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URBAN STREAM DAYLIGHTING
Case Study Evaluations

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Abstract

Emerging opinions held by resource planners, engineers, ecologists, environmental scientists and landscape architects who specialize in natural systems design and stream restoration reflect the overwhelming attitude that the practice of removing streams from buried conditions (known as 'daylighting') restores life and health to streams, reduces flooding (especially in urban locations), saves money, and creates valuable public spaces.

However, several issues related to the aftermath of stream daylighting projects remain unclear and warrant further investigation. Some examples include: how long did it take, on average, for these projects to successfully restore stream health; how and when was said stream health monitored; when were reductions in municipal maintenance costs realized; how and when did these projects meet any other intended objectives; were these projects cost-effective and affordable and how were they paid for.

The objective of the following research is to collect, review, categorize and analyze documents on case studies of completed stream daylighting projects and to evaluate the ecological – as well as social - effectiveness of these projects. A secondary objective is to determine which projects included post-daylighting monitoring such as biological measurements and/or hydrologic and stream structure analyses to ascertain the long-term impacts of comprehensive stream restoration practices.

Introduction

Twenty first century America is approaching a turning point in its urban stormwater management system. This turning point is precipitated by the deterioration of industrial-era pipes that were built to capture stormwater runoff and contain streams and creeks that interrupted the dense development patterns of the 19th century. The turn-of-the-century engineering that made rapid land development possible in communities across the country is now failing and creating a host of present-day ecological problems that cannot be remedied simply by replicating the same outdated technology. Unfortunately, the vision held by many contemporary municipalities is to replace this underground infrastructure system indefinitely.

At the beginning of the twenty-first century, though, the traditional view of urban streams not the only vision available for community leaders. With emerging trends in environmental awareness and stewardship, it is possible to imagine and ultimately build a more holistic future for American cities and their now-invisible waterways. The newly emerging science of urban stream daylighting is a distinctly valuable and viable tool in such a future. When added to the arsenal of other low-impact “green infrastructure” technologies, stream daylighting offers multiple and often simultaneous engineering, economic, ecological, and social benefits.

Even though daylighting is often considered a better option than leaving streams buried in underground pipes, several post-construction issues related to stream daylighting remain unclear. Examples of these unresolved questions include but are not limited to: how long did it take, on average, for these projects to successfully restore stream health; how and when was said stream health determined; how often has the stream been monitored and what are the monitoring objectives; how and when did these projects meet any other intended objectives (such as expanding environmental awareness and education programs); were these projects cost-effective and affordable; and how were they paid for.

The following research begins by exploring the basic history of urban stormwater management in the United States and how its early expression continues to shape today’s decisions regarding the treatment of streams in built environments. The newly emerging technology of stream daylighting is then explored through case study reviews to evaluate it as a tool for restoring natural water systems in built environments, and to draw conclusions about the effectiveness of this method as a “green infrastructure” tool.

Brief History of Urban Stormwater Management

The link between human settlement and the control of water flow in those settlements dates back at least 4,000 years. "Sites excavated in the Indus Valley and in Punjab show that bathrooms and drains were common in Indian cities 4 millennia ago…Even in two millennia B.C., the Greeks and Egyptians had adequate supplies of drinking water for their cities, drained streets, had bathrooms in their houses and, in Crete, water flushing arrangements for toilets" (James, 1998). Earthenware pipes were used before 1500 B.C. and some pipes in Mesopotamian cities from that era are still in working order.


Figure 1. Hand drawn image of the "industrial city"

In European and American cities prior to the mid-1800's, small neighborhood grids allowed for the management of water with a localized supply and treatment approach that included collecting rainwater in cisterns and designing useful channels in narrow roads and alleys. However, when the industrial revolution came to full force and it was no longer possible to manage city water flow using pre-industrial methods. "The much greater quantities of water needed…as well as the increased stormwater from the larger urban area generated the need for new technology, new management processes and new urban form. The industrial city had many new sources of waste that it could not manage" (Newman, 2000).

As rapid urban expansion took place, concern about pollution in public drinking water led to placing thousands if not millions of miles of creeks and rivers into pipes. For instance, if a town's industrial and human wastes were dumped into a river, public health risks grew along with the town. Many communities dug trenches to contain these streams during flooding, or buried the streams in pipes underground to avoid associated health risks (National Park Service). Simultaneously, pristine water sources were captured to prevent them from becoming contaminated and to carry drinking water into cities, while other streams were deliberately converted into sewer channels to efficiently remove human waste. "Cities that were developed before the automobile arrived were created in dense patterns. For them, stormwater created problems. Impossibly muddy streets and compromised sanitation prompted engineers of the time to develop systems of underground pipes to carry the waste water…to adjacent rivers" (Wenk and Gregg, 24).

A critical symbiosis emerged as a result of this technology: the link between burying streams and creeks and the rise of automobile-oriented cities. This is a very important connection, because the culverting of surface water channels necessitated filling in extensive valleys with many tons of fill dirt, a leveling process that was done in advance of urban expansion to accommodate vehicular traffic. "Once the streams were buried underground, the towns also found it easier to grow. They built streets, housing, and industrial plants over the buried streams. And the public health problems also disappeared--at least for awhile" (National Park Service).

Figure 2. Wingohocking Creek Sewer under construction. 1909

"Building sewers in advance of development…gave engineers freedom in their designs….especially in areas of the city where the rectangular grid system of streets prevailed" (Levine, 2005). By placing water systems underground, adequate sewage removal was achieved, large swaths of terrain were conveniently flattened, street grids were laid out, and real estate parcels were neatly divided and quickly sold. This approach appeared to solve a wide range of problems believed to be caused by natural water in urban environments.

Sadly, development patterns have changed since then but the management approach toward urban streams has not. Many of today's urban stormwater management systems are replications of the ones that emerged in the 19th century. According to author Gary Strang, in contemporary cities the hydrology of the place is still largely ignored. "Drainage systems have been put underground unnecessarily or channelized with concrete, erasing the visual and spatial logic of the region" (Strang, Theory, 223). According to Richard Pinkham of the Rocky Mountain Institute, most urban dwellers have no idea that streams run

Figure 3. Piped Stream

underneath their feet (Pinkham, 55). The early engineering efforts have proven successful at wiping water literally off the map.

