitment to do so." Crews weaken and eventually eliminate problem patches by cutting back the vines several times a year and applying herbicide if needed.

According to Tiernan, project design had to be simple because funding was limited. Since the project had no budget for stream studies, it was clear from the start she would have to design the channel using her best judgment, based on her experience with other stream-restoration projects and visual examination of open upstream sections. Nevertheless, she counsels, "It's important to take the time up front. You should study the system and get the basic information, even if ultimately you go with your gut on some things."

Sources: ILSI Risk Science Institute 1998; Tiernan 1999.

The creek about a year after daylighting. The section in the foreground was previously open, but had its banks regraded; the daylighted section lies in the background. Courtesy of DeKalb County Parks Department.

Barrington, Illinois

Kilgoblin Wetland

In 1995, the Village of Barrington removed 300 feet of 36-inch storm sewer immediately above the line's confluence with Flint Creek and shoehorned a one-acre wetland between in-ground utilities on a three-acre site near downtown. The marginal cost over a proposed upsizing of the storm line through the property was relatively modest.

Watershed:	1.2 square miles; urban and suburban
Flow rates:	Unavailable; has perennial flow
Length daylighted:	300 feet of culvert removed
Year daylighted:	1995
Project costs:	$55,000, excluding land acquisition
Primary objectives:	Improve downstream water quality
Notable features:	Daylighting storm sewers to create a wetland

Background

Located 35 miles northwest of Chicago, the Village of Barrington has a population of about 10,000 in its incorporated area of four square miles; surrounding communities bring the total local population to 45,000. Barrington hosts corporate research, office, and manufacturing facilities and regional retail and service businesses.

Flint Creek runs through Barrington, forming a riparian corridor and the community's main storm drain. As part of a storm sewer improvement project, in 1994 the municipality condemned a little-used three-acre triangular parcel of land mostly bounded by railroad tracks and touching on Flint Creek at one corner. The town planned to replace about 1,800 feet of an old, 36-inch storm sewer line that ran through the central business district and across this property to the creek with a new 48-inch line. This storm sewer had buried a small, unnamed tributary to Flint Creek decades before.

About this time, public works director John Heinz attended a conference presentation on stream restoration and began to think, "Why not in Barrington?" As Heinz puts it, the project then became a matter of "putting a whim into motion and finally into reality." His hope was that opening the culvert and creating a wetland by Flint Creek would improve water quality by trapping sediment and removing some nutrients, and would "create something unique" for the town. After all, urban centers like Barrington don't have many opportunities for restoration projects.

Public outreach was not a significant undertaking in this project. The affluent and environmentally sensitive citizenry was supportive of the effort. A local nonprofit organization, Citizens for Conservation, regarded the wetland creation as a bonus, given that most public works departments would have done the usual and carried out a storm sewer replacement with no daylighting. Also, the project was located in a semi-industrial section of town with no immediate residential neighbors. The municipality worked with the firm engineering the new storm sewer line to modify the project and obtained assistance designing the wetland from Natural Areas Ecosystems Management, an Illinois company.

Actions

Contractors built the project in 1995. At the upstream end of the storm sewer project, they replaced 1,000 feet of the old 36-inch line through the town with the new 48-inch line. Below that section, it turned out that 500 feet of the old 36-inch line was in good condition. The public works department decided to install the new 48-inch line as planned, and left the old pipe in place alongside it to provide additional on-line storm capacity.

The daylighting portion of the project was restricted to the remaining 300 feet of storm sewer where it crossed the three-acre site between the railroad tracks and Flint Creek. To prevent kids from crawling into the two pipes—the old 36-inch and the new 48-inch—that now terminated at the upstream edge of the parcel, crews installed pre-cast, flared-end sections covered by grates. Below these outlets they graded a depression and shallow side slopes for a new one-acre wetland. Overdigging at the wetland's upper end created a sediment trap that can be dredged by town backhoes from time to time. A weir controls the wetland's water level at its downstream end, where it abuts Flint Creek. Rip-rap prevents erosion of the one-foot drop between the top of the weir and the creek.

The new wetland is named Kilgoblin Wetland. The remaining two acres of the site are planted with prairie grasses. A larger wetland was not possible because of the many underground utilities running across the site. These included the town's sanitary sewer trunk line and a Commonwealth Edison nine-duct electric wire package, which would have been prohibitively expensive to move.

Results

Heinz reports that the new wetland/prairie complex has been well received by local residents. Citizens for Conservation gave Barrington its conservation award for this project and for stream bank stabilization efforts along Flint Creek.

The parcel remains in passive open space. The town does not envision developing it as a park, due to its awkward location surrounded by railroad tracks, and because the tall prairie grass is not conducive to picnicking. However, the town may route a bike path along the property in the near future, if it can reach an agreement with the Union Pacific Railroad to create a bike and pedestrian underpass at an existing nearby railroad bridge.

As for water quality, no one has directly confirmed the treatment benefits of the wetland. However, tests of water quality downstream, conducted during planning for a modification to Barrington's wastewater treatment plant, indicate that the health of Flint Creek macroinvertebrate communities, as measured by the Macroinvertebrate Biotic Index, has recently improved from "fair" to "good." Upstream bank stabilization efforts, as well as the wetland, have probably contributed to this improvement.

Since this project, the town has required a private developer to daylight a section of Flint Creek (see "Additional Completed Projects").

Economics/Funding

Barrington incorporated the wetland project costs into the overall budget for the new storm sewer line project, which came to $800,000, paid from the town's general fund. The wetland project expenses totaled $140,000, not including land costs. The cost to simply extend the 48-inch line across the site would have been $85,000, so the incremental cost of removing the older line and creating the wetland was $55,000. The Board of Trustees felt the additional expense was justified by the potential environmental benefit. In the end, nearly half that amount—$27,000—was reimbursed by the Illinois Environmental Protection Agency, thanks to an unexpected windfall. When the Lake County Stormwater Management Commission found it had leftover Illinois Environmental Protection Agency funds after completing a local creek conditions inventory, it secured approval to transfer the surplus to Barrington to apply toward the wetland project.

Maintenance costs now come to less than $1,000 per year, mainly for annual burning of prairie and wetland vegetation at the site. In a few years, the town will face some additional costs when it dredges the sediment basin.

Challenges and Lessons

John Heinz notes several lessons from this project. First, expectations and hopes must sometimes be adjusted once construction begins. Barrington had to reduce the size and change the configuration of the wetland when the constraining utilities were located.

Second, he observes that the right circumstances must be present to allow a project to happen. In this case, the town was able to condemn the land relatively cheaply and easily because the property was landlocked between railroad lines.

Third, expert opinions may vary about important aspects of a project. In Barrington, an ongoing challenge has been sorting out many different opinions on how to manage the new wetland's vegetation. Some undesirable species such as purple loosestrife and common reed (Phragmites australis) have invaded. Some experts have told Heinz to burn, others say cut, and still others advise use of herbicides. Having now tried all these approaches, Heinz says annual burning with selective herbicide application appears to be working best on this site.

Sources: Heinz 1998/99.

Kilgoblin Wetland after construction. Crews seed the banks, install protective cages around plantings, and prepare to roll out erosion control blankets. Grates cover the two culvert outfalls in the lower left.
Courtesy of Village of Barrington Department of Public Works.

Urbana, Illinois

Embarass Creek

The Urbana Park District re-established roughly 4,000 feet of the headwaters of Embarass (pronounced "Em-bruh") Creek in the early 1970s by plugging and removing farm field drainage tiles at a newly purchased park property. Crews graded a rough channel into the landscape, allowing the creek to surface and redefine its path. This project was probably among the first in the country to re-establish a creek previously hidden by human actions, but it has received little attention to date. While culvert removal is the most recognized means of daylighting, the Embarass Creek story shows that streams can be re-established in other situations as well. Many other streams across the country could be candidates for daylighting via deactivation of drainage tiles.

Watershed:	<1 square mile, suburban
Flow rates:	Small stream; ephemeral in dry summers
Length daylighted:	~4,000 feet of new channel
Year daylighted:	Early 1970s
Project costs:	Unavailable
Primary objectives:	Create stream amenity for new park
Notable features:	Deactivation of farm field drainage tiles to surface the creek

Background

The twin cities of Champaign/Urbana make up a college town of 100,000 people located in an agricultural region of east-central Illinois. As the cities grew in the late 1960s, the Urbana Park District recognized the need for more public parkland and purchased 130 acres of farmland on the outskirts of town to establish Meadowbrook Park. The new park's fields were in the very upper reaches of Embarrass Creek. Previous farm owners had drained the area with clay tile lines—clay pipes, 5 to 40 inches in diameter, placed below the reach of plows and about 100 feet apart. Water seeps in through joints between sections of pipe and drains away, making the heavy lowland soils of this nearly flat region tillable.

Actions

No creek was present on the surface when the land was purchased. The park district plugged or ripped out the drainage lines in the early 1970s, graded a rough channel through the park's low points for the creek to re-establish itself in, and planted the channel banks. Over time the soils became saturated again, and water began to flow on the surface once more on its roughly three-quarters-of-a-mile course through the park. The district has allowed the stream—a small creek that one can jump across throughout most of the park—to meander and define its own channel over the years. Much of the riparian vegetation has recolonized naturally. The district has restored prairie vegetation to large portions of the park.

At the time of the daylighting, few people lived near the park, so no direct neighborhood involvement occurred, either for or against the project. The district did seek public participation in developing the park master plan, which included the daylighting element. Over the years the district has established a strong reputation for serving environmental as well as recreational needs.

Results

"People love the park," says Robin Hall, director of the Urbana Park District. The creek is an important adjunct to the paths, tallgrass and shortgrass prairie areas, community garden, and conventionally landscaped spaces there. To other communities considering daylighting in public spaces he says, "Do it! People are drawn to water in a park. It adds so much." Among the benefits, Hall lists recreational opportunities (kids play in the creek; adults birdwatch there), aesthetic improvements, habitat creation, and runoff control. The creek's floodplain and the park's 80 acres of restored prairie act as a giant sponge that retains water, helping prevent erosion and flooding downstream. The park is now surrounded by housing upstream and by university orchards and forest lands downstream.

Economics/Funding

The park district is a special authority with its own taxing powers under Illinois law, governed by a board of five elected and uncompensated commissioners. It self-funded the daylighting project expenses. Because the project took place so many years ago, the exact costs were not available for this study. However, Hall indicates that the costs were considered low and were simply absorbed into the overall budget for the initial creation of the park. Subsequent landscaping and development of foot and bike paths and other recreational features in the park have been supported by the district's own funds and assistance from the Illinois Department of Natural Resources, the federal Intermodal Surface Transportation Efficiency Act (ISTEA) program, and gifts from individuals, civic organizations, and businesses.

Challenges and Lessons

No major technical challenges arose during the project. Permitting and other regulatory burdens were low at the time. Erosion of some stream banks initially turned out to be greater than desired, so the district subsequently softened some of the banks (reduced their gradient) and replanted riparian vegetation. Since then, maintenance has been limited to occasional pruning and thinning. The district does not mow the prairie areas surrounding the creek.

Beavers have from time to time moved into the area and constructed dams on the creek. When this occurs, park workers install pipes in the beaver dams to regulate the flow, wrap the lower trunks of valuable trees with wire mesh, and monitor the beavers' activities closely. The beavers are tolerated so long as they only take down volunteer streamside willows; the district live-traps and relocates them if they begin felling planted landscape trees or if they breed.

This project shows that streams can be easily daylighted by removing or plugging drainage tiles. Similar projects could be considered in many places. Of course, the extent of stream channel excavation and restoration required to restore a functional stream will depend on the land alteration activities (clearing, filling, leveling, development, etc.) that have taken place subsequent to the installation of the tiles. Fortunately, many tiled fields and watersheds have few roads, buildings, underground utilities, or other "hard" infrastructure, so the amount of open space to work with for re-establishing a stream channel will usually be generous.

Sources: Hall 1998/99.

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Embarass Creek, once sucked dry by farm field drainage tiles, runs once more on the surface through restored prairie. Courtesy of Urbana Park District.

Rowley, Massachusetts

West Ox Pasture Brook

Small private properties no doubt present myriad daylighting opportunities across the country. In Rowley, Massachusetts, multiple organizations cooperated with homeowners to daylight 85 feet of West Ox Pasture Brook in a backyard.

Watershed:	0.35 square miles; low-density suburban
Flow rates:	Unavailable; small perennial stream
Length daylighted:	85 feet of culvert removed
Year daylighted:	1999
Project costs:	$1,200, plus donated materials and time
Primary objectives:	Stream restoration and riparian habitat creation
Notable features:	Backyard daylighting; cost savings on a home septic system replacement

Background

West Ox Pasture Brook drains a small, low-density suburban watershed in Rowley, a small community located about one hour's drive north of Boston. The brook is a small, barely perennial tributary of the Mill River, which flows to the Parker River and then to the Atlantic Ocean at Plum Island Sound. It is culverted and grassed over in some of the residential backyards it crosses.

Rowley Conservation Commission administrator Tim Purinton noticed this section of culverted brook when he walked the lot after its owners approached the commission for a permit to replace a failing septic system. Purinton suggested the homeowners daylight the brook, and offered them assistance to help the project happen.

A number of agencies and organizations took interest. A U.S. Fish and Wildlife service employee helped "sell" the homeowners on the habitat-creation benefits of the project and enrolled them in the Partners for Wildlife program, which protects and creates habitat on private property. The U.S. Natural Resources Conservation Service provided the surveying and engineering necessary to obtain a state wetlands permit. Purinton says of the NRCS, "We couldn't have done the project without them. They put it on paper. And they don't usually take on something this small." The Parker River Clean Water Association worked with the homeowners to develop a planting plan for the restoration.

Actions

A contractor removed the 85-foot, 24-inch corrugated-metal culvert and graded the stream banks in the fall of 1999. As planned, the contractor used the excavation spoils to cover over the new septic system. Volunteers from the Parker River Clean Water Association, supervised by a professional landscaper, mulched the banks with hay and planted various native species. They plan to add some wetland emergent plants at the toe of the banks in the spring of 2000.