More importantly, "…many towns and cities are beginning to think differently about the streams buried under their streets. For some towns, the pipes that encase the streams have rusted and must be replaced. For other towns, the volume of water flowing into the underground pipes has increased, and now, during winter storms, the pipes back up and water overflows onto streets and other places" (National Park Service). In a post-modern context it is likely that so-called traditional methods for confining streams and stormwater are no longer valid. The "old" system may have worked temporarily to satisfy the needs of human settlement at the time, but it is argued that piping streams is no longer a desirable scenario. The act of making sub/urban water systems visible again is becoming a viable design and engineering alternative (Brown and Schueler, 2004).

Introduction to Daylighting

> "No single park, no matter how large and how well designed, would provide the citizens with the beneficial influences of nature…A connected system of parks and parkways is manifestly far more complete and useful" – *Frederick Law Olmsted*

At the turn of the century, famous landscape architect Frederick Law Olmsted held a vision of community development that was supported by wildlife biology and landscape ecology experts. Plants, animals, and ecosystem processes must be part of a network of protected natural areas in order to thrive (State Environmental Resource Center). The concept of "green infrastructure" was only just emerging in the midst of the Industrial Revolution, but it would take another hundred years to be fully defined. Today, it is considered "an interconnected network of green space that protects natural ecosystem values and functions, and provides associated benefits to human populations" (State Environmental Resource Center). It is a post-industrial conservation approach that considers ecological needs within the context of human activities.

Urban stream "daylighting" is one manifestation of green infrastructure. It attempts to address the complex and dynamic aquatic processes at work in streams surrounded by human development. As attitudes toward surface water in urban environments change over time, daylighting perhaps embodies the most radical expression of this revolution. "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" (Pinkham, IV).

Figure 4. Strawberry Creek daylighting, 1984

Stream daylighting is a relatively new tool, however. "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" (Pinkham, IV). The term 'daylighting' is often unfamiliar to most people, who confuse it with bringing daylight into the interior of a room or building. "The term describes projects that deliberately expose some or all of the flow of a previously covered river, creek, or stormwater drainage" (Pinkham, IV). In short, daylighting projects usually remove a stream from an underground pipe and restore the waterway to open air.

Given that many post-industrial waterways are now in pipes underground, why would it be considered worthwhile to dig up a culvert and restore its original surface stream? There are many motivations and objectives: ecology, economics, education, and aesthetics. The most frequent justifications for removing buried streams from their pipes are ecological ones, a trend which supports the concept of daylighting as a function of green infrastructure. It is recognized that stream daylighting can improve riparian habitat and water quality along newly created stream banks and reduce flood impacts by increasing storage capacity over that of a culvert (Pinkham, IV). It can potentially reduce the urban "heat island effect" and reduce greenhouse gases by increasing tree canopy cover (Williams, 2006).

Economically, "many communities are finding that the costs associated with 'daylighting' a stream can be less than designing new pipes and re-burying the stream" (National Park Service). Daylighted streams can increase property values and business investment opportunities in stream redevelopment zones, add intrinsically valuable public open space to dense urban communities, and reduce municipal budgets by replacing deteriorating culverts with open streams that are easier to maintain and repair (Pinkham, IV; Williams, 2006).

Stream daylighting offers psychological benefits as well. "In many ways these streams are a metaphor for the way we have 'buried' our connection with nature. Daylighting these streams restores not only natural ecological processes, but…it can restore a sense of place and the natural importance of water even in the most urban settings" (Williams, quoting Jessica Hall, 2006).

"In the past decade daylighting activity has steadily increased across the United States" (Pinkham, IV). There are underlying assumptions about daylighting, however, and they influence attitudes and decisions regarding their long-term impacts on streams. Aside from the potential benefits stated above, most people instinctively think that a body of water flowing on earth's surface is better than having it in a pipe. But the science of daylighting is not necessarily the same thing as stream *restoration*. While the two commonly go hand-in-hand as objectives of daylighting, it is not necessarily true that bringing a previously buried stream back to the surface will restore it ecologically. Numerous stream daylighting projects have been undertaken since the mid-1980's in order to improve ecological function of their respective streams. But it is not known if these projects actually restored anything or how long it took for them to do so. Did communities conduct follow-up monitoring to confirm claims of restoration or flood reduction? If reducing municipal maintenance costs was one of the project goals (by daylighting instead of replacing pipes), when were cost-savings realized? The following case study reviews attempt to answer the above questions and to evaluate the social and ecosystem benefits provided by stream daylighting.

Methods of Research

The methods used to research completed stream daylighting projects included case study reviews, literature reviews, personal interviews and site visits. Case study reviews were chosen as the primary research method due to the relatively limited number of publications about stream daylighting. While there is more than sufficient literature available related to stream ecology, environmental hydrology, and stream restoration, there is much less literature written specifically about the art and science of stream daylighting. Therefore, case study documentation is most likely the best source of information about the practice.

Additionally, they offer opportunities to compare design methods, technical challenges and solutions, and successes and failures to find common threads that might be applied to future projects with similar parameters. Investigations of the case studies will include a discussion of how many projects stated ecological objectives versus aesthetic ones, how effectively the projects met their stated objectives, how long it took the projects to do so, and whether or not they are currently being monitored.

The literature review specific to daylighting was considered equally as important as the case study reviews, however due to the relatively small amount published it is composed almost entirely of journal articles, newspaper and magazine articles, and stream restoration agency manuals which lightly touch upon the subject.

A few interviews were conducted either in person or via telephone or email where it was necessary to fill in additional information relating to budget breakdowns, project objectives and design intent, and whether or not any post-completion monitoring took place.

Where possible, site visits to daylighted streams were conducted to view, date, and photograph the results. This included a tour of “The Dell” on the campus of the University of Virginia, Charlottesville, Virginia in July 2006. A “visit” to Blackberry Creek in Berkeley, California took place in the form of a video tour from Ann Riley’s “Urban Stream Restoration” video (Nolte Media, 1998).

CASE STUDY REVIEWS

Case Study Reviews

The case study reviews involved a total of 19 completed projects selected from across the United States (Appendix A). The projects represent a wide range of political, economic, hydrologic, and geographic issues. Some were small backyard projects that cost only a few thousand dollars to implement while others involved the redesign of several city blocks and cost millions of dollars to design and build. Some projects were meant to restore fish habitat while others created urban parks for human benefit. Despite such apparent contrasts, similarities were found among them and were categorized to facilitate the comparison process.

Two important considerations explored in this research are: 1) the extent of any pre-daylighting hydrologic studies conducted on each restored reach and; 2) subsequent post-daylighting monitoring efforts. If the claim is made that stream daylighting serves ecological restoration and/or green infrastructure purposes, then what hydrologic studies were performed to ensure the new stream's hydraulic success, and what monitoring parameters were established to verify if in fact the daylighted streams accomplished ecological objectives?

From the total number of case studies, five basic categories were created based on noticeable trends in their stated goals. However, it is important to emphasize that multiple objectives were often achieved simultaneously within each project and category.

CASE STUDY CATEGORIES

- Creation of a Park Amenity
- Economic Development / Flood Reduction
- Ecological Restoration
- Creation of an Outdoor Classroom / Campus Amenity
- Residential Daylighting

A description of each category will precede the relevant case studies within it. Within each category, two detailed case studies are presented, one with the largest project costs and daylighted lengths and one with the smallest project costs and daylighted lengths (not necessarily in that order). A discussion about the unique features and outcomes of each highlighted project will follow.

Separately, each highlighted case study will be presented as a large pull-out sheet that will include its project name, location, daylighted length, important dates, key contacts, and project budget. A small introductory section will provide a background for the project, along with pre-daylighting hydrologic considerations, channel design elements, results, and post-daylighting monitoring methods.

Creation of a Park Amenity

The designation of a category specifically related to the creation of park space appears at first to be elusive. Most if not all stream daylighting efforts involve the construction of a physical space accessible to (and often paid for by) the public, thus a 'park'. The strength of embedding a stream daylighting initiative within a larger park design is that the public will often more readily embrace the idea of a new stream despite technical challenges or perceptions of danger because the trade-off – a new community park – is considered a valuable amenity (Pinkham, V; Williams, 2006).

The first example, Blackberry Creek in Berkeley, California, stands out because it is located on the property of an elementary school. It is not uncommon to encounter public resistance to stream daylighting proposals when the physical safety of young children is a concern. However, in this instance the idea for daylighting the creek came directly from PTA members themselves, and was implemented in combination with a new Tot – Lot Park design (Pinkham, 22). Children were an integral consideration in Blackberry Creek's revival, as was the desire to provide a better park for the neighborhood

Figure 5. Blackberry Creek after construction

The second example is Cow Creek running through Avenue A Park in Hutchinson, Kansas. Originally, Cow Creek ran lengthwise directly under Avenue A, which more or less acted as a bridge over the buried stream. The "bridge" needed to be replaced but turned out to be too costly and reconstruction would have interrupted downtown business traffic for up to three years (Pinkham, 22). City engineers decided to reroute Cow Creek altogether and fill in the old streambed, rebuild the road, and completely avoid a bridge (National Park Service).

Figure 6. Cow Creek site pre- and post-construction

The daylighted 800-foot-long stream section is now the centerpiece of a new park that includes a walking path right next to the channel, a grassy amphitheater and stage for shows, and a large water play area with fountains fed by city water (Pinkham, 45).

Despite differences in size, geographic location, and budgets, both projects are considered successful because popular new parks were built in conjunction with the daylighting effort. In terms of stream restoration and function, though, the newly created channels do not automatically entail ecological outcomes from the standpoint of either water quality or aquatic habitat improvement. While Blackberry Creek has managed to contain flood events without problems (Gerson et al., 2005), it is still a heavily controlled channel with gabion walls on either stream bank (Riley video tour, Nolte Media, 1998). Cow Creek is even less ecological because the stream is surrounded on all sides except the top by concrete. Thus, “success” defined by increased human use in new parks is not intrinsically linked with success for other species.

Economic Development / Flood Reduction

Flooding in present-day urban and suburban communities is often attributed to storm drains and culverts that are old and collapsing (particularly in older urban neighborhoods and business districts). Often, they were too small when installed and thus cannot handle increased amounts of impervious surface. Depending on the economic viability of the community, flood damage can remain in place for long periods of time and contribute to - or exacerbate - urban decay. Stream daylighting projects have therefore been undertaken to reduce urban flooding and to promote subsequent urban revitalization and redevelopment efforts.

Arcadia Creek Festival Place in Kalamazoo, Michigan and Grand River Cap Removal in Jackson, Michigan were both undertaken to reduce impacts caused by the culverting of their respective waterways. In the case of Arcadia Creek, daylighting portions of the stream was an integral part of the city's overall 13-block redevelopment plan (Pinkham, 32). However, the Grand River Cap Removal project led to unexpected business development and investment along the newly opened waterway.

Figure 7. Arcadia Creek Festival Site

Arcadia Creek is especially noteworthy because it represents one of the most highly urbanized locations known to be daylighted. It involved the acquisition and demolition of property, including an existing public parking lot, to make room for the daylighted channel and stormwater pond. It is considered a successful project because the resulting "stream" and "pond" have worked very well to mitigate the urban flooding problems Kalamazoo had been facing for years. Downtown businesses no longer have to pay flood insurance, there is protection from a 500-year storm event, and the city's floodplain map was completely redrawn (Pinkham, 33). Other financial benefits have since manifested: the site now generates approximately $12 million annually in festival and concert fees, which has more than paid for the $7.5 million price tag associated with the park's creation as well as its $50,000-per-year maintenance costs (Pinkham, 33).

On the other hand, the Grand River Cap Removal project is noteworthy because it was undertaken in response to a series of deaths. The cause: children being swept into the box culvert, thus the Grand River culvert was deemed an “acute health hazard” (Michigan Department of Environmental Quality). The primary goal was to remove the culvert (or “cap”) and make it possible for a person to escape the river if necessary. After it was completed, the relatively short 300-foot-long daylighted section began to attract commercial and business development along its newly-designated ‘waterfront’ stretch near downtown Jackson (Michigan Department of Environmental Quality).

Overall both projects are considered successful because they met their primary objectives. Due to the highly urbanized nature of both locations, though, final designs for both streams are very controlled water channels and concrete-lined basins. The resulting “waterways” do not resemble streams *per se*, but rather canals with surrounding parkland and new businesses. As with the creation of a park amenity, in terms of ecological function neither project guarantees a holistic environmental outcome.

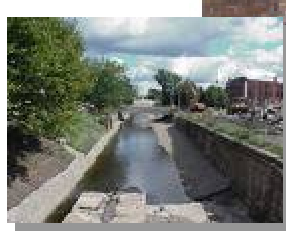

Figure 8. Grand River Cap Removal during and after construction

Ecological Restoration

A frequent assertion about stream daylighting is that it is an ecological solution to an engineering problem. This is often true in densely built urban environments where underground pipes have removed streams from their natural systems in order to accommodate large areas of impervious surface. However, the phenomenon of stream burial is not restricted to dense city grids. As post-World War II development patterns spread to areas outside urban cores and fringes, so, too, did the construction practices associated with them. Thus, in sprawling suburban neighborhoods and business districts the act of placing streams into pipes and culverts to make way for houses and roads has carried on.