Results

Water once again flows at the surface along this section of West Ox Pasture Brook. The homeowners are reportedly pleased to have running water in their backyard. They plan to place a small bridge over the brook, and look forward to the vegetation establishing itself and to an increase in visiting birds and butterflies.

Economics/Funding

The cash costs for this project, primarily for excavation, came to only $1,200. The U.S. Fish and Wildlife Service Partners for Wildlife Program put up $800 and the Rowley Conservation Commission $400. Material and time donations were important to the project. The Parker River Clean Water Association provided plants as part of its waterfront buffer planting program, which is supported by grants from the Essex County Ecology Center, the Massachusetts Riverways Program, and the Massachusetts Environmental Trust (funded by Massachusetts vanity license plate fees). The Fish and Wildlife Service, Natural Resources Conservation Service, and Rowley Conservation Commission all donated staff time on the project.

The homeowners did not contribute toward the daylighting costs. In fact, the project somewhat reduced their costs for the needed septic system—the soils excavated to create the new stream channel were used to help cover the system.

Challenges and Lessons

Purinton reports that the homeowners needed some coaxing and "hand-holding" to agree to the project. Betty Lambright, a professional landscape designer, worked with the Parker River Clean Water Association on the project. Her skills as a native-plants landscaper were critical in convincing the homeowners to consider daylighting the stream. Typical homeowners want to have neatly groomed yards, which is not what most small streams look like when surrounded by natural buffers. Lambright's landscape drawings, and her marketing skills in showing the homeowners photos of the native plants in various seasons, convinced the homeowners that their stream restoration would still look attractive.

The new septic system presented a design challenge. To meet the required 50-foot setback, the new stream curves away from its expected course a bit. The septic system's location could not be adjusted because of the lot's configuration.

Opportunities for projects like this abound. As Becka Roolf of the Parker River Clean Water Association says, “This is perhaps a little different than a typical daylighting of a larger river system in an urban area. Yet I believe many miles of these little tiny creeks pop in and out of culverts all across suburban America—and we need to show homeowners what can be done even on a small, individual scale.”

However, Purinton notes that even this small project took a lot of coordination and effort, especially for permitting. As the administrator of the local conservation commission—which under Massachusetts law has jurisdiction over all work done within 200 feet of perennial streams—he is essentially a “professional permitter,” and brought to the project skills and experience that homeowners and many other local officials might lack.

Sources: Mehaffey 1999; Purinton 1999; Roolf 1999.

A backhoe halfway through removing a culvert and grading the banks of West Ox Pasture Brook in a Rowley, Massachusetts backyard. Courtesy of Rowley Conservation Commission.

Kalamazoo, Michigan

Arcadia Creek

The city of Kalamazoo daylighted a five-block section of Arcadia Creek in downtown as part of a multi-year, multi-million-dollar redevelopment project completed in 1995. While the new channel could not be naturalized, this project does show that waterways can be daylighted in very dense urban centers.

Watershed:	7.4 square miles; urban
Flow rates:	<5 cfs seasonal low flow
	1,015 cfs 100-year peak flow
Length daylighted:	1,550 feet (5 city blocks)
Year daylighted:	1995
Project costs:	$7.5 million
Primary objectives:	Flood relief; creation of downtown amenity
Notable features:	Daylighting in a central business district; use of a confined channel; part of a major redevelopment project

Background

Kalamazoo is a city of 80,000 people at the hub of a concentration of 250,000 people in southwestern Michigan. The city's economy is diverse and supported by several colleges and universities, regional hospitals, a major pharmaceutical company, and a number of manufacturing firms. However, by the mid-1980s, the northern portion of its central business district was in decline. With rundown buildings, increasing crime, and a history of flooding, this core area had come to be perceived as a risky place for investment.

Arcadia Creek had been buried underneath downtown for more than a century. The creek drains a highly urban watershed encompassing much of the city before joining the Kalamazoo River just east of the central business district. As development in the watershed progressed through the middle part of the 20th century, flooding problems increased because the culvert was not sized to accommodate greater runoff from increased impervious surfaces.

Planning began in 1986 for a 13-block redevelopment project intended to attract business to the rundown portion of downtown. An important part of the redevelopment effort was to reduce flooding by increasing the creek's capacity. The city formed a Downtown Development Authority to coordinate and fund the project. Land purchases, public involvement in planning, and preliminary engineering continued into 1990. As part of this process, the idea of daylighting Arcadia Creek surfaced during a national design competition for the redevelopment zone. Some citizens complained that exposing the creek would be too costly, but engineering studies revealed that an open channel could provide the necessary flood capacity at relatively low incremental cost over improving and re-burying Arcadia Creek's aging culvert. The overall redevelopment project went through several iterations, which scaled back costs from the original plans.

From 1989 to 1992, the Downtown Development Authority and its consultants completed engineering studies and design work, secured development agreements, and funded the project. Construction took place from 1989 to 1995. STS Consultants Ltd., an engineering firm with offices throughout the Midwest, led the development of the daylighting portion of the project with comprehensive planning and construction management services.

Actions

Kalamazoo daylighted Arcadia Creek through five large blocks of downtown—three blocks of concrete-lined channel and two blocks as an open stormwater pond with grassy slopes for recreation. Room did not exist to create a meandering, naturalized channel and vegetated riparian corridor through downtown at reasonable cost. Also, because impervious surfaces and storm drain systems cover much of the watershed, the ground water receives so little recharge that the water table has dropped well below the level of the Arcardia Creek channel. An earthen-bottomed stream here would lose water into the area's sandy soils and carry little or no flow except during storms.

The newly opened section of the creek first passes through three blocks in an open concrete channel 20 feet wide by 12 feet deep, fitted with six weirs that pond water in the channel about 1.5 feet deep. Without the weirs, the water would ordinarily flow only a few inches deep. The designers felt that an illusion of deeper flow would prove more attractive. At the same time, they kept the weirs relatively low to retain considerable flood capacity between the weir tops and the top of the channel. Slowing water in the channel also causes the creek to drop much of its sediment load there, where a small front-loader can periodically scrape silt off the concrete bottom with relative ease, reducing the frequency of more difficult dredging operations at the earth-lined, grass-banked stormwater pond downstream.

A stormwater pond completes the final two blocks of the daylighted section of Arcadia Creek. Its gentle, grassed slopes provide an area for people to relax and recreate. This landscaped area and an adjacent parking lot are also used as a festival site. The total length of the reopened system is 1,550 feet, including the channel, several wide bridges, and the pond. Downstream of the pond, Arcadia Creek passes underground for another nine blocks before joining the Kalamazoo River. In this section, engineers used the existing culvert and constructed an additional new culvert to increase storm capacity.

Results

The combined channel, stormwater pond, and double culvert provide Kalamazoo with protection from a 500-year flood. Authorities have now redrawn local floodplain maps. Downtown properties no longer pay flood insurance, and the perception of flood vulnerability has been lifted.

The flood-protection benefit and amenity value of the creek combine with the overall redevelopment effort to boost the attractiveness of Kalamazoo's downtown for private investment. Ken Nacci, director of the Downtown Development Authority, puts it succinctly: "What we have is much better than what we had." Public-sector investments of $18 million for the entire redevelopment project have leveraged more than $200 million in private development, including a new museum, a bank headquarters, and other institutions and businesses. Property tax revenues to the city from the redevelopment zone have increased from $60,000 to $400,000 annually. Activities at the new festival site by the stormwater pond generate an estimated $12 million annually in sales and payroll for local businesses.

Economics/Funding

Of the city's $18 million investment, $7.5 million were related to the creek corridor project, including environmental assessments, engineering, and construction. Much of the expense related to technical challenges described below. To pay for the investments, the Downtown Development Authority issued bonds based on tax-increment financing; these bonds are now being repaid by property-tax revenues from the redevelopment zone. Private philanthropic organizations helped reduce costs to the city by funding acquisition of some of the necessary properties.

The Downtown Development Authority pays the maintenance costs associated with the channel and pond (sediment and trash removal, mowing, and so on). These costs average $50,000 per year—more in years when pond dredging is required, considerably less in other years. "The channel has worked beautifully," says Nacci, "but you do have to maintain it for silt, weeds, algae, and so on."

Challenges and Lessons

This project daylighted a sizeable stream in a dense downtown setting. The proximity of the culvert and the new channel to several existing buildings required special measures to shore up foundations during and after construction. Contaminated soils also produced significant challenges. Because Kalamazoo's downtown was once subject to heavy industrial use, the engineering work for this project included both surface and subsurface environmental assessments. Soils in a number of locations required excavation and replacement; in others, contaminated soils were capped. These structural and environmental measures contributed significantly to the $7.5 million price tag for the stream corridor work, though one capping project saved the city $1.3 million versus the expected costs of excavation.

In addition to the technical solutions to the contaminated soil problems, the city decided to maintain ownership of the land to protect developers from potential environmental liabilities. The city leases out each parcel in the redevelopment

The daylighted section of Arcadia Creek, beginning near the top center of this photograph, runs through three full city blocks in downtown Kalamazoo, Michigan, then opens into a stormwater pond. Courtesy of STS Consultants, Ltd.

zone, and indemnifies developers from future environmental problems related to the site.

The aged infrastructure under downtown created some surprises for the city public works department and some property owners. Crews found (and often broke) a number of unmapped water service lines. Also, after they sealed the old storm culvert, some buildings experienced water backups because roof drains or basement sumps had been connected directly to the culvert instead of tapped into official laterals.

The city razed several buildings during the redevelopment effort. This provoked concerns over historic preservation and integration of new buildings with Kalamazoo's existing architectural flavor. As a result, the city instituted a commission that reviews new buildings for their sensitivity to local architectural conditions.

Asked his advice for other cities considering major projects like this, Ken Nacci said it's important to remember that "things like this don't happen overnight." Kalamazoo's project took almost 10 years from inception to completion. And once the construction is done, the work is not all over. Says Nacci: "You can't build it and let it set there. We still have some available properties, and could have done a better job marketing the redevelopment zone to the world."

Sources: Nacci 1999; Sheff 1999; STS Consultants 1999.

St. Paul, Minnesota

Phalen Creek

Daylighting projects do not necessarily have to commit all a culvert's flow to an open channel. In 1987, the city of St. Paul daylighted 2 cfs of Phalen Creek's flow as part of a culvert reconstruction and park development project.

Background

The lower portions of Phalen Creek, meandering through a hollow below the bluffs on which downtown St. Paul is built, supported an industrial shantytown from the mid-1800s to the 1950s. Once featuring outhouses propped directly over the creek, this was a low-rent settlement area for waves of immigrants: Swedes, then Italians, and finally Hispanics. The creek was culverted over the years, and the housing stock deteriorated badly throughout much of the 20th century. In about 1956 the city condemned and razed all the buildings there. The area lay neglected throughout the 1960s, accumulating illegally dumped refuse.

In the 1970s, community members and the St. Paul Garden Club began cleanup and replanting efforts. The city made the area into Swede Hollow Park, and people began to discuss reopening the creek. The St. Paul Public Works Department began making plans for storm and sewer line improvements in Swede Hollow in the mid-1980s. Then, in 1986, a major storm blew out much of the infrastructure in the hollow and provided an opportunity to implement something unique. With urging from residents and Olivia Dodge, a well-connected Garden Club member, the city agreed to restore a portion of Phalen Creek's flow to the surface. Because of the very large storm volumes in Phalen Creek, the confined topography of Swede Hollow, and concern for other infrastructure running through the hollow, the city did not choose to daylight the entire flow of the creek.

Actions

In 1987 the city installed a 108-inch reinforced-concrete culvert through Swede Hollow. Where this culvert enters the park, the city installed a manhole with a sump and gate valve that allow water to flow out the bottom of the main culvert into a 21-inch reinforced-concrete culvert. This smaller culvert runs underground for about 100 feet, then opens to a small sediment-settling pond. From there, a small creek channel runs a few hundred feet to a second, larger pond. This channel is surfaced with grouted limestone in places, due to its steep slope and the constraints posed by water and sewer pipes running underneath it. From the second pond, the creek meanders over 1,000 feet through the hollow's flatter bottom land. It then enters a third pond, the largest, which has a drain at its lower end where water re-enters the main culvert for its remaining three-quarters-of-a-mile trip to the Mississippi underneath various streets and highways and a railyard. The daylighted channel and ponds total about 0.4 miles in length. Throughout the park, the creek and ponds are surrounded by planted grasslands, pre-existing woodland, paths, and benches

Watershed:	2.4 square miles; high-density residential and industrial
Flow rates:	~2 cfs (continual controlled flow)
Length daylighted:	~2,100 feet of surface channel and ponds created
Year daylighted:	1987
Project costs:	Unavailable
Primary objectives:	Create stream amenity for park
Notable features:	Partial-flow daylighting

Results

The diversion structure passes a constant flow of about 2 cfs into the recreated stream channel. This is its maximum capacity—most storm-event water continues down the main culvert. Storm flows in the culvert were not available for this study, but given the size (over two square miles) and high imperviousness of the watershed, large storms probably produce flows of many hundreds of cfs. Base flows were also unavailable. However, this much is known: discharges into the main culvert of cooling-tower effluent from a Stroh's brewery and a 3M manufacturing plant, both sourced from local ground water, have historically exceeded 2 cfs, and join an unmeasured amount of natural base flow in the culvert. Thus the daylighted stream enjoys a steady flow and little erosion of its banks from stormwater pulses.