Fortunately, the nature of suburban development patterns is different from existing urban ones in that the land area cleared for this settlement style is large and not densely built upon. This leads to opportunities to daylight streams with more physical room to achieve ecological objectives, such as restoring fish passage, improving aquatic habitat, and improving water quality. Rather than restrict a newly daylighted stream to concrete canals and lawn-edged stormwater basins, stream daylighting in open, suburban locales can actually provide opportunities to recreate floodplains, meandering stream channels, wider and more diverse riparian planting buffers close to the stream's edge, and in-stream habitat structures like large woody debris and log revetments.

Figure 9. Darbee Brook post-daylighting

Darbee Brook in Roscoe, New York is emphasized because it was a small, ecologically-based project that worked successfully to reintroduce fish passage to a famous fishing stream in the Catskills (Pinkham, 36). The site was on a portion of a public middle school that had culverted Darbee Brook in the 1960s to make room for larger playing fields. Over time, the culvert subsided and caused damage to the fields it was intended to protect. It finally failed in the winter of 1996 after a significant rain / thaw event. The project involved a large government agency for funding (FEMA), along with the New York Department of Environmental Conservation (DEC) and the independent organization Trout Unlimited. A new 160-foot-long open channel was built to divert Darbee Brook from its culvert, and the old pipe was removed and replaced with fill dirt to stabilize the playing fields (Pinkham, 36).

Follow-up monitoring has taken place on the new stream channel and "…electrofishing samples 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" (Pinkham, 37). According to DEC consultant Ed Van Put, "This was the first time we could take a stream out of a culvert and make it live again" (Pinkham, 37). An added bonus was its price tag: it was considered far less expensive to daylight the brook at $9,000 than to replace the existing damaged culvert which was estimated to cost up to $50,000 (Pinkham, 37).

Contrasted with Darbee Brook is Jenkins Creek in Maple Valley, Washington. The daylighting and restoration of Jenkins Creek was part of a comprehensive county-wide watershed management plan targeting the Soos Creek basin southeast of Seattle (Pinkham, 40). The creek flows from a county park in the Lake Wilderness area, yet development had still managed to alter it: two sections ran in underground pipes since the 1950s, negatively impacting water quality and preventing fish passage to a nearby lake.

The watershed management plan emphasized the need to repair and protect aquatic habitat along Jenkins Creek; a fish habitat survey identified salmonids downstream as well as fish passage barriers along the stream's length (Pinkham, 40). Daylighting Jenkins Creek occurred in two phases at two locations: an 800-foot-long channel in the Lake Wilderness Golf Course and a 700-foot-long channel in Lake Wilderness Park (which ran previously underneath a parking lot there). An additional 500 feet of existing surface stream was also restored in this phase.

Figure 10. Jenkins Creek restored stream

Both phases required the recreation of a floodplain and designing extra flow capacity into the stream channels themselves, in anticipation of future watershed development (Pinkham, 41). Other ecologically-based structures included bioswales that were put in place near roads and parking lots to intercept pollutants and sediment, and a berm designed above the golf course floodplain to capture nutrient-laden runoff. Gravel bars placed in the creek to divert flow during construction were allowed to remain in place and supply material to the new streambed (Pinkham, 41).

In the case of Jenkins Creek, extensive public meetings were conducted during development of the overall watershed management plan, including two public meetings just for daylighting Jenkins Creek. After completion, a public education campaign was undertaken in single-family neighborhoods near Jenkins Creek to teach homeowners proper maintenance practices along the newly restored stream corridor, such as not to fertilize near the creek's edge or to dump lawn clippings and other debris into the stream (Pinkham, 41).

Overall, both of these projects represent successful efforts to restore the inherent ecological functions originally present in both streams. Monitoring has taken place at both locations and has revealed that fish species are indeed returning to the streams, and that vegetation has successfully re-established itself. These are examples where intended ecological objectives were met.

Creation of an Outdoor Classroom / Campus Amenity

It is not uncommon to find biological and ecological science studies in American school curricula. Basic knowledge of how the earth's natural systems work together and overlap one another is considered a critical part of any students' overall education. The desire to explore these inter-relationships is being actualized with greater frequency in the construction of outdoor classrooms on school campuses throughout the country. Students are then able to engage with different ecosystems on a regular basis, learn how to identify plant and animal life, and to document small- and large-scale patterns in systems ranging from classroom terrariums to the weather.

One component of the trend toward outdoor education is the study of aquatic ecology. Understanding how ponds and streams work, and the life they support (including human life), is a common goal of many outdoor science classrooms. In some cases, stream daylighting on school grounds has lead to the advancement of these types of programs. In other cases, simply revealing waterways that were previously buried reconnected students and residents to a larger living system that had been forgotten about.

Jolly Giant Creek in Arcata, CA is a successful example of daylighting a stream on school property to reclaim its function and aquatic habitat specifically for students to study. The project was spearheaded by Arcata High School's biology professor and assisted by graduate students in the fisheries department of nearby Humboldt State University.

Figure 11. Jolly Giant Creek at Arcata High School

Pre-design hydrologic studies were carried out by university students, followed by channel and pond designs meant to optimize aquatic habitat and natural channel function. Not only did the completed project provide the outdoor classroom intended by the biology professor, but Jolly Giant Creek has become a valuable new public space and pedestrian greenway (Pinkham, 15). Students participated directly in the daylighting project, and today they continue to monitor the stream and ponds for resident native salmon, trout, and redds (Pinkham, 15). They also use the new greenway as a path on their way to and from school.

In the case of “The Dell” on the campus of the University of Virginia in Charlottesville, Virginia, the goal was not to restore a fully-functioning stream ecosystem so much as it was to reclaim the history of the site as a former stream corridor and pond. In so doing, architects, stream specialists, and engineers aimed to capture sediment and partial flood waters that might otherwise end up downstream, while providing a newly defined community space on campus that brought people in closer contact with the natural settings surrounding the university (Williams, 2006). By allocating nearby ball fields as floodplains and creating a large sedimentation basin surrounded by native riparian plantings, designers successfully restored the importance of water in the most urban settings and reversed the loss of “cultural space” (Williams, 2006).

Figure 12. Sedimentation basin at “The Dell” pre- and post-construction

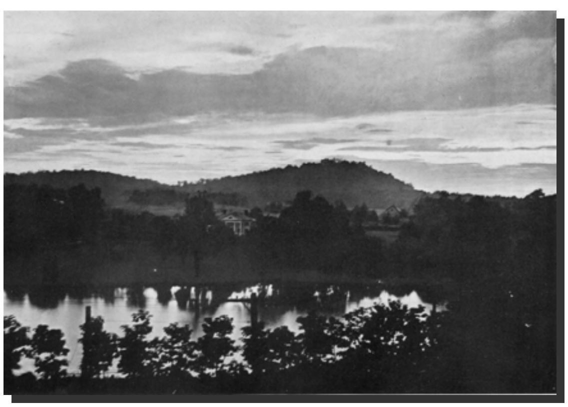

Figure 13. “Dell” site in 1919

The results of these two projects are a reasonably well-blended representation of the definition of “green infrastructure”, in that they attempt to promote ecological function while addressing the existing human context. The physical design of the Dell in particular was deliberately given straight edges on two sides to symbolically include the built environment surrounding the basin as an influencing design factor. Jolly Giant Creek represents the more ecological outcome of the two examples, because it was undertaken with ecology and habitat in mind. The Dell is less so, but has retained successful flood mitigation and sediment deposit functions as intended.

Residential Daylighting

Many streams run in pipes beneath suburban residential neighborhoods across the country. The vast number of private properties in the United States offers a wide range of opportunities to engage in "backyard" daylighting. However, natural concerns about costs and technical challenges leaves this category the smallest of the five specified in this report. Literature revealed only two case studies of daylighted streams on private residential property, both very different from each other.

Figure 14. West Ox Pasture Brook during daylighting

The first example is West Ox Pasture Brook in Rowley, Massachusetts. This was a very small (85 linear feet) residential daylighting project undertaken to restore the stream and its riparian habitat near the location of an old septic system. The home owners needed a lot of support during the design and construction process of the daylighted stream. They received substantial aid – from permitting to design to funding - from various groups such as the U.S. Fish and Wildlife Service, Partners for Wildlife, and the Parker River Clean Water Association (Pinkham, 30). Despite the concerns of the owners, they are reportedly happy to have the small stream in their backyard now, and did not pay anything toward the costs of daylighting it.

The second example is located in McClean, Virginia at the bottom of a forested, 17-acre watershed that feeds into Pimmit Run. A small ephemeral brook that ran through the top of the property had been placed into a small pipe that overflowed during large storms (Pinkham, 46). A landscape architect was responsible for designing an aesthetically pleasing alternative to this pipe while still accommodating large storm flows without damaging the house or eroding uphill soils. Ultimately, the design of this daylighted stream remained fairly controlled in runnels, vegetated swales, and new pipes running under the driveway. An impervious liner had to be installed under the more naturalized log check dam pools above the house to prevent low flows from disappearing in dry weather, thus preventing ground water recharge (Pinkham, 46). This particular project was aptly described as "micro-daylighting" by the Rocky Mountain Institute (Pinkham, 46). No visual documentation is currently available.

Results and Discussion

A total of 19 completed case study projects were reviewed during this research and are listed in detail in Appendix A. Eight projects were from the West coast, six from the Midwest, three from the Southeast, and two from the Northeast. California and Washington had the highest and second highest numbers of case studies, respectively. From the total, eleven projects were undertaken with either primary or secondary goals to create a park for human use and enjoyment. This total increases to twelve if Phase I of Jenkins Creek in Maple Valley, WA is included, as it was incorporated into an existing golf course. The desire to create an attractive amenity for people led to "success" being defined by the number of people who used the site after project completion, rather than by other more ecological parameters.

Only four projects were initiated strictly to improve water quality and/or improve fish passage and habitat within the daylighted stream section. A fifth project, Jolly Giant Creek in Arcata, CA was simultaneously an ecological restoration and outdoor classroom endeavor. Thus, out of all the projects, almost 75% focused on long-term benefits to humans while only 25% were concerned with aquatic life and water quality. The projects aimed at providing amenities for people were by and large successful in doing so.

Of all the projects, only one, Jenkins Creek in Maple Valley, WA *required* post-daylighting monitoring which consisted of vegetation counts, stream structure reviews, and fish species counts every year for three years after construction. Unofficial monitoring was reported at four other sites: Jolly Giant Creek, Blackberry Creek, Darbee Brook, and Valley Creek. Most, if not all, unofficial monitoring was conducted by local elementary, high school, and university students. The evaluation criteria typically used is limited to visual fish species identification and counting, visual plant identification and counting, and other species identification such as birds, snakes, insects, and amphibians. If there are greater numbers of species and/or more of any one particular species - and the plants are alive - then the project is usually deemed "successful". None of the daylighted sites have recorded any negative impacts of the restoration work; all are reported to be in good condition and doing well.

In the case of Blackberry Creek, though, post-project appraisals were conducted in addition to local monitoring in 1996 and 2000. In 2005, three graduate students from the University of

California, Berkeley surveyed the longitudinal profile and two cross-sections of the creek, and identified a 10-year storm event that occurred in 2002. They found that the channel's flood capacity and gradient appeared stable even though the channel may have migrated within the high bankfull. (Gerson et al., 2005)

In one particular instance, a post-daylighting report indicates positive improvements to downstream ecosystems, but it is not clearly documented. At Phalen Creek in St. Paul, MN, it is stated that "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….Macroinvertebrates and amphibians have recently been observed" (Pinkham, 35). Additionally, it is written that "Local environmentalists…believe the [new] stream and pond system captures some nutrients and other urban pollutants" (Pinkham, 35). However, no additional information is provided to verify these assertions, such as who performed the monitoring to conclude that macroinvertebrates had returned to the stream or that microscopic nutrient loads had been reduced. Thus it is hard to say with confidence that this particular site experienced any quantifiable improvements due to stream daylighting.

As stated earlier daylighting a stream is not necessarily the same thing as stream restoration. Ideally, though, the same types of preparatory measures used in stream restoration would be followed prior to restoring a buried stream to the open air. "Comprehensive restoration applications require careful consideration of current and future storm discharges, floodplain elevations, infrastructure, encroachment, and erosion potential" (Brown and Schueler, 19). A small number of projects (5) reported conducting hydrologic studies prior to construction, while many others simply designed by "trial and error". The most common forms of pre-design hydrologic studies were upstream meander and width measurements and modeling of hydraulic events for bankfull discharge during storm events. Designs done by "trial and error" often used quick reviews of aerial photos or reference reaches as guides for stream channel placement.