This configuration also creates some issues. Because the diversion is off the bottom of the main culvert, considerable amounts of sediment flow into the creek and settle out in the three ponds. (No one contacted for this study knew the maintenance/dredging schedule.) Also, the cooling-tower water is treated with a biocide. Sometimes the water diverted into the open stream consists almost entirely of cooling-tower effluent. As a result, the stream has historically had little aquatic life, though goldfish introduced to the middle pond in 1990 have thrived. However, when the Stroh's brewery closed and its cooling-tower discharges ceased in 1998, the ratio of biocide-treated effluent to creek water and stormwater dropped. While continuing discharges from the 3M plant help maintain the diversion at capacity, biocide-treated water now makes up a low enough proportion of the total water flowing into the open stream that some additional life is returning. Macroinvertebrates and amphibians have recently been observed.

The stream and ponds provides a restful amenity for users of the park. Local environmentalists note that the ponds prevent some sediments from reaching the Mississippi River, and they believe the stream and pond system captures some nutrients and other urban pollutants.

A major restoration initiative is now under way in the area between Swede Hollow Park and the Mississippi River. A community-based organization, the Lower Phalen Creek Project, has raised approximately $1 million to date. Proponents are negotiating purchase of an abandoned 25-acre Burlington Northern Santa Fe railyard. A portion of this land will be placed in a conservation easement. Preliminary plans for a large wetland (fed by local streams and storm drains), paths, and wildlife habitat are already drawn up. If successful in this first phase, restorationists hope eventually to develop a second phase that would daylight some of Phalen Creek in this riverside brownfield area.

The Lower Phalen Creek Project is also now promoting measures to filter stormwater in the urban neighborhoods above Swede Hollow, before it reaches the park. Demonstration rain gardens have been installed or are planned at several residential, commercial, and school sites, and educational programs are under way for schoolchildren and homeowners.

Economics/Funding

Sources did not recall cost figures for this project, and the information was archived years ago and not available for this study.

Challenges and Lessons

According to Pat Byrne of the St. Paul Public Works Department, the only significant stream design question was how much of the channel to reinforce. Creating the flow splitter was a fairly straightforward design and construction chore.

This project shows that partial-flow daylighting is an option worth considering when full-flow daylighting is too complicated or costly. Partial-flow daylighting is an especially interesting option when storm flows are very large and when topographic, land use, infrastructure or other conditions raise concerns about managing the flow entirely in an open channel. It also shows that designers must still consider sediment-transport issues and how a flow-splitting structure will affect the qualities of the water reaching a daylighted channel.

Sources: Middleton 1999; Middleton and Olson 1997; Byrne 1999.

Roscoe, New York

Darbee Brook

When a major storm blew out a deteriorating culvert on the grounds of the Roscoe Central School, federal emergency aid provided the final funding necessary to implement a previously proposed and partially funded daylighting project. Local angling groups supported the project because it removed a major barrier to upstream fish passage on Darbee Brook. The school gained improvements to its athletic fields and opportunities for new stream-based curricula. While this daylighting project could not incorporate a significant floodplain due to site constraints, all parties consider it a considerable improvement over the old culvert, and it cost less than a conventional culvert replacement.

Watershed:	~1.5 square miles; agricultural and residential
Flow rates:	~0.5 cfs seasonal low flow 30-40 cfs annual peak flow
Length daylighted:	330 feet of culvert removed 160 feet of new channel
Year daylighted:	1996
Project costs:	$9,000, plus undetermined earthmoving costsand donated services, materials, and labor
Primary objectives:	Replace deteriorating culvert; improve school playing fields; allow fish passage
Notable features:	Trade-offs to achieve a win-win project for school, state regulators, and fishing groups; less costly than culvert replacement

Background

Darbee Brook is a low-gradient, ground-water-rich tributary to the Beaverkill, a world-famous trout stream in the Catskill region of southeastern New York. The last 330' of the brook was culverted in the 1960s, when the New York Department of Transportation offered the Roscoe Central School road fill to build up and extend its playing fields into former floodplain. The culvert terminated several feet above the normal water surface elevation of the Beaverkill, effectively preventing fish passage into Darbee Brook for spawning or thermal refuge in its cool, spring-fed waters. While native brook and wild brown trout continued to live in the stream, its value to the Beaverkill system was significantly diminished by the culvert. This loss was especially poignant to many anglers because the Darbee Brook culvert emptied into Junction Pool, one of the most storied pools in the world's fly-fishing literature.

The culvert had subsided since its installation in the 1950s, causing damage to the school's athletic fields. In 1994, when the school approached the New York Department of Environmental Conservation (DEC) about this problem, Ed Van Put and Jack Isaacs of the department suggested replacing the culvert with an open channel. Van Put approached local fishing organizations for financial assistance and secured limited funding from Trout Unlimited.

Then, in January of 1996, a major thaw and rain event caused extensive flooding damage around Roscoe, a town of 4,000, and surrounding rural communities. The Roscoe school's field sustained further damage. The Federal Emergency Management Agency provided funding to the school and the region for repairs and measures to mitigate damage from any future flooding. At this point Trout Unlimited went to the school board at the state DEC's prompting to explain the financial, biological, and hydraulic advantages of returning Darbee Brook to an open channel. The school board voted unanimously for the proposal.

Actions

The DEC's Isaacs and Trout Unlimited's Jock Conyngham collaborated on the design. Conyngham says that limited time, funding, and site constraints required design "on the fly"; they could not undertake rigorous geomorphic studies as he would have preferred. The design was mainly based on a few measurements of channel widths for representative riffles in the brook above the culvert. A retired local New York Department of Transportation engineer prepared the construction drawings.

In late 1996, crews constructed a new 160-foot-long channel, diverted Darbee Brook into it, then replaced the 330-foot-long, 48-inch-diameter metal culvert with fill, providing a new, stable base for the football/general purpose athletic field. The new channel was shorter than the culvert because it took a more direct route to the Beaverkill. In addition, contractors relocated 100 feet of the open portion of Darbee Brook immediately above the daylighted section. This allowed the school to improve and formalize a previously substandard soccer field. The DEC judged that this additional disturbance would not be unduly detrimental to the stream.

The daylighted and relocated brook runs between a softball field and a swimming pool in a corridor about 25 feet wide. At summer flow levels, the brook gently meanders in a two-foot wide channel through this corridor. The banks are planted with willows, poplar, birch, ash, and other native species. Students and volunteers from local fishing groups and the community did much of the planting and placed a footbridge over the newly opened brook. Volunteers also maintain the new brook.

Results

Electrofishing samples subsequent to the restoration have documented fish entry into the system from the main river as well as utilization of the opened channel by a diverse assembly of aquatic species. Says Ed Van Put, "For once, we were delighted to find hatchery fish in a wild trout stream, which proved fish were coming up from the Beaverkill. I've worked for the DEC for 30 years and have administered many stream disturbance cases. This was the first time where we could take a stream out of a culvert and make it live again, which was what was really exciting about this project." In addition to the Darbee Brook ecological benefits, fishing groups also gained a new access parking lot and revegetation of some of the Beaverkill's banks on the school grounds as part of the project.

The Roscoe Central School has regained an attractive stream and living laboratory on its grounds. According to George Will, superintendent for the 350-student, K-12 school, the restored brook will be the focus of a new environmental science summer camp and the basis for an elective senior science course on water chemistry. The restoration has already augmented two ongoing science curricula. The third-grade "River in Our Backyard" program teaches children how local brooks and rivers, including the aquatic insects and streamside shade trees as well as trout, support the tourism- and fishing-based economy of Roscoe. In the sixth grade, students grow trout in an aquarium, learning about biology and chemistry in the "Trout in the Classroom" program before they release the fish into Darbee Brook.

Economics/Funding

Trout Unlimited contributed $9,000 to earthwork, revegetation, and fencing. In turn, its source for this support included grants from the National Fish and Wildlife Foundation, the Trout and Salmon Foundation, Prospect Hill Foundation, the National Park Service, American Forests, and the Orvis Company (a fishing equipment manufacturer). Trout Unlimited also arranged a donation from Outdoor Life magazine for nursery tree and plant stock, which was provided at cost by Haledon Nursery, a company based in New Jersey, where many Beaverkill anglers live.

Funds from the Federal Emergency Management Agency contributed to the project, but the amount could not be determined as the earthmoving expenses it supported were not separated from other non-stream-related work at the school. While the school did not make a direct cost comparison, Superintendent Will believes opening the brook was far less costly than the alternative of replacing the culvert, which was estimated at $45,000-50,000. The school did not incur any out-of-pocket expenses for this project thanks to the support from FEMA and the organizations mentioned above. Volunteer labor and donations of time for design and permitting were important cost-cutting measures for the project. Also, inmate work crews from a nearby prison installed a fence along the brook.

The Roscoe school's stream- and trout-based curricula are supported by the Catskill Fly-Fishing Center, Trout Unlimited, and the Theodore Gordon Fly Fishers. These organizations have spread some of these programs to other schools.

Challenges and Lessons

This project illustrates that compromises and trade-offs must sometimes be made to achieve a daylighting project. According to Jock Conyngham, the new configuration is infinitely better than a culverted brook, but less than ideal because it does not include sufficient meander sinuosity in an appropriately sized floodplain. Building those features would have cut unacceptably into the school's playing fields and incurred significant expenses to move excavated fill. Relocating part of the already open channel was a minor ecological trade-off, but a worthwhile one to make the project more viable for the school. The school gave up some flat, open spaces on its grounds for the brook corridor and revegetation along the Beaverkill, but obtained increased functionality on two athletic fields. In the end, everyone got something much better than they started with.

Ed Van Put notes that the politics of seeking financial support can get interesting. One fishing group he approached refused to support the project unless the DEC would declare Darbee Brook a catch-and-release-only fishery. The DEC would not accept this condition because the brook is where many local children catch and take home their first fish.

Sources: Conyngham 1999; Van Put 1999; Will 1999.

Port Angeles, Washington

Valley Creek

The Port of Port Angeles (a special-purpose district adjacent to the city of Port Angeles) and a lumber mill recreated an estuary by removing 490 feet of culvert in 1997, in part to improve efficiencies at the mill. This project demonstrates how businesses, local government, and citizen groups can make daylighting an economic, environmental, and civic win-win project.

Watershed:	4.2 square miles; forested and urban
Flow rates:	15 cfs average base flow 120 cfs 2-year peak flow 545 cfs 100-year peak flow
Length daylighted:	490 feet of culvert removed
Year daylighted:	1997
Project costs:	$1 million, including park amenities; includes value of considerable donated time and materials
Primary objectives:	Reduce costs for an important local business, retain jobs, create habitat and recreational amenity
Notable features:	Restored a coastal estuary; high return on investment for a business

Background

Valley Creek flows northward from the foothills of the Olympic Mountains of northwestern Washington to the south shore of the Strait of Juan de Fuca, draining a watershed of 4.2 square miles that is rural and forested in its upper reaches and increasingly urban toward the strait. Reaching Port Angeles, a city of 18,000 people, the creek traverses a residential area, then flows 2,000 feet (pre-daylighting) through an industrial area in an 84-inch culvert before emptying into the strait just east of the Port of Port Angeles's marine terminals. The Port is a special-purpose district established by Washington state legislation to promote economic development; it cooperates with but is a separate entity from the city of Port Angeles. The area is moving from an economy based strongly on sawmills and fish processing to tourism, services, and desirability as a retirement location.

In the late 1980s, the K-Ply plywood mill at the port lost its source of cedar logs due to logging restrictions in the region, and turned to cottonwood. Loggers previously floated the cedar along the shore and into the mill's log pond; after the change, truckers shipped in the cottonwood and unloaded it at a staging area located where Valley Creek's estuary had been filled and culverted years ago, on the other side of the log pond from the mill. Moving the logs around the now useless log pond was costing the mill an extra $150,000 a year.

The K-Ply mill and the Port proposed in 1993 to fill the log pond so that the staging area could be relocated there, next to the mill. State regulators insisted on mitigation for loss of the open water habitat of the log pond. Recreating the Valley Creek estuary at the to-be-abandoned staging area provided an obvious opportunity. Excavation to recreate the estuary would also provide much of the necessary fill for the log pond. The mill, the Port, and the Port's engineering consultant Parametrix, Inc. enlisted the help of the City of Port Angeles and local volunteer groups such as the Soroptimist Club (a women's service organization) and Rotary Clubs to design a restoration plan and public park. Public enthusiasm for the project was strong. Local engineering companies NTI and Polaris and the Lindberg local architectural firm donated professional services. Four years of permit negotiations and planning led to construction in late 1997.

Actions

The project involved removing nearly 400 feet of the seawall along the Port Angeles harbor, excavating a 2.8-acre estuary, filling the log pond with the spoils, removing the lower 490 feet of culvert pipe, and installing habitat-enhancement features such as shading logs, beach logs, and root masses. The creek now flows from the shortened culvert in a stream-like but tidally influenced channel for its first 50 feet. It then meanders through the estuary and empties into the strait in a manner that closely resembles the original natural flow. The estuary is largely open water, with some marsh along its banks. Some of the banks are reinforced with rip-rap to prevent erosion from wave action.

The remaining 1.2 acres of the four-acre project surround the estuary in upland areas for the new park. Local volunteer groups are landscaping this area as funds become available. They have routed the Port Angeles waterfront trail around the estuary and installed a viewing tower, and are now raising funds for interpretive signage.

Results

The estuary park is a popular draw. Located close to downtown, it provides an opportunity for people to see waterfowl and other birds and experience a naturalized break in the seawall that fronts the harbor. The habitat value of the new estuary is considerably higher than the old industrial mill pond. Students from Peninsula College monitoring the project have documented an increase in the number of species, and have sighted salmonid smolts feeding within the estuary.

Economically, the project is a success as well. For its $200,000 investment (see below), the mill has reduced log movement costs by $150,000 annually. The project helped keep the mill from relocating elsewhere; the city kept the mill's 200 jobs, and the Port retained an important tenant.

The community is considering daylighting additional portions of the Valley Creek culvert. Some studies have been

The newly recreated estuary of Valley Creek in Port Angeles, Washington. The project used excavation spoils from the estuary to fill the K-Ply mill's log pond, once located where the log piles lie between the estuary and the mill. Courtesy of Port of Port Angeles.

done, indicating the engineering could be difficult and the costs considerably higher, but the idea is still in discussion.