And yet *all* of the projects documented a range of channel intervention from gently re-grading existing banks to installing rock weirs, flow diverters, and meander bends, constructing new channel geometries, removing seawalls, and recreating floodplains. Such interventions are known to potentially alter a stream's existing hydrologic processes, which is why they're utilized. However, a relatively small proportion of projects (26%) actually took those processes into account prior to designing and constructing the new stream and its related ponds, wetlands, and floodplains. Without frequent and regular monitoring of these sites, it is difficult to ascertain whether or not any lasting harm may have actually been done to the existing stream system by implementing designs that were not fully researched and modeled prior to construction.

It is also not necessarily true that bringing a previously buried stream back to the surface will fully restore its ecological functions, as asserted by proponents of the practice. The most notable examples of this are Arcadia Creek in Kalamazoo, MI, Grand River Cap Removal in Jackson, MI and Cow Creek in Hutchinson, KS. The resulting daylighted "streams" are really not much more than concrete-lined canals meant to pass water efficiently – and in a controlled fashion – through urban neighborhoods. There is little possibility for these streams to interact with their surroundings to replenish ground water levels or provide in-stream aquatic habitat. In fact, the water table in Arcadia Creek has dropped so low due to a century-long depletion of ground water (caused by impervious surfaces) that the new "stream" *had* to be contained or its water level would disappear into the soil below (Pinkham, 32).

Furthermore, in the Kilgoblin Wetland in Barrington, IL, it is unclear whether or not stream daylighting was the actual objective. It appears to have been a project intended to create a wetland by daylighting underground storm sewers, rather than re-establish any sort of stream channel. Out of a potential 1,800 linear feet that were supposed to be daylighted, only 300 feet were removed from underground pipes. The rest of the community's storm sewer lines that were slated for daylighting were simply replaced with new pipes. The wetland itself is encircled by rip-rap and tall prairie grasses which have been given a negative cast because "they are not conducive to picnicking" (Pinkham, 26). Thus it is hard to judge just how effectively this project met any intended ecological objectives.

Cost Analysis

Stream daylighting can be an expensive endeavor due to a range of technical and physical realities. According to the Rocky Mountain Institute, several "pricey" activities are linked with daylighting:

- Technical studies
- Design work and permit applications

- Property acquisition
- Excavation and rough grading
- Hauling fill
- Materials for the stream bed and in-channel structures
- Vegetation purchases
- Hand labor for final grading and planting

This is an extensive list that actually comprises most, if not all, the aspects of daylighting a stream. It is difficult to imagine anything included in this breakdown that might be *in*expensive. Overall, the case studies examined in this research revealed certain cost trends depending upon length of stream daylighted. These trends are depicted in Table 1.

Table 1. Stream Daylighting Average Cost Breakdowns by Length

Small Scale = < 250 linear feet	
Average length	144 lin. ft.
Average cost	$9,800
Cost/lin. foot	$68.05

Medium Scale = 250 - 1,000 linear feet	
Average length	480 lin. ft.
Average cost	$48,250
Cost/lin. foot	$100.50

Large Scale = > 1,000 linear feet	
Average length	2,287 lin. ft.
Average cost	$1,857,250
Cost/lin. foot	$812.09

The most expensive project completed to date was Arcadia Creek at $7.5 million and 1,550 linear feet, while the least expensive project was West Ox Pasture Brook at $1,200 and 85 linear feet. A list of cost breakdowns for selected case studies is presented in Appendix B (general costs for each of the nineteen case studies are available in Appendix A). In general, the longer the length daylighted, the higher the costs. Also, the more urban the location, the more expensive the project became. This was often due to significant physical constraints such as the need to purchase and/or demolish existing property and to construction costs associated with structures like concrete channels necessary to contain the new stream near building foundations.

Experienced practitioners estimate the costs of daylighting to range from $300 - $1,000 per linear foot (Pinkham, 10). Kennon Williams, project manager for Nelson Byrd Woltz Landscape Architects (the designers of “The “Dell” at the University of Virginia), places the minimum cost at $200 per linear foot (Williams, 2006). To date, there is no direct cost comparison available between installing traditional culverts and stream daylighting to determine which is more cost effective over a long period of time. Cost estimates for some of the individual components of a stormwater pipeline system are listed in Table 2.

Table 2. Costs of Stormwater Pipeline Components (Source: USEPA)

Material	**Cost**
Median diam. 24 inch corrugated metal pipe	$30.10 / lin. ft.
Median diam. 36 inch reinforced concrete pipe	$74.40 / lin. ft.
Excavation of clay soil trench at 1:1 ft ratio	$7.09 / cu.yd.
Bedding costs for trench 24 in. diam.x 4 ft. wide	$8.52 / ft.
Manhole 4 ft. diam. x 4 ft. deep	$1,860.00 / ft.
Paving Costs:	
Prepare and roll subbase > 2500 sq.yd.	$ 0.88 / sq. yd.
Base course (3 in. crushed stone)	$3.39 / sq.yd.
Asphalt pavement (3 in. binder course)	$5.91 / sq.yd.
Asphalt pavement (2 in. wearing course)	$4.52 / sq.yd.
Curb and gutter (24 in. diam. concrete)	$6.95 / lin. ft.

Project longevity is an important factor when comparing the two methods. The material used to build underground pipes decays over time and in contact with water; as a result, pipes need to be replaced periodically. Some pipes deteriorate faster than others. In the case of Arcadia Creek in Kalamazoo, MI, the pipes had been in place for more than 100 years before they started causing significant winter flooding (Pinkham, 32), whereas at Darbee Brook in Roscoe, NY, the culvert had been in place only since the 1960s before it began to fail (Pinkham, 36). In contrast, it can be argued that daylighting a stream – and incurring the associated costs - will take place only once. An additional justification for stream daylighting is that it has the real potential to reduce costs associated with flood damage because the new stream will store and convey rain water levels better than a traditional pipe (Pinkham, 7). Also, any miscalculations of surface stream size can be recognized and fixed more readily than they can be for an underground, out-of-sight pipe.

Currently, there is little information available to facilitate a cost comparison between maintaining a pipe and maintaining a new stream. In the end, daylighting projects can be expensive, but many have been completed at lower costs due to donations of services, materials, and volunteer labor (Pinkham, 10). A list of funding sources by state is provided in Appendix C.