Economics/Funding

According to David Hagiwara, deputy executive director at the Port of Port Angeles, this was a roughly $1 million project once all cash transactions and the value of donated time and materials are totaled. There were three major cost categories: excavation and filling, estuary restoration, and aesthetics. The value of the work and materials to excavate the estuary and fill the log pond amounted to $500,000. The K-Ply mill invested about $200,000 in equipment time and labor to excavate the estuary and move the spoils to the log pond. The estuary dig produced about two-thirds of the fill needed for the mill pond. For the other one-third, local construction projects donated about $200,000 worth of fill material, and the Port provided another $100,000 of fill.

The work of shaping and restoring the estuary was valued at $215,000, but this figure was also reduced by in-kind donations. The Port of Port Angeles paid $150,000 to contractors to remove the culvert, shape the estuary banks, and place armor rocks, beach cobble, shade logs, root wads, and other structures. Local construction projects, including a nearby highway bypass that had uprooted a number of mature trees, donated $65,000 worth of root wads and other materials.

The third cost category—totaling $300,000 and the object of ongoing fundraising—includes landscaping the uplands, creating a trail, constructing a viewing tower, and placing interpretive features. Two local health maintenance organizations donated funds toward these expenses—the Clallam County Physicians pitching in $30,000 and the Virginia Mason Hospital Association $40,000. Numerous citizens and businesses have donated or funded benches, light posts, and other amenities. Individuals and families have "sponsored" bricks (which can be imprinted with names) for the trail at $25 per brick. The Soroptimist Club has held many fundraising events, including a recent "Reno Night" that netted $16,000.

Parties to the project will incur some additional costs when an additional 1.2 acres of mitigation is developed, as described below.

Challenges and Lessons

Permitting this major project took a long time, much of it for negotiations over mitigation ratios. The state wanted the mill and Port to create two or three times as much habitat as the area to be filled at the mill pond. The proponents argued that the habitat value of the mill pond was very low, so the mitigation ratio should be substantially reduced. Eventually, the parties settled on a roughly one-to-one ratio. The limited four-acre space available required the designers to balance creation of open estuary habitat and upland park areas. The state allowed mitigation credit only for the area below the estuary's mean high water mark, a total of 2.8 acres. Because the log pond was 3.9 acres, the mill and Port must still find another 1.2 acres of mitigation. Probably this will be provided by stream restoration opportunities now under consideration in Valley Creek upstream of the city.

Potential vulnerability of the estuary to waves and storm surges was a significant concern in the design and construction of its edges and banks. The designers and regulators had to strike a balance between naturalized marsh and beach edges and rip-rap protection for exposed areas. A city sewage pump station posed a particular constraint—it was protected by keeping the area around it in upland and protecting that area's bank with rip-rap.

Asked for his advice, Ken Sweeney, planning and environmental manager for the Port of Port Angeles, echoed the advice of other daylighting project veterans: "Line up as much community support in advance as possible." Getting buy-in from the community, he said, is essential to smooth sailing through the regulatory and planning processes. Gathering all the relevant agencies together prior to official permitting actions is another key step, he noted, to make sure that "everyone is on the same page."

Sources: Hagiwara and Sweeney 1999; Port of Port Angeles 1999.

Maple Valley, Washington

Jenkins Creek

As part of a comprehensive watershed management plan, in 1994 and 1996 the King County Surface Water Management Division daylighted sections of Jenkins Creek previously culverted under a golf course fairway and a county park parking lot. These projects created a total of 1,500 feet of new channel and removed obstructions to salmonid passage. Altogether, the division improved a mile of Jenkins Creek through daylighting, additional surface channel restoration work, and public education campaigns.

Watershed:	Phase 1:	1.6 square miles; rural and mid-density suburban
	Phase 2:	0.6 square miles; rural and low-density suburban
Flow rates:	Phase 1:	3.3 cfs mean annual flow 39 cfs average annual peak flow 55 cfs 100-year peak flow
	Phase 2:	1.7 cfs mean annual flow 6.8 cfs average annual peak flow 24 cfs 100-year peak flow
	Low summer flows—ephemeral some years	
Length daylighted:	Phase 1:	800 feet of new channel
	Phase 2:	700 feet of new channel
Year daylighted:	Phase 1:	1994
	Phase 2:	1996
Project costs:	Phase 1:	$645,000, including purchase of an easement
	Phase 2:	$400,000
Primary objectives:	Improve upstream salmonid passage and spawning/rearing habitat	
Notable features:	Daylighting on golf course and daylighting of a parking lot; design for fish passage and habitat	

Background

Portions of the Soos Creek basin southeast of the city of Seattle are experiencing some of the most rapid growth in metropolitan King County. To address increased flooding, erosion, sedimentation, degradation of water quality, and loss of fish habitat, the King County Surface Water Management Division prepared the Soos Creek Basin Plan in 1990. The plan recommended a variety of land use controls, educational programs, monitoring activities, and capital improvement projects.

One set of capital improvements focused on the first mile of Jenkins Creek, which flows from Lake Wilderness, site of a county park. Development had significantly altered this ephemeral stream. Two sections ran in pipes placed in the 1950s and 1960s, preventing fish access to the 69-acre lake and additional habitat upstream and impairing water quality downstream. Water-level control structures for wetlands and detention basins in the first mile also obstructed fish passage and caused sedimentation of the streambed. Lower sections of the creek remained relatively intact as fish habitat and riparian corridor.

The Soos Creek Basin Plan recommended that projects on Jenkins Creek be designed to emphasize repair and protection of aquatic habitat, while simultaneously reducing flooding and controlling flows resulting from additional development. Studies to determine how to achieve these objectives began in 1993. The daylighting option emerged through these technical reviews. A fish habitat survey confirmed the presence of salmonids downstream, identified fish passage barriers, recommended new channel configurations and features, and noted the need for riparian revegetation to reduce high water temperatures. Other consultants studied the stream's hydrology and identified hydraulic elements, including wetlands, culverts, weirs, and detention ponds along and adjacent to the first mile of the creek. A route feasibility study examined right-of-way needs for various routes of a restored channel. A geotechnical firm analyzed foundation conditions at the site of a recommended new bridge. In mid-1994 this work led to the completion of designs, which called for daylighting two sections of the creek in a two-phase project. After completion of Phase I, additional design work on the second phase was completed in 1996.

The county hosted extensive public meetings during development of the Soos Creek Basin Plan. As the Jenkins Creek project proceeded, the county called two additional public meetings, one for each of the sections to be daylighted. In addition, county officials met informally with area residents. Local residents raised no major concerns with the projects on Jenkins Creek, known locally as the "Lake Wilderness channel improvements."

Actions

The overall project is divided into three segments:

1) In the downstream-most segment, which was completed in 1994 as part of the Phase I effort, the county replaced a pipe that ran under the 18th fairway of the Lake Wilderness Golf Course with approximately 800 feet of new surface channel. This project required purchase of an easement from the golf course owner. The designers incorporated the waterway into the golf course as a water hazard, and landscaped it with shorter trees and shrubs rather than taller canopy trees so as not to interfere with golfers' shots. Contractors installed a new golf cart bridge and culverts for a road and a driveway. These culverts are

77-inch corrugated metal arch pipes with gravel bottoms that are more conducive to fish passage than ordinary pipes. To reduce percolation of water out of the streambed during low-flow periods, the engineers underlaid the project with a six-inch impervious clay layer. In a few locations, they cut holes in the clay layer to allow known springs to feed ground water into the creek. This helps cool the creek during the summer.

2) The middle segment, also addressed during Phase I, passes through an area of single-family homes. Many of the homeowners had cleared surrounded vegetation from the existing surface channel, creating erosion problems. Given the land use and multiple ownerships, the county chose a public-information approach over acquiring rights-of-way for structural interventions. During 1994 and 1995, the basin steward (a county employee designated in each major watershed to liaise with the public) and other county officials educated local residents about the objectives for restoring Jenkins Creek, explaining why residents should not fertilize to the creek edge or dump grass clippings or other refuse into the waters, and how to landscape in ways helpful to the creek. The outreach techniques included a public meeting and mailing of a "Streamside Savvy" brochure.

A section of Jenkins Creek shortly after daylighting, showing meanders and vewly installed habitat features such as root wads and control logs. Courtesy of Ken Nilsen.

3) Phase II addressed the upper segment in Lake Wilderness Park, which prior to the project passed under a parking lot and then through a wetland. The county parks department, after extensive negotiations, agreed to reduce the size of the parking lot to make room for daylighting the creek. In late 1996, the King County Surface Water Management Division removed the culvert and created 700 feet of new channel and restored another 500 feet of the existing creek. Landscaping was completed in early 1997.

Construction of both daylighted segments involved recreation of a floodplain as well as development of the stream channel itself. The floodplain in this project could be smaller than that of similar streams in the region, as Lake Wilderness acts as a natural "detention basin," attenuating storm and snowmelt runoff. However, the designers did build in extra capacity to accommodate increased flows from future development. Vegetated biofiltration swales intercept pollutants and sediments flowing off roads and parking areas toward the stream. A lip graded into the slopes just above the floodplain at the golf course project captures, infiltrates, and filters some of nutrient-laden runoff from the golf course.

While the work was under way, the creek flow was rerouted through temporary pipes around the sites. Gravel bars placed to divert the flow later became part of the streambed material.

As the primary project objective was to improve fisheries, the project engineers, fishery biologists, and contractors gave considerable attention to developing optimum channel depth and velocity conditions to create spawning beds, rearing areas, refugia pools, and other habitat needs. This attention began with field surveys, continued through hydraulic modeling of channel geometries, and culminated in grading of the pool/glide sequences and installation of appropriate gravel spawning substrate, cobble and boulders, root wads, fill trees, control logs, and other structures.

Results

The King County Department of Development and Environmental Services' grading permit required that the project be monitored for three years following construction. The final monitoring of the golf course segment, in 1997, showed that stream structures were still intact, even after high flows the previous two winters. A number of landscaping trees and shrubs had died, but overall survival rates were good for all species except western red cedar, which was probably an inappropriate choice for exposed locations along the reach. The monitoring technician noted that some noxious species, particularly Scotch broom, were beginning to invade the area, and he recommended their removal. He also observed coho salmon in the project area during November and noted one possible spawning redd, indicating salmonids were passing through and using the channel as hoped. However, in August the channel was dry except for three pools, all of which had temperatures too high for salmonid survival. Project sponsors hope the pools will stay cooler once riparian vegetation has grown enough to shade the stream.

Public reaction has been favorable. Golfers reportedly like the new water hazard. Some residents in the middle segment have taken stream protection to heart. The county hopes peer pressure will turn the remainder around over time. At the park, the recent work is rapidly naturalizing.

In 1995 the golf course project and three other capital improvement projects in the Soos Creek basin together won first place nationally as the U.S. Environmental Protection Agency's Outstanding Municipal Stormwater Control Program.

Economics/Funding

Costs for the Phase I daylighting at the golf course totaled \$645,000, including \$289,000 for design, permitting, and right-of-way acquisition, and \$355,200 for earthmoving, labor, channel and landscaping materials, and other construction expenses. The Phase II daylighting at the county park totaled \$400,000, with \$159,300 for design and permitting and \$240,700 for construction. Since the park was owned and operated by King County, there was no charge for the stream easement. The county did not use volunteer labor in these projects. Maintenance and repair expenditures to date have been insubstantial. The county tried to minimize future costs by using vegetation that would not require pruning or other follow-up.

These costs were all paid by the King County Surface Water Management Division. No other agencies or funders were involved. The Division is self-funded by a "surface water charge" billed semi-annually along with property-tax assessments. Residential properties pay a flat fee of \$84 per year. Commercial properties pay a rate based on the proportion of the property in impervious surface. At one time the division funded capital improvement projects only from accrued revenues, but in recent years it has accelerated projects by issuing bonds to be paid off with future surface water charge revenues.

Challenges and Lessons

The Lake Wilderness channel improvements were not overly difficult to develop and implement. Acquiring permits was relatively straightforward for the capable consulting team and the King County Surface Water Management Division. In addition to the grading permit mentioned above, other required permits included a Washington Department of Fisheries Hydraulic Project Approval and a Washington Department of Ecology Temporary Water Quality Modification Permit.

The low density of surrounding land use allowed some freedom in designing the restored channel, and single ownerships in the two daylighted sections facilitated design and right-of-way negotiations. However, according to Ken Nilsen, King County's project engineer at the time, working with the parks department and the local public on the disposition of the parking lot was a lengthy process. The public reacted negatively to the parks department's original proposal to move the parking to a ball field. Eventually the department and public accepted simply reducing the amount of paved parking in the park. On the few days each year when parking capacity is exceeded, overflow parking on grassy areas is allowed.

Nilsen notes that stream restoration design work is guided by project objectives, but also constrained by site conditions. In the case of the golf course segment, maximizing spawning habitat was an objective, but the gradient was insufficient to establish the velocities needed to flush sediments from gravel beds throughout the reach. This condition obligated designers to use most of the gradient in short sections and accept long, slow areas in the remainder of the reach. Much of the channel design was based on the "50 percent exceedance flow" that typifies flows at critical times for salmonids—the upstream spawning run in the November to January period, and the out-migration of fingerlings during February to April.

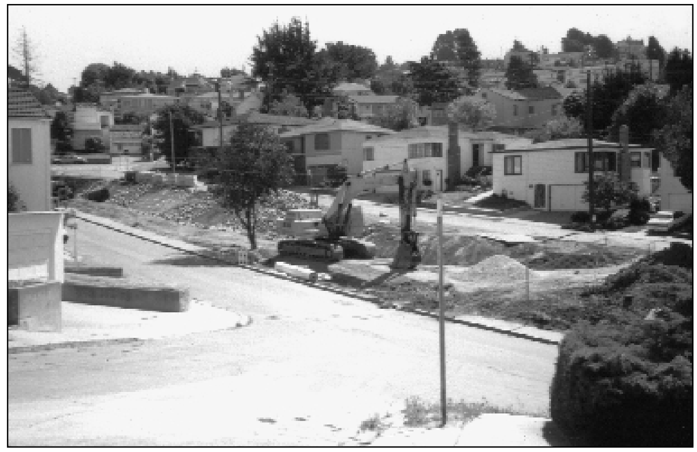
Nilsen also observes that using native landscaping is not always straightforward from a public relations perspective. Many people envision a channel bordered with the exotic species they are accustomed to from standard landscaping practices and nursery stock. Landowners and the public must often be educated on the beauty and functional superiority of native species.