The aspect of time has another facet worth considering. Once a stream is placed into a pipe underground and the final layer of paving is applied, the project is complete and the objective is immediately met. But on the opposite end of the spectrum the question remains: what is the average length of time it takes for daylighted streams to meet their financial objectives? Available literature provides no definite timeline for these results. From the nineteen case studies reviewed, the average year of completion was 1994. The earliest known daylighting project was Embarrass Creek, Urbana, IL in the early 1970s (Pinkham, 28), while the most recent was “The Dell” in Charlottesville, VA built in 2004 (Williams, 2006). The dominant literature source for the case studies was “Daylighting: New Life for Buried Streams”, published by the Rocky Mountain Institute in September, 2000. Thus, subtracting the publication year (2000) from the average daylighting year (1994) results in a mean length of six years before outcomes can be observed and recorded.

General trends from the case studies, and what they may imply for future daylighting projects, are discussed in the next chapter. Some of the questions asked at the beginning of this research – and whether or not the research answers them - will be addressed in the following section.

Note: the costs for the Grand River Cap Removal in Jackson, MI were not included in the total cost calculations because it was largely a concrete cutting activity rather than a stream restoration design. However, $62,000 of the $1,100,000 total budget went toward excavation and disposal of contaminated soils.

Major Conclusions

The case study evaluations conducted in this research revealed several interesting trends for streams that have been daylighted to date. Daylighting is indeed "feasible in a variety of situations" (Pinkham, 55), regardless of geography, stream size, hydrologic function, and available funding. Daylighting is also a new phenomenon under the broader umbrella of stream restoration work; the majority of known projects in the United States have taken place only in the last ten years, and as of literature printed in 2000 proposed projects give little or no indication when they might commence.

The most important finding of the case study review was that the majority of projects were not necessarily undertaken with the specific intent – or outcome – of restoring a stream. This was an unexpected discovery given that one of the main benefits of daylighting cited by proponents (and thus a justification for it) is the restoration of ecological function, water quality, aquatic habitat, and riparian buffers (Pinkham, 55; Williams, 2006; Brown and Schueler, 1). According to Ken Brown and Tom Schueler of the Center for Watershed Protection, "While all of these objectives are important and legitimate in urban settings, only a few seek to actually restore stream conditions in an ecological sense. Indeed, full ecological restoration may be difficult or impossible to achieve in many urban streams" (Brown and Scheuler, 1).

This was the case for the projects reviewed in this research. At least three-quarters of them set out to create a public park for human use and enjoyment, and the daylighted stream was just one element (albeit a key element) of the new park. In that regard, all the projects were deemed "successful"; they created attractive and valuable spaces that people now use on a regular basis where what stood before was an empty or derelict lot. But the ecological component seems to be lacking in many of them. The underlying presumption seems to have been that a surface-level channel was better for the stream than piping it and that simply exposing it to air and sunlight would automatically improve its quality with no further intervention required. However, simply placing water at earth's surface and rendering it visible again does not necessarily make it healthy, alive, or valuable to species other than humans (Hession and Wynn, 2006).

As a result, it becomes difficult to determine whether or not ecological functions and water quality were restored to a given stream reach or how long it took, on average, for daylighting to do so. This question is intrinsically linked to that of monitoring: if some form of ecological restoration was the goal, how was success defined, what sort of monitoring took place to verify success, and how often did monitoring occur? The five projects that sought to improve water quality, fish passage, riparian corridor vegetation and aquatic habitat measured their success using widely variable parameters. One project, Darbee Brook in Roscoe, NY, took scientific samples of fish species and quantities using electrofishing techniques (a controversial method due to decreased survival rates of small fish that come in contact with the mild electro-shock probe). It is unclear whether or not this monitoring was required or voluntary, or if this sampling method occurred more than once.

The other four projects relied strictly upon visual surveys, species identification, and counting by trained volunteers and student monitors. With the exception of Jenkins Creek, which retained a trained technician to conduct follow-up site monitoring for three years after construction, confidence in other project monitoring results is low due to the unknown amount of training and knowledge possessed by individual volunteers. Also, it is possible to mistake successful vegetation growth for in-stream water quality restoration; the pleasant appearance of healthy, full-sized plants just a year after installation can potentially lead monitors to conclude that the project achieved ecological goals regardless of actual water sampling results. Only one project, Kilgoblin Wetland in Barrington, IL, relied on benthic measurements using the Macroinvertebrate Biotic Index after completion to assess its success (Pinkham, 27). That project was completed in 1995, and its literature was published in 2000; therefore it took less than 5 years for measurable benefits to be detected. In general, though, most projects that restored some form of naturalized stream channel reported the re-appearance of fish species, aquatic insects, and successful vegetation establishment less than five years after completion.

In terms of “green infrastructure” function, it appears that all projects undertaken to reduce urban flooding problems succeeded in achieving that goal. New stream channels and/or larger open water canals that replaced failing culverts and deteriorating pipes greatly minimized or removed any previous stormwater overflows and damage. Downtown Kalamazoo, MI no longer requires businesses to purchase any sort of flood insurance (Pinkham, 33), while localized flooding at smaller sites has all but disappeared. The time frame when these results became apparent is not directly known, but is presumed to have been noticed after the first significant post-project rainfall event.

The issue of cost-effectiveness is a relative assessment. One way it can be determined is to compare it with the costs of replacing pipes and culverts, which is at best an indirect and incomplete comparison. It is harder still to compare it with the unknown costs of damaging complex and diverse aquatic ecosystems. Perhaps a better term for evaluation is “affordability”. In the case of Darbee Brook, which cost $9,000 for a length of 330 linear feet, daylighting proved to be far more *affordable* than installing a new culvert (estimated at $45,000 - $50,000). Cow Creek in Hutchinson, KS was rerouted and daylighted because it was a more *affordable* option than building a new bridge and redirecting traffic for three years. The city of Kalamazoo, Michigan decided to daylight Arcadia Creek despite the $7.5 million price tag because long-term flood damage to its downtown business district was far more costly. The new park associated with the daylighted stream generates $12 million each year in concert and activity fees, more than paying for project costs (Pinkham, 33). In these and other cases reviewed, daylighting definitely helped revitalize neighborhoods, increase property values, and benefited nearby businesses, thus justifying the money spent.

Richard Pinkham asserts that “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” (Pinkham, 55). In the end, most experts agree that daylighting can be cost effective compared to the expense of repairing a failing culvert, even if direct proof of such effectiveness is elusive.

Finally, it is likely that all the projects met their intended educational objectives. Once schoolyard wetlands and stream corridors were in place students and adults alike began to learn about the valuable dynamic life systems taking place in them. In the case of Jolly Giant Creek, students took part in daylighting the stream, grew fish salmonids in class to release in the new stream, and planted stream bank vegetation. They continue to conduct monitoring every year to evaluate the health of the system. An additional educational reward: several participants went on to pursue ecological and biological sciences in college after graduation (Pinkham, 15). This example validates the argument that daylighting projects foster stewardship of natural resources.