An additional public relations challenge presented itself the first year after construction of the Phase II project. Unusually heavy rains raised the level of Lake Wilderness, flooding some docks and shoreline structures. The county had to educate lakeside property owners that the high water level was natural, correcting some perceptions that the stream restoration project had somehow backed up flows from the lake.

Sources: Alpha Engineering Group 1994; King County Department of Surface Water Management 1997; King County Surface Water Management Division 1990; Nilsen 1998/99.

ADDITIONAL COMPLETED PROJECTS

These projects are presented in less detail, either because time did not permit development of full case studies or because detailed information was not available. Nonetheless, these descriptions—brief as they are—reveal interesting situations and experiences.



Construction of the Baxter Creek daylighting project at a hillside park in El Cerrito, California in 1996. Courtesy of Lisa Owens-Viani.

El Cerrito, California

Baxter Creek

When El Cerrito passed a bond measure in the mid-1990s to replace failing stormwater drains, the California Urban Creeks Council helped the city obtain a grant to add daylighting of a 250-foot section of Baxter Creek in Poinsett Park to the project. The park was simply a 75-foot-wide patch of grass between two streets in a hillside residential neighborhood. Unfortunately, the initial project engineers, unfamiliar with stream restoration, implemented a design with a straight V channel and sharp rip-rap along the banks. The banks were steeply sloped in order to preserve some lawn areas around the perimeter of the narrow strip of park, but created a hazard for children to slip and fall into the creek. Neighbors complained and eventually the city called in the Waterways Restoration Institute to redesign and reconstruct the daylighted stream channel.

Watershed:	0.25 square miles; residential
Flow rates:	Unavailable; small perennial stream
Length daylighted:	250 feet of new channel
Year daylighted:	1996
Project costs:	Unavailable
Primary objectives:	Storm drain renovation; create open stream in neighborhood park
Notable features:	Repair of a poorly engineered project; daylighting on a steep slope

With labor provided by the California Conservation Corps, the institute added meanders to the stream channel and removed the rip-rap, using some of it to build small grade-control structures anchored into the streambed. These allow the water to drop in six-inch to one-foot increments, dissipating energy and forming a "step-pool" stream type appropriate for Baxter Creek's steep drop through the daylighted section. Neighbors agreed to give up some of the park's lawn area to allow more gently sloped stream banks. Crews used fascines, erosion-control fabric, and plantings of native willows, alders, ninebark, dogwood, and currant bushes to stabilize the slopes. Today, the park and stream is largely maintained by neighborhood residents. (Owens-Viani 1997; Schemmerling 1998/99; "Urban Stream Restoration" 1998.)

The project in mid-1998, showing the exuberant vegetative growth typical in the early years for projects that stabilize streambanks with bioengineering techniques. Courtesy of Lisa Owens-Viani.

The site and the stream's vegetative canopy as of July 2000. Photograph by Richard Pinkham.

Flint Creek

Watershed:	~4 square miles; semi-rural
Flow rates:	Unavailable; average flows 6' wide by 1' deep, low to moderate velocities
Length daylighted:	250 feet of culvert removed
Year daylighted:	1999
Project costs:	$60,000
Primary objectives:	Stream bank restoration; reduce municipal maintenance costs
Notable features:	Special-use zoning permit used to require daylighting on private property

When a developer applied for special zoning to build a 36-unit condominium complex on a former industrial site, the Village of Barrington Public Works Department pushed for daylighting Flint Creek's run through two 72-inch reinforced-concrete culverts at the site. According to director John Heinz, "The two culverts were acting as a trash rack. After every large storm, we had to go in there and clean out the trapped debris." Daylighting also fit with ongoing efforts to restore streams and stabilize creek banks throughout the town.

The developer fought the proposed requirement, but the town held firm. The developer claimed daylighting would cost $400,000; Heinz estimated costs at $100,000; and the actual costs came out at $60,000. Heinz finds some irony in the fact that the condo developer later named the project Creekside Point and uses the daylighted creek as a marketing point.

Construction crews removed the 250-foot-long double culvert in 1998, and installed a short span of six-foot-wide by four-foot-high box culvert as a bridge to the site. They placed coir fiber rolls at the toe of the new stream bank slope to prevent erosion while the banks revegetate. They also completed some stream bank stabilization work on another 250 feet of Flint Creek on the developer's property below the daylighted section. (Heinz 1998/99.)

Hutchinson, Kansas

Cow Creek

Watershed:	1.5 square miles, plus 6.8 square miles divertible to a levy in storm events
Flow rates:	<30 cfs design flow >700 cfs 100-year peak flow
Length daylighted:	800 feet of new channel
Year daylighted:	1997
Project costs:	$1.25 million for stream and new park; $4 million total
Primary objectives:	Speed a large bridge replacement project; create a downtown park
Notable features:	Use of confined channel through an urban park

Hutchinson, a city of 40,000 people in rural Kansas northwest of Wichita, relocated Cow Creek in 1997. Previously the creek ran lengthwise under Avenue A, a major thoroughfare through downtown; effectively, the four-lane avenue was built on a bridge which, instead of crossing Cow Creek, ran on top of it for a considerable distance. Because the creek was completely obscured, heavy trucks frequently ignored posted vehicle weight limits for the bridge, causing great concern to the city's street department. The aged structure needed to be replaced, but building a similar new bridge directly over the stream would have taken three years and rerouted traffic for an unacceptably long time to downtown businesses. Instead, the city acquired and demolished a number of properties south of Avenue A, created a new channel for Cow Creek through the area, and made the now-daylighted 800-foot section of creek the centerpiece of a new park there. The old creek bed was filled and Avenue A rebuilt on solid earth, allowing for timely reconstruction.

The entire project cost $4 million, most of which was supported by an 80-percent cost share from the Bridge Replacement and Transportation Enhancements Programs of the federal Intermodal Surface Transportation Efficiency Act (ISTEA). The park portion of the project came to $1.25 million. Cow Creek curves through the park in a concrete channel about 10 feet wide and 30 inches deep. A wide path made of concrete paver blocks follows the edge of the channel. A grassy amphitheater and a stage face each other from opposite sides of the creek. The park also has a large water play area with many fountains and water features fed by city water.

While the state fish and wildlife agency wanted a naturalized, earthen-bottomed channel, the city felt this would be inappropriate for this downtown park, and would create a maintenance problem. Due to Cow Creek's low gradient (1 foot drop per 1,000 linear feet), it drops a lot of sediment in this area. City crews can easily remove this sediment with periodic scraping of the concrete channel. City engineer Hal Munger also notes that while the creek water passes coliform standards for human contact, the city must still post the creek against entry to discourage kids from playing in it and potentially drinking the water, due to the proximity of the water play area. (Munger 1999.)

Prior to daylighting, Cow Creek ran underneath much of Avenue A in the center of this photograph. The arrow shows one end of the culvert. The creek was moved to the outlined area and daylighted there in a new park. Courtesy of City of Hutchinson.

The relocated, daylighted section of Cow Creek in Avenue A Park, Hutchinson, Kansas. Courtesy of City of Hutchinson.

McLean, Virginia

Pimmit Run tributary

Watershed:	0.03 square miles (17 acres); forested
Flow rates:	Ephemeral creek <10 gpm (0.02 cfs) seasonal low flow >7 cfs flow in large storms
Length daylighted:	50-100 feet (exact length unavailable)
Year daylighted:	mid-1990s
Project costs:	Unavailable
Primary objectives:	Storm runoff control; create amenity
Notable features:	Residential-scale "micro-daylighting";partial-flow daylighting

The home of Ralph and Bobbi Terkowitz in McClean, Virginia lies at the bottom of a wooded, 17-acre watershed that feeds into Pimmit Run. Previous owners had diverted an ephemeral brook running through the property into a small pipe that began just uphill of the house. The undersized pipe would overflow in large storms and runoff would erode the gravel driveway.

Landscape architect Michael Vergason devised a scheme that brought low flows (up to 10 gallons per minute) to the surface to run through a series of log check dam pools above the house, and then through a runnel (shallow stone-lined channel) across a stone pavement between the house and garage and along the driveway to Pimmit Run. This design creates an open, trickling water amenity for the residence. When flows exceed 10 gpm (0.02 cfs), excess flow enters the original drain pipe. In very large storms, flows exceeding 7 cfs are diverted into a vegetated swale, routed through a new pipe under the driveway's parking area, and resurfaced downslope of the parking area to cascade through a lower series of log check dams.

This project demonstrates that flows can be daylighted functionally and aesthetically at the residential level. However, achieving this particular design entailed some trial and error and required some compromises. An earlier design which routed high flows as sheet flow across the paved parking area proved impractical given the amount of runoff and sediment loads caused by poor erosion control at an upstream house lot. Also, aesthetics required maintaining flow in the system as many days as possible. The landscape architect therefore installed an impervious liner under the upper step pools, which he acknowledges does not allow for natural seepage into the soil and recharging of the ground water. (Mays 1999.)

Omak, Washington

Omak Creek

Watershed:	140 square miles; range land and commercial forestry
Flow rates:	1 cfs seasonal low flow 30 cfs bankfull flow 900 cfs 100-year peak flow
Length daylighted:	1,500 feet of culvert removed
Year daylighted:	1998
Project costs:	$788,000, including special arch culvert logging deck
Primary objectives:	Improve fish passage and stream function; repair flood damage and reopen lumber mill
Notable features:	Fast-track designand permitting; adaptive construction management; incremental introduction of flows

When spring flooding in 1998 damaged a 1,500-foot, 84-inch corrugated-metal culvert running under the Quality Veneer & Lumber mill in Omak, Washington, the mill was forced to close and temporarily lay off many of its 600 employees. The mill's owners and the Colville Confederated Tribes leapt into action, putting together a project to reduce the flood hazard and restore Omak Creek. The culvert had previously been identified by the tribe and the U.S. Natural Resources Conservation Service as a barrier preventing endangered Upper Columbia River steelhead from accessing 30 miles of prime stream habitat in the 140-square-mile watershed upstream.

For construction to take place during the winter low-flow period, project engineering had to be completed and permits secured from the U.S. Army Corps of Engineers, National Marine Fisheries Service, Washington state, and Colville Confederated Tribes between June and October of 1998. This required expedited analysis of reference reaches to design the restoration channel and floodplain geometries. Some agencies were unable to complete their design reviews prior to construction, resulting in negotiations and adjustments during construction. With design and construction technical support from Ridolfi Engineers, four local contractors completed excavation, grading, and bioengineering of the new channel in time to introduce flows in May of 1999. Increasing the flows in four incremental stages until late June allowed the project team to adjust channel shapes and structures to minimize erosion. Crews seeded and planted the new stream banks during this flow-introduction period. The "adaptive management" strategy of the team was crucial throughout the project.

Besides abandoning the culvert, the restoration replaced 300- and 500-foot sections of engineered trapezoidal channel with a new channel geometry reflecting conditions in the stream's reference reaches. It created a total of 2,600 feet of naturalized stream along the creek's historic route around the mill, reintroduced low-flow and bankfull channels, and re-established a floodplain.

This daylighting project faced and met several additional challenges. Designers took care to maintain hydraulic conditions immediately downstream of the site at a highway bridge. The area's glacial silt and "sugar sand" conditions required special attention to erosion control, and created a hazard during installation of a unique 23-foot-wide steel arch deck—or "bottomless culvert"—that spans a 220-foot length of the creek through a log-loading area and allows for fish passage and refuge underneath. Trenching for the arch in the difficult soil conditions required the unplanned temporary closure of an adjacent county road. Financial assistance was also difficult to secure given the rapid timeframe. The mill paid the $788,000 cash costs upfront (nearly $300,000 was for the arch culvert) and has since recouped $180,000 from a Congressionally funded state salmon restoration program. The Colville tribes provided materials and work crews for planting and assisted in construction supervision. Woody bioengineering materials came from sources available to the mill. (Alvarez, Kinman, and Ridolfi 1999; Alvarez and Ridolfi 1999.)

Others

Time constraints did not allow research and presentation of the following projects:

- Providence, Rhode Island relocated and daylighted portions of the Woonasquatucket and Moshassuck rivers, which had been buried for years by highways, streets, and parking decks. This project created Waterplace Park in the city's core and has sparked considerable downtown reinvestment and redevelopment (Kay 1999).
- A 1992 project daylighted base flows for a portion of Indian Creek in Olympia, Washington and took other steps to provide salmonid passage and address flooding problems (National Park Service 1996).
- The National Forest Service and Portland General Electric Company have daylighted a short length of a tributary to Camp Creek in the Mt. Hood National Forest in Oregon (Koehler 2000).
- Daylighting projects have also been completed on Village Creek in Berkeley, California and on City Creek in Salt Lake City, Utah.

A portion of the daylighting project by the Quality Veneer & Lumber mill in Omak, Washington, a few months after completion in 1999. Vegetation is just beginning to take hold. The new "bottomless culvert" in the upper middle of the photo spans a short stretch of the opened stream. Courtesy of Ridolfi Engineers.

PROPOSED PROJECTS

Streams are busting out all over! A number of daylighting projects are currently under consideration throughout the United States. Some are merely twinkles in proponents' eyes, others have been the subject of serious study. The following notable proposals illustrate the level of daylighting activity under way. These projects may proceed as described, in modified form, or not at all.

Berkeley, California

Derby Creek

People's Park, famed as the site of many 1960s protests in Berkeley, may someday feature a restoration of Derby Creek. In 1998 Wolfe Mason Associates and the Waterways Restoration Institute prepared a restoration feasibility study. Derby Creek drains a densely urbanized, roughly 0.25-square-mile watershed. The recommended option—chosen for sound hydraulic performance, appropriately designed and stable channel and bank conditions, and retention of as much of the existing lawn area and trees as possible—would bypass about 350 feet of the existing culvert under an adjacent street and create roughly 450 feet of new creek, at an anticipated cost of $500,000. The People's Park Community Advisory Board reviewed the study and suggested that the University of California, which owns the park, consider further cost and construction analyses. The university is reportedly interested "in concept," but unable to make the investment in daylighting at this time due to other, more pressing priorities, including a multi-billion dollar seismic upgrade program for campus facilities. (Blomberg 1999; Wolfe Mason Associates 1998.)

Berkeley, California

Strawberry Creek

Separately, Berkeley is considering daylighting Strawberry Creek in the heart of downtown, just below its mostly open run through a 1.4-square-mile watershed encompassing much of the University of California campus. The section under study is about six blocks upstream of the 1984 Strawberry Creek Park daylighting project, described earlier.

Wolfe Mason Associates, under contract to the city and in association with five additional consultants, has examined options and published an extensive data collection and implications study. This study gathers important data on hydrology/hydraulics, rights-of-way, circulation, parking, land use and urban economics, and utilities for a nine-block area (three blocks by three blocks) of downtown. It outlines key implications of the data and presents five scenarios: "no constraints," full-flow restoration allowing for property acquisition; full-flow restoration primarily in a public right-of-way; creation of a partial-flow but naturalized stream in a public right-of-way; partial-flow restoration in an architectural canal; and symbolic acknowledgement of the buried creek using fountains and signage in lieu of daylighting.

At the time of writing, city staff were preparing for public workshops to gather input on the options. They will then prepare a summary of findings and present the results to city council for consideration. (Turner 1999; Wolfe Mason Associates 1999.)

Denver, Colorado

Westerly Creek

Denver is seizing the development opportunities created by the recent closures of Lowry Air Force Base and Stapleton International Airport, both east of downtown. The city has established redevelopment authorities for these huge urban infill sites (1,900 acres and 4,500 acres respectively) and contracted out extensive planning and development studies and programs. Some development has already begun. The plans call for establishment of an ecological and recreational corridor along Westerly Creek, which runs north through Lowry, an existing residential neighborhood, and Stapleton before joining Sand Creek.

Much of Westerly Creek is now culverted underneath residential streets and the former airfield runways. The section through the existing neighborhood will remain culverted, but several other sections will be daylighted. One portion will retain an existing 0.6-mile-long culvert that transports releases from a large stormwater detention basin, but remove from the conduit and restore to the surface flows originating below the basin. Several other reaches amounting to another 0.6 miles will be fully daylighted. This includes an undersized culvert on the Stapleton site that now backs up in large storms, flooding some adjacent commercial properties and developable areas. In total, 1.2 miles of Westerly Creek will be fully or partially daylighted, and another 0.6 miles dechannelized and restored. (Wenk 2000.)

Meriden, Connecticut

Harbor Brook

Harbor Brook drains a 10-square-mile urban and suburban watershed before entering a half-mile section of double box culvert under downtown Meriden. Milone & MacBroom has recently completed preliminary design work for a $30-million project that will daylight 2,000 linear feet of the culvert and restore a total of four miles of the brook (really a river at this point). Motivated in part by a need to address flood threats to several hundred commercial and industrial buildings in the floodplain, the project will establish a new floodway—essentially a substitute floodplain excavated to a lower level than the natural floodplain that was previously developed. A new bankfull channel with instream aquatic habitat features will meander through the vegetated floodway, which will also include a recreational trail. One small dam has already been removed, and eight of the twenty-nine bridges over the river will be abandoned and removed, without replacement. The city is currently acquiring some buildings and parking areas in the proposed floodway, with plans to remove them once the leases of current tenants expire. The project will take at least seven years to complete. It also includes steps to reduce non-point sources of pollution. (Anderson 1999; MacBroom 1999.)

District of Columbia

Seeking daylighting opportunities

Staff of the District of Columbia's Environmental Health Administration are laying the groundwork for what could be a long-term daylighting program. They have recently completed a mapping project to identify long-buried streams and potential daylighting opportunities. Staff determined where streams should be located in the landscape using a 200-year-old topographic map and additional predevelopment maps that show streams and associated wetlands. They correlated this with present-day maps showing all the sump pumps in the city, coded according to the volume of flow. The city is seeking opportunities to daylight a significant length of stream, most likely a tributary of the Anacostia River. Staff anticipate projects would most likely begin at the mouth of a tributary and move up until streets or buildings are reached. (Wald 1999.)

Atlanta, Georgia

Daylighting recommendations

A 1998 study of urban runoff mitigation and stream restoration opportunities in Atlanta recommended that greater consideration be given daylighting opportunities. This study identified potentially suitable daylighting demonstration sites on the Lullwater Fork of Peavine Creek and North Utoy Creek at John A. White Park. (ILSI Risk Science Institute 1998.)

Waukegan, Illinois

South Branch of the Waukegan River

The Waukegan Park District, the Illinois Environmental Protection Agency, and the U.S. Environmental Protection Agency are cooperating to replace a culvert with a bridge under four-lane Illinois Route 120. While the South Branch of the Waukegan River will still be somewhat covered by the bridge, the project will re-establish a natural stream bottom, stream channel, and stream corridor and allow the installation of a fish ladder on an existing sedimentation basin dam in Roosevelt Park just upstream of the roadway. The expected benefits of this daylighting project include reduction of water quality impacts and removal of fish barriers in an urban stream. This will allow Lake Michigan salmonids to access habitat in parts of the roughly 2.5-square-mile watershed of the South Branch above the dam. Restoring a limited natural salmonid migration will enhance the ongoing urban fishery restoration efforts of the Waukegan Park District. This proposed project will be funded in part by Section 319(h) of the Clean Water Act, through a Financial Assistance Agreement between the Illinois EPA and the Waukegan Park District (the recipient). (Tomkins 1999.)

Boston, Massachusetts

Muddy River

The Muddy River runs through the "Emerald Necklace," a park and drainage system in Boston and Brookline designed by famed landscape architect Frederick Law Olmsted in the 19th century. Subsequent to Olmsted's design, some sections of the Muddy River were culverted, and dense urban development took place. Significant flooding along the Necklace occurred in the fall of 1996 and again in June of 1998, causing millions of dollars in property damage and sparking considerable public scrutiny of the Muddy River and associated drainage systems. The U.S. Army Corps of Engineers, the Federal Emergency Management Agency, and the Boston Water and Sewer Commission have prepared hydrologic and hydraulic studies. These studies recommend dredging accumulated sediment from the Muddy River and increasing hydraulic capacity at bottlenecks caused by culverts and other structures. Culverts at three sites must be enlarged or daylighted. Citizen groups promoting restoration of the Emerald Necklace are keenly interested in the daylighting option. The Boston Parks Department has filed an environmental notification form with the state to begin the regulatory process for review of future actions on the Muddy River. As of late 1999, the department was developing a contract with an engineering firm to prepare an Environmental Impact Report analyzing the costs, hydraulic results, and environmental impacts and benefits of various combinations of dredging, culvert enlargement, and daylighting. (Smith 2000.)

Holyoke, Massachusetts

Wyckoff Country Club

The Wyckoff Country Club will daylight approximately 350 feet of a small unnamed stream on its golf course as part of a pond and wetland restoration project. The daylighted stream will cross a fairway, forming an interesting new water hazard on the course. The club and its consultant have secured the necessary permits and expect to complete the work in 2000. They had hoped to undertake construction in the fall of 1999, after the summer's deep drought. Unfortunately, the day after they received final approval from the state, Hurricane Floyd hit the region and soaked the course. Costs for this project will be low, as the golf course has the necessary equipment to do the earthmoving itself. (Beaulieu 1999.)

Jackson, Michigan

Grand River

The Grand River rises southwest of Detroit, draining a 163-square-mile watershed before entering the city of Jackson, where it flows through a 2,850-foot culverted and channelized reach. Except for about 700 feet of surface channel in the middle of this reach, the river's typical flows disappear underground in a box culvert—constructed in the 1920s to alleviate insect problems occurring in shallow, low-flow conditions—while high flows surge along a trapezoidal concrete channel above the culvert. Drownings of three children in the last decade have sparked an effort to replace the dangerous culvert/channel structure with a safer design and more natural riverway features where possible. As of this writing, engineering and design had been completed on a $2.5-million redevelopment project ($2 million of it related to channel reconstruction), and the city had secured most of the funding in the form of a $1.1 million Clean Michigan grant and a $250,000 Economic Development Initiative grant from the federal Community Development Block Grants program. Construction is expected to begin in 2000.

Room along the river is inadequate to establish a naturalized channel and riparian zone for the full length of project. Some sections will remain walled and bottomed by concrete, without vegetation. In one location, an existing parking lot will be cut back from the river, and a park-like, more naturalized setting created. Work here will include redeveloping the city's farmer's market. The increased amenity value at this site is considered an economic development benefit of the project. Ultimately, depending on funding, the city hopes to create a bike path along the length of the project. (Sims 1999; Wilcox 1999.)

Minneapolis, Minnesota

Bassett Creek

The city of Minneapolis will break ground in 2000 on the Near North Side Neighborhood Redevelopment Project. One of two large tunnels that carries Bassett Creek through central Minneapolis passes under the 100-acre redevelopment site, located about a half mile from downtown. The daylighting component of the project involves pulling some of the flow of Bassett Creek and tributary storm drains out of the tunnel and establishing a naturalized surface channel for this portion of the flow.

Housing projects with a total of 400 units were built here in the 1940s and 1970s, but high-organic-content soils, fill, and unstable clays on parts of the site are very difficult to build on—the ground has settled and the buildings are badly damaged. The city recently undertook a year-long planning process culminating in a master plan for the site. It has hired a developer to build new housing, and a consultant team is preparing final plans. The damaged buildings will be torn down and 600-900 new units will be built on parts of the site with sound soils. The area with unstable soils will become a central stream corridor and surrounding park. The portion of Bassett Creek fed by local runoff, which currently is piped down into the turn-of-the-century tunnel, will be diverted to run once again on the surface, over the top of the tunnel. Several storm conduits feeding into the system, including a 42-inch and a 60-inch pipe, will also be daylighted.

This project is especially notable for combining daylighting with very high-density development. Also of note, stormwater infiltration systems and other measures to manage the quality of runoff from the site will be incorporated on private properties, even in areas with housing densities as high as 30 units per acre. (Wenk 2000.)

Raleigh, North Carolina

Rocky Branch

North Carolina State University intends to daylight a minimum of 250 feet of Rocky Branch as part of a campus greenway and stream restoration project. The Rocky Branch Greenway Project will restore proper channel geometries to

6,100 feet of the stream, bioengineer the stream banks, expand the floodplain where possible, establish a riparian buffer zone, install stormwater Best Management Practices in the watershed, and create a path along the stream that will link to city greenways. It will replace three culverts under roads with bridges that will allow sub-grade crossings for pedestrians and wildlife, and re-establishment of a natural stream bottom. The university team has secured $1.8 million in funding for the project to date, and has grants pending for the remainder of the $5 million total project budget. (Doll 1999.)

Seattle, Washington

Ravenna Creek

One of the most studied daylighting projects in the country would restore over 4,000 feet of Ravenna Creek in a highly urban northeast Seattle neighborhood.

This reach of the creek currently flows in a combined sewer from an open segment in Ravenna Park to a regional sewage treatment plant. In 1991, as part of a combined sewer overflow control project, the King County sanitation authority recommended installation of a new 18-inch culvert to carry the creek's clean water directly to Union Bay on Lake Washington, bypassing the combined sewer and treatment plant. Residents of the local Ravenna and University neighborhoods mobilized to investigate daylighting the creek as an alternative to the pipeline. They prepared a preliminary feasibility report in late 1991, and incorporated the nonprofit Ravenna Creek Alliance in 1992 to promote daylighting the creek.

The Alliance saw daylighting as a way to tie the community together, foster stewardship of the local environment, provide drainage improvements, and create a range of new and improved fish and wildlife habitat and a variety of human amenities from better pedestrian routes to an outdoor classroom. The Alliance lobbied successfully for county and city daylighting resolutions in late 1993 and early 1994, and sponsored and published the Ravenna Creek Master Plan in late 1994, by which time Alliance membership numbered 500 people.

A 1997 county-sponsored engineering feasibility study placed daylighting costs at $9.8 million (excluding land acquisition costs) for one alignment and somewhat less for two alternatives. It identified a number of technical and institutional difficulties for the project. The Alliance sharply questioned the alignment (which included private land), as well as many of the data values, assumptions, and design choices in the report. Proponents subsequently calculated a cost of $7.5 million for an alignment entirely on city-owned public land. The county earmarked $3 million for daylighting, and Washington's U.S. Senator Slade Gorton secured $375,000 in federal funding for the project. The Alliance was on track to raise the remainder through competitive grants or private donors. However, when it went to the city of Seattle in mid-1998 for a further resolution of support to assist in these fundraising efforts, a committee of the city council refused to advance the resolution to the full council for a vote, citing technical concerns, potential city maintenance responsibilities, and other priorities on other city creeks. The Alliance says it has answers to all the city's objections, but has been unable to establish further dialogue with the relevant officials.

As this report went to press, the prospects for daylighting Ravenna Creek in the near future looked dim: without city support, it appeared that the earmarked county and federal funding would disappear. (O'Neill 1999; Ravenna Creek Alliance 1994 and 1999; SvR Design Company 1997.)

Others

Research for this report uncovered additional daylighting projects that are proposed in the communities listed below. Most of these are in early discussion stages. A few are further along, but time constraints precluded researching and describing them in this report.

- San Luis Obispo, California
- Bristol, Connecticut
- Boston, Massachusetts
- Cambridge, Massachusetts
- Foxboro, Massachusetts
- Worcester, Massachusetts
- Portland, Oregon
- Philadelphia, Pennsylvania
- Salt Lake City, Utah
- Janesville, Wisconsin

The International Experience

Daylighting of streams and storm drainages is quite common in some countries. The brief accounts below indicate the level and purposes of daylighting activity in several countries.

Canada

Daylighting is rapidly taking off in and around Vancouver, British Columbia. A 1997 project reopened about 230 feet of Vivian Creek on a fairway of Vancouver Park's Fraserview Golf Course (Olyslager 1999). A small project is planned for Tatlow Park, and major daylighting activity is proposed for Hastings Park (Hill 1999). Now that fairground operators have left the long-running Pacific National Exhibition at Hastings Park, the Vancouver Parks Board plans to turn the 160-acre property into a multi-purpose park for this high-density part of the city. Daylighting will likely occur over a timeframe of decades as combined sewer lines in the surrounding area reach the ends of their useful lives and are replaced by separated sewers. A project is also under study by the Steelhead Society Habitat Restoration Corporation on Vancouver's China Creek (Bauer 1999). Projects have taken place or are proposed in the nearby cities of North Vancouver and Surrey (Hill 1998).

Halfway across the country, in Toronto, Ontario, daylighting is also the talk of the town. The Taddle Creek Watershed Initiative is "a grassroots alliance of residents' associations, business and community organizations, institutions, and local environmental groups in the center of Toronto working together to give new life to the creek hidden at the heart of the city" (Taddle Creek Watershed Initiative 1999). One promising location for daylighting on Taddle Creek is Philosopher's Walk on the University of Toronto campus, where the original shallow ravine topography of the creek still exists in a relatively open setting. However, because the creek now runs in a combined sewer underneath, daylighting its full flow would be difficult and require expensive treatment facilities. One vision calls instead for a new surface creek and ponds over the top of the buried creek/sewer and fed with water captured from several sources before it enters the sewer. Sources for the new creek could include surface runoff, snowmelt, roof water, water from basement sumps, possibly stormwater from nearby separated sewers, and perhaps graywater from the subway ("A Multidisciplinary Feasibility Study" 1997/98). Other opportunities up or down Taddle Creek or along five other significant, now-buried Lake Ontario tributaries in Toronto may exist.

Denmark

Over many years, brooks and rivers throughout Denmark have been channelized or culverted to improve soil drainage for agriculture. By 1995, of some 48,000 miles of watercourses, only 1,600 miles retained their original meandering form. But in recent decades, environmental values have taken root in Danish culture, and desires to restore stream systems and the fish and other animals dependent on them have intensified. Amendments in 1982 to Denmark's Watercourse Act set out maintenance and restoration of a diverse flora and fauna as legitimate objectives of watercourse management, supplementing the traditional emphasis on drainage. The legislation also provided new legal powers for restoration efforts by national, county, and municipal government bodies.

Since then, over 1,000 restoration projects have taken place, including installation of habitat features, reconstruction or bypassing of weirs and other barriers in order to allow fish passage, many dechannelization projects, and, as of mid-1999, at least 33 daylighting projects that have reopened many miles of streams, primarily in rural areas. As agriculture becomes less essential to the economy, daylighting deteriorating pipes is a cost-effective alternative to expensive culvert replacements, as well as an ecological enhancement. (Hansen 1999.)

England

A 1994 project led by England's Environment Agency daylighted a 650-foot section of the River Alt, a highly urban river in Liverpool. Since then, additional sections of the river totaling another 4,600 feet have been de-channelized or improved. These projects aim to increase aquatic and riparian habitat and improve water quality. Also in northwestern England, a daylighting project was completed on Maghill Brook to help alleviate a flooding problem in a rural area. (Guthrie 1999.)

A number of projects are now in planning or preparation throughout the country. As of late 1999, a daylighting project was to begin shortly in Feltham, near London, on a former railway marshalling yard. The project will demolish an 800-foot-long, 16-foot-wide arch culvert and create a new river channel (Faulkner 1999). In Barbourne, near Worcester, Severn Trent Water Ltd. is decommissioning a water treatment plant and developing plans for a housing and park project on the 13-acre site. The proposal includes daylighting of a tributary brook to the River Severn and excavation to recreate a floodplain for the brook and the river ("Liquid Assets" 1999). The city of York and the nonprofit group Friends of St. Nicholas Fields are considering daylighting of Osbaldwick Beck (brook) in St. Nicholas Fields Urban Nature Park. An interim feasibility study has been completed. Soil and ground water contamination studies are an essential next step (McBain 1999).

Daylighting is official policy in Leeds, which discourages culverting and encourages daylighting of previously culverted waterways. Its 1993 Unitary Development Plan states: "Culverting or canalisation [the British equivalent of channelization] of watercourses within or related to development sites will not normally be permitted, unless there are public safety considerations or development could not be achieved in any other way. The City Council will promote actively re-opening culverts and restoration of canalised watercourses to a more natural state." No daylighting projects have occurred to date, but the city remains watchful for opportunities. (Walker 1999.)

Germany

The city of Aachen sits in a valley rimmed by forests and agricultural land. Population density increases as elevation diminishes. The historic water sources of the city, the Paubach and the Johannisbach, emerge from forests, farms, and newly protected "natural" landscapes referred to as biotopes. The streams become culverted they enter the lower, built-up areas. They have been culverted at the city center for over 100 years.

Aachen has undertaken an ambitious program to become the environmental city of the future, with support from the regional government. A primary objective of the work is to recover Aachen's rating and recognition as a spa, or "bath-town," which was lost when pollution from the industrial era lowered air quality below federal standards. Taking an innovative approach to the problem, the city planners and engineers studied, modeled, and are now implementing a daylighting plan for the city's creeks. Designers believe that restored stream corridors will help channel cool, clean air into and through the central city, restoring the bath-town rating and providing significant ecological, social, and economic benefit as a result. In 1999, part of the flow of the Johannisbach was daylighted in a shallow, stone-lined architectural channel running through three blocks and a plaza within the inner ring formed by the old city walls. Plans were under way for further natural restorations just outside the core of the city.

Gestures toward the buried streams and their potential are important to city officials in Aachen. Surveying the city's stormwater system for a 1999 art exhibition at the Ludwig Forum for International Art, two artists from the United States, Tim Collins and Reiko Goto, were surprised to find brass plaques naming each confluence of streams under the city streets. Collins and Goto decided to complete an image of the historic stream systems, marking the Paubach and the Johannisbach along and across city streets with a line of gold leaf, a material chosen to provoke discussions about the value of the hidden waterway. According to Collins, "City officials told us they don't want to treat the buried streams like sewers. This project was about keeping the system alive as a cultural construct, and getting the community to invest in something they can't see, don't understand, and have forgotten why they should appreciate." Collins believes this kind of cultural restoration is essential to any drive for ecological restoration. (Collins 1999; Stadt Aachen 1994.)

Several sources indicated daylighting has also taken place in the city of Leipzig. Attempts to reach authorities in Leipzig within the timeframe for this report's research were unsuccessful.

Switzerland

During the last 130 years, over 60 miles of streams running from hillsides around Zürich have disappeared into underground pipes. Now, because of limited wastewater treatment plant capacity and a 1991 Swiss law mandating removal of clean water inputs to combined sewer systems, the city of Zürich is hard at work recreating surface streams. Engineers are rerouting spring water, clean runoff, and some roof runoff from the old pipes into the new, naturalized channels that run to the

The city of Zürich, Switzerland has daylighted over nine miles of streams and stormwater drainages. These photos show one project before (top) and after. Courtesy of Zürich Sewerage Department.

Limmat River. Since 1988, the city has created or restored nine miles of perennial and ephemeral brooks, which altogether divert an average flow of 4.5 million gallons per day from the city's two treatment plants. (Dry-weather flows to these plants total 71 mgd.) Eventually this program, dubbed the Bachkonzept ("brook concept") to differentiate it from traditional drainage and sewerage approaches, will recreate or revitalize over 18 miles of surface streams and drainages. (Conradin and Villiger et al. 1993; Conradin undated (1); Conradin undated (2).)

Zürich's engineers daylight brooks and stormwater conduits even in highly built-up portions of the city. Courtesy of Zürich Sewerage Department.

CONCLUSIONS

The completed projects described in this report demonstrate that daylighting is feasible in a variety of situations. Daylighting projects can restore streams to a naturalized state, or bring water to the surface in more architectural treatments where the stream corridor is highly constrained by surrounding development. They can restore or create new stream channels, ponds, wetlands, and estuaries. They can reveal all or part of a buried waterway's flow.

Daylighting can provide multiple benefits—tangible and intangible—for every dollar expended. These include improvements to the functional values of waterways and urban stormwater systems through increased hydraulic capacity for flood control, lowering of water velocities to reduce downstream erosion, removal of water from combined sewers, improvements to water quality, and more. Daylighting can improve aquatic habitat and provide "new" riparian corridors for wildlife. It can revitalize neighborhoods, increase property values, and benefit nearby businesses. It can be cost effective compared to the expense of repairing a failing culvert. Daylighting projects help educate children and adults alike about the workings and values of stream corridors and wetlands. In doing so, they foster stewardship of natural resources and energize people with a sense of "setting things right." What more powerful restoration project is there than recovering a buried, out-of-sight and out-of-mind waterway that seemed lost forever?

These multiple benefits can create many allies for daylighting projects, from citizens and businesses at the neighborhood level to branches of local, state, and federal government. For most of the projects identified in this report, their proponents found strong support from relevant agencies, including permitting agencies. Potential funding sources are diverse.

Of course, most projects also face a variety of social, institutional, and technical challenges. Fear and unfamiliarity is the undercurrent of most public and institutional reluctance. Some thorny legal and management issues can arise. And the potential technical challenges are myriad. But with robust public involvement, strong leadership, and competent technical assistance, the barriers can be overcome.

Not every buried waterway is a good candidate for daylighting. There are many excellent technical, economic, institutional, and other reasons many buried waterways should not be unearthed. But as the proposed projects described in this report make clear, interest in daylighting is increasing across the United States.

As more citizens and agencies eye additional daylighting projects, the risk that some projects may be ill-conceived or poorly designed will increase. A notable daylighting failure and its attendant adverse publicity would be unfortunate, both locally and for restorationists nationwide. This report offers for consideration the experiences and results of veteran daylighters, both to encourage proponents of new projects and to help them identify potential pitfalls earlier rather than later. With care and attention, streams and people across the country can reap tremendous rewards from this new ambition to resurrect America's lost waterways.

GLOSSARY

Arch culvert: A culvert with an arched or rounded top and flat bottom.

Average annual flow: Discharge (see below) averaged across a year.

Bankfull channel: The channel formed by the bankfull flow. The top of the bankfull channel is generally marked by a convexity in the stream bank, above which the floodplain begins.

Bankfull flow: The stream flow that just fills the bankfull channel. On average, the bankfull flow occurs every 1.5 years. In most streams, flows of this magnitude (rather than extreme flood events) have the greatest impact on the geometry of a stream channel and the formation of pools, riffles, and meanders.

Base flow: The flow of a stream in dry weather, which comes from a watershed's ground water. Sometimes called seasonal low flow.

Bioengineering: The use of plant materials to stabilize stream channels and stream banks.

Biofiltration: The use of soil and vegetation to take up, transform, or otherwise neutralize pollutants.

Box culvert: A culvert with a square or rectangular cross-section.

Brownfield: A site that was previously used for industrial or other purposes that may have contaminated the soils there.

Brush layering: A bioengineering technique which deeply buries a mat of woody plant cuttings perpendicular to a slope, with the growing tips exposed.

cfs: Cubic feet per second, a measure of stream discharge.

Channel geometry: A catch-all term referring to such characteristics of a stream channel as its depth, width, sinuosity, meander wavelength and amplitude, and other measurable dimensions.

Channelized: Referring to a stream that has been straightened and usually reinforced with concrete, rip-rap, or other hard materials.

Check dam: A structure placed across a stream channel to pool water above and allow a short drop below. Check dams are usually made of rock or logs, are intended to control flow and reduce erosion along a steep stream, and are prone to failure if used inappropriately.

Cobble: Rocks of softball to basketball size in a streambed.

Coir: A biodegradable erosion-control fabric made of coconut husk fiber.

Combined sewer overflow: The release of excess water from a combined sewer system (a system carrying storm runoff and sanitary sewage together) that occurs at a regulator structure designed to overflow when the system reaches capacity in wet weather.

Confined channel: A stream channel restricted to flow within banks reinforced by concrete or other hard, constructed surfaces.

Culvert: A pipe or other conduit that carries water underground.

Daylighting: Any project or action that deliberately exposes some or all of the flow of a previously covered river, creek, or stormwater drainage.

Detention: Temporary delaying of water flow, typically in a basin or reservoir to reduce peak flows downstream.

Discharge: The volume of water passing down a stream in a given period of time, usually measured in cubic feet per second (cfs).

Drainage tiles: Pipes used to drain farm fields, usually 5 to 40 inches in diameter, made of clay, and placed below the reach of plows and about 100 feet apart. Water seeps in through joints between sections of pipe and drains away.

Ephemeral: Refers to flow that dries up at some time during the year, usually summer.

Erosion-control fabric: Fabric made of coconut fiber, straw, or photo-degradable plastic netting, used to cover exposed soil.

Equilibrium: A stable stream condition in which channel morphology has evolved such that neither excessive erosion nor excessive deposition of sediments is occurring. Put another way, the amount of sediment leaving a stream reach in equilibrium matches the amount entering it. A stream in "urban equilibrium" has stabilized after adjusting to changes in flow and sediment transport resulting from urban development in its watershed.

Fascine: A bioengineering technique in which long bundles of mainly live shrub cuttings are buried on contour to create mini-terraces. They root into the bank as they sprout. Species used often include willow, cottonwood, and dogwood.

Floodplain: The area above the bankfull channel that is inundated by flows exceeding the bankfull discharge.

Floodway: A substitute floodplain excavated to a lower elevation than a natural floodplain so that flood flows may pass without inundating structures developed on the natural floodplain.

Flow: Movement of water. Also frequently used as a synonym for discharge.

Fluvial geomorphology: The study of how landscape and moving water interact and influence the formation and stability of stream channels.

gpm: Gallons per minute, a measure of very low stream flows.

Head: Pressure exerted by water.

Headwall: A reinforcing structure around a culvert opening.

Hydraulics/Hydraulic: The study of/pertaining to the behavior of water flowing in channels or pipes.

Hydrology/Hydrologic: The study of/pertaining to the amounts and movement of water in the environment, e.g. in a watershed.

Impervious surface: Roofs, roads, parking lots, sidewalks and other surfaces that do not allow water to pass through to the soil.

Infiltration: The soaking of water into the soil.

Macroinvertebrates: In the context of stream ecology, macroinvertebrates are the insects that spend a portion of their life cycle in a stream, usually among the rocks and sediment deposits on the streambed.

Meander: A bend in a stream channel. There are strong relationships between stream characteristics such as bankfull discharge and meander characteristics such as wavelength (the longitudinal distance from the apex of one bend to the apex of the next bend in the same direction), amplitude (the cross-wise distance from the center of the channel at one bend to the center of the channel in the next bend turning the opposite direction), and radius of curvature.

Morphology: The geometry of a stream channel and floodplain.

Naturalized channel: A stream channel restoration that includes an earthen bottom and banks, vegetated stream banks, and some allowance for the channel's geometry to change over time, as a stream channel in nature would. A naturalized channel is stabilized by the geometry of its design and sometimes by bioengineering techniques, rather than confinement by large amounts of concrete or rip-rap.

Outfall: The downstream termination of a culvert.

Partial-flow daylighting: Daylighting of a portion of stream flow, leaving or putting other flow underground.

Peak flow: The greatest discharge occurring in a given time period. Annual peak flow indicates the greatest discharge occurring in a year, averaged over many years. Two-year, 10-year, 25-year, 50-year, and 100-year peak flows are other common measurements, indicating the greatest discharge that can be expected to occur in each respective timeframe.

Perennial: Refers to flow that occurs year-round.

Pole cuttings: Live stakes of shrub and tree branches driven into stream banks, usually at a density of two to four stakes per square yard. The cuttings rapidly sprout and develop into saplings. This bioengineering technique is sometimes also used to hold structures such as erosion-control fabric.

Pool: A portion of a stream that is deep and slow-flowing (in contrast to a riffle).

Rain Garden: A landscape feature, usually vegetated and built with loose soils, that collects runoff and infiltrates it into the ground.

Reach: A section of a stream.

Redd: A fish "nest" (site of egg deposition).

Reference reach/stream: A section of a stream, or a separate stream, judged to be in good health that is measured to help design a restoration project.

Revetment: A structure of rock, blocks, pavement, or other hard material placed on a stream bank to prevent erosion.

Riffle: A portion of a stream that is shallow and swift-flowing (in contrast to a pool).

Riparian: Pertaining to a stream corridor and its associated vegetation and ecological systems.

Rip-rap: Rocks placed on a bank to prevent erosion from stream flow or wave action.

Root wad: A stump and its root mass. Root wads are sometimes anchored into a stream bank or pond bottom to increase stability or provide cover for fish.

Runnel: A small constructed channel for flowing water. This architectural term is usually used for a channel placed in a plaza, patio, or other hardscape.

Salmonid: Any member of a family of fish species that includes trout, salmon, and steelhead.

Seasonal low flow: See base flow.

Sediment load: The amount of sediment (soil particles) a stream moves over a period of time. The transport of sediment and the morphology of a stream channel are strongly interrelated (see equilibrium).

Sinuosity: The amount of meandering of a stream channel. Sinuosity is calculated by dividing the distance between two points following the stream channel by the straight-line distance between those points.

Smolt: A juvenile salmonid.

Stabilize: To prevent excessive erosion of a stream channel or stream bank.

Steelhead: A migratory trout.

Sump: A pit or cavity that collects water to allow it to be pumped or moved by gravity.

Swale: A low area or open channel that carries water in wet weather.

Toe: The bottom of a stream bank, where the bed of a stream channel begins.

Trapezoidal channel: A channel with a flat bottom and uniform, sloped sidewalls, usually constructed of concrete or rock.

Watershed: All the land that drains to a given stream or low point; a drainage basin defined by topographic divides.

Weir: A low structure placed across a flowing water channel to control or measure water elevation or flow.

Wetland: A land area covered by shallow water or wetted frequently enough to support plant and other species adapted to life in saturated soil conditions.

SUGGESTED RESOURCES

Technical references

The following publications and videos are helpful technical references for stream restoration work. While these materials will help orient newcomers to the field, Rocky Mountain Institute strongly recommends that daylighting project proponents seek experienced assistance. Several nonprofit organizations and government agencies that can help locate competent professionals are listed in the next section, and a number of qualified firms and independent consultants are listed among the references for this report.

Applied River Morphology. By Dave Rosgen. 1996. Wildland Hydrology, 1481 Stevens Lake Rd., Pagosa Springs, CO 81147. A richly illustrated manual presenting a classification system for different stream types. Discusses the importance of understanding stream morphology and the principles that affect stream stability before intervening in channels and floodplains.

Biotechnical and Soil Bioengineering Slope Stabilization: A Practical Guide for Erosion Control. By Donald H. Gray and Robbin B. Sotir. 1996. New York: John Wiley & Sons, Inc. Presents a comprehensive and detailed review of soil erosion processes, the role of vegetation in slope stabilization, and the techniques of biotechnical and bioengineering approaches to slope stabilization, including the conjunctive use of plants with earth-retaining structures, revetments, and reinforced ground cover systems.

Field Manual of Urban Stream Restoration. By Robert Newbury, Marc Gaboury, Chester Watson, and staff of the Nonpoint Pollution Control Program of the Illinois State Water Survey, Illinois Department of Natural Resources. Undated. Available from the Conservation Technology Information Center, 1220 Potter Dr., Room 170, West Lafayette, IN 47906, 765-494-9955, Fax: 765-494-5969, ctic@ctic.purdue.edu, http://ctic.purdue.edu. Describes and illustrates basic principles of fluvial geomorphology and selected techniques of pool/riffle reconstruction and biotechnical stream bank stabilization.

Restoring Streams in Cities: A Guide for Planners, Policy Makers, and Citizens. By Ann L. Riley. 1998. Washington, DC: Island Press. A comprehensive overview of urban stream restoration. Describes and illustrates basic principles of fluvial geomorphology and stream restoration methods. Reviews the roles of citizens and a host of agencies and professionals. Discusses many examples of stream restoration and the evolution of stream alteration and stream restoration activities in the United States.

Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group. October 1998. Available online at www.usda.gov/stream_restoration/. Printed version or CD-ROM with search capabilities available from National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161, 800-553-6847, Fax: 703-605-6900, orders@ntis.fedworld.gov. A voluminous treatment of stream restoration, from analysis to planning, design, implementation, and monitoring. Useful for professionals, but also very accessible to the lay reader seeking a comprehensive reference.

"Urban Stream Restoration: A Video Tour of Ecological Restoration Techniques, with Ann Riley." 1998. Nolte Media, 405-A West College Ave., Santa Rosa, CA 95401, 707-544-0499, Fax: 707-579-3902, www.noltemedia.com. Provides a one-hour introduction to stream restoration and a tour of six restoration sites, including three San Francisco Bay area daylighting projects described in this report: Strawberry Creek, Blackberry Creek, and Baxter Creek.

A View of the River. By Luna B. Leopold. 1994. Cambridge, MA: Harvard University Press. A presentation of the fundamental principles of river action and behavior by a pre-eminent fluvial geomorphologist. A rigorous treatment, but accessible to a broad audience.

Organizations

The following national nonprofit organizations and government agencies can assist with publications, seminars, consulting services, referrals to professionals, and networking with other people and organizations interested in sharing experiences and advice. Many of these entities have regional, state, or local offices, chapters, or affiliates.

Coalition to Restore Urban Waters. A network of urban stream restorationists: contact them through the Save Our Streams program of the Izaak Walton League.

Natural Resources Conservation Service, U.S. Department of Agriculture. Check local listings for the nearest office, or see the USDA-hosted Federal Interagency Stream Corridor Restoration Working Group web site: www.usda.gov/stream_restoration/.

River Network, 520 SW 6th Ave. #1130, Portland, OR 97204, 503-241-3506, 800-423-6747, Fax 503-241-9256, info@rivernetwork.org, www.rivernetwork.org.

Rivers, Trails, and Conservation Assistance Program, National Park Service, U.S. Department of the Interior. Call the national office, 202-565-1204, for referral to a regional office, or see their web site: www.ncrc.nps.gov/rtca/.

Save Our Streams, Izaak Walton League of America, 707 Conservation Lane, Gaithersburg, MD 20878, 301-548-0150, 800-284-4952, Fax: 301-548-0146, sos@iwla.org, www.iwla.org/SOS/index.html.

Society for Ecological Restoration, 1955 West Grant Rd. #150, Tucson, AZ 85745, 520-622-5485, Fax: 520-622-5491, info@ser.org, www.ser.org.

Trout Unlimited, 1500 Wilson Blvd. #310, Arlington, VA 22209-2404, 703-522-0200, 800-834-2419, Fax: 703-284-9400, www.tu.org.

U.S. Environmental Protection Agency. Check local listings for the nearest office, or refer to the EPA's River Corridor and Wetlands Restoration web site: www.epa.gov/owow/wetlands/restore/

The Waterfront Center, 1622 Wisconsin Ave. NW, Washington, DC 20007, 203-337-0356, Fax: 203-625-1654, www.waterfrontcenter.org.

Waterways Restoration Institute, 1250 Addison St. #107, Berkeley, CA 94702, 510-848-2211, Fax: 510-848-2219.

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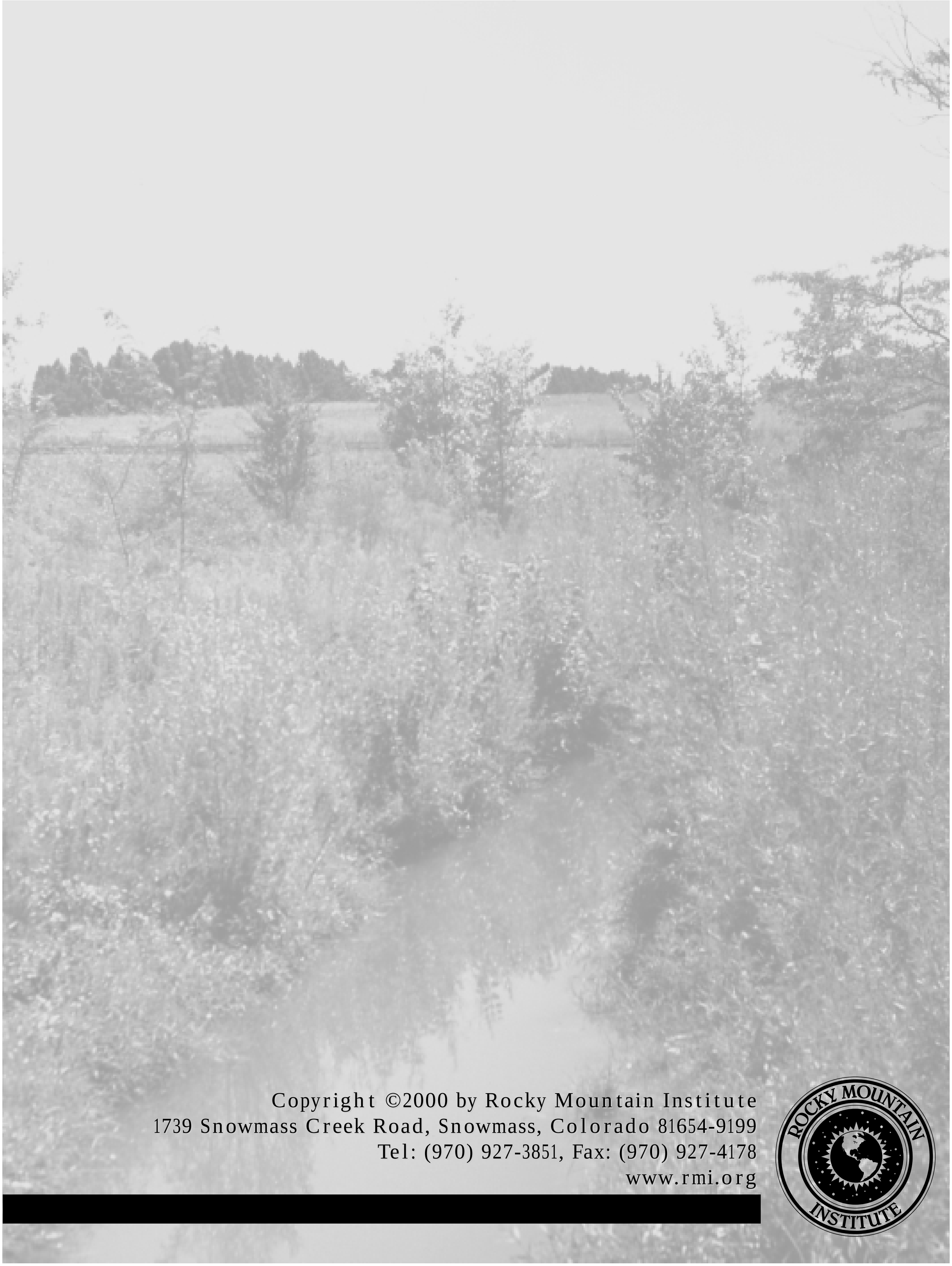

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