The total number of case studies reviewed for this research revealed the following key facts:

- Most projects are *not* undertaken primarily to restore stream health, ecology, function, or habitat
- Most projects are initiated to provide public parks for human use
- Ecological restoration efforts vary widely, although they tend to want to improve in-stream habitat and fish passage
- Projects that are undertaken to restore some sort of ecological function often do not engage in scientific monitoring to evaluate whether or not this goal was obtained over time
- Approximately one-quarter of all projects used some form of mathematical hydrologic study to estimate current stream conditions as well as the effects of building a new stream; the rest of the projects designed by "trial and error"
- Stream daylighting seems to provide significant flood protection and sedimentation control
- Stream daylighting has been very successful in promoting outdoor education on school campuses

The act of rendering a buried and forgotten waterway visible again has a profound impact on the human psyche. Case studies demonstrated that although the preferred outcome of many daylighting projects was to improve the environment, the reality was that most efforts focused attention on aesthetic appeal and public enjoyment of the new waterway. These were considered by far the most popular and "successful" projects according to the literature. Thus, by revealing pieces of the system that have been covered over, daylighting projects to date have displayed greater potential to improve human understanding and awareness of larger systems in the environment rather than improving the environment *per se*. As defined by "green infrastructure", stream daylighting is indeed a very effective strategy for uniting natural and human ecologies within the built context. By promoting a change in attitudes and values toward water resources, perhaps stream daylighting can prevent future burial of other surface water systems. This would be the ultimate act of ecological restoration.

> "With care and attention, streams and people across the country can reap tremendous rewards from this new ambition to resurrect America's lost waterways." – *Richard Pinkham*

Recommendations for Future Research

It remains unclear from the case study literature when stream daylighting is *not* recommended. Further research into prohibitive costs, site conditions, and even political struggles and public resistance would help clarify situations in which daylighting a stream is not a viable alternative. A few items were found in various pieces of literature, but none were presented in detail. The Rocky Mountain Institute simply says “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” (Pinkham, 55). But there is no elaboration is to what those considerations might be. In “The History of Philadelphia’s Watersheds and Sewers” Adam Levine briefly states that daylighting older combined sewer systems would be prohibitively expensive “…since it would mean building a completely separate system of pipes to carry the sewage” (Levine, 2005).

The presence of contaminated soils can affect the candidacy of a stream for daylighting. Tanner Springs Park in Portland, OR was slated to include a daylighted section of Tanner Creek. However, it was discovered that a century of industrial contaminants from railroad sidings remained on site (Abbate, 2006). The Oregon Department of Environmental Quality required the contaminated soil to be capped, sealing it off from any infiltration that would degrade nearby waterways. Landscape architects working on the project therefore decided to keep Tanner Creek in culverts underground (Abbate, 2006).

A final consideration for the viability of daylighting involves the stream’s health. The Center for Watershed Protection rates the support capabilities of streams using percentage of impervious surface cover as an indicator. “**Non-supporting streams** range between 25 and 60% subwatershed impervious cover [IC] and no longer support their designated uses, as defined by hydrology, channel stability habitat, water quality or biological indicators. Subwatersheds at the lower end of the IC range (25 to 40% IC) may show promise for partial restoration, but are so dominated by hydrologic and water quality stresses that they normally cannot attain pre-development biological conditions, without continued maintenance. Under some circumstances, streams in the upper range of the non-supporting category (40 to 60% IC) may show some potential for partial biological restoration, but the primary restoration strategy is often to meet community objectives such as protecting infrastructure, creating a more natural stream corridor and preventing bank erosion” (Brown and Scheuler, 5). As a result, situations involving non-supporting streams may have to rule out daylighting for ecological objectives altogether.

A second recommendation for future research is to follow proposed projects and evaluate them using the same criteria applied to completed projects. This would be done in an effort to see if they in what ways they vary from existing ones and whether or not they meet their intended objectives. The proportion of proposed projects is higher in the Northeast as opposed to the proportion of *completed* projects in the West. Will there be differences in project designs and outcomes as a result of geographic and/or hydrologic differences? Imminent demonstrations worth following will be Indian Creek in Caldwell, Idaho (on the verge of being daylighted as of 2006), and Rocky Branch Creek on the campus of North Carolina State University in Raleigh, NC (daylighting is part of a larger campus greenway and stream restoration project).

Accompanying the evaluation of future projects should be research into the process by which permits are obtained for comprehensive stream restoration projects, including stream daylighting. Understanding the technological requirements, design studies, and application fees associated with removing a buried stream from its underground pipe may shed light on the constraints that may initially dampen enthusiasm for such an endeavor.

Ultimately, the ideal scenario is to prevent streams from being buried in the first place. A number of communities have stream protection ordinances that discourage the culverting of open waterways (Pinkham, 6) and these initiatives warrant further examination. In the most extreme case, the city council of Seattle, WA drafted legislation in early 2006 that will, if passed, ban construction that interferes with streams that have the potential to be daylighted on the site (Stiffler, 2006). Proponents of the bill "…want to preserve the option to daylight in the future by ensuring that a developer cannot place a building on top of a creek, whether that creek is temporarily in a culvert or not" (Stiffler, 2006).

At the other end of the spectrum lie measures such as Blacksburg, Virginia's "Creek Overlay Zones". These zones outline buffers around local streams beyond which no development is allowed to take place. There are important questions about the popularity and efficacy of such requirements, and whether or not they can be retrofitted over streams that have already been put underground in anticipation of future restoration.

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APPENDIX A: INDIVIDUAL CASE STUDIES

LOCATION	Watershed	Flow rates	Length daylighted	Additional stream length	Costs	Primary Objectives	Secondary Objectives
West Coast							
California		5 cfs avg. annual flow					
Jolly Giant Creek	1.7 sq. mi./ rural and	128 cfs annual peak	160 linear feet	570 ft. surface restored	$120,000 plus	Create 'outdoor classroom' on high school property;	Links multiple daylighting projects
Arcata, CA ('91, '95, '97)	urban	250 cfs 100-yr peak			lots of donated	restore and older, dewatered stream channel;	and restoration reaches
					materials & labor	create a new public park	
Strawberry Creek	2.0 sq.mi/urban and	2-6 cfs avg annual flow	200 linear feet		~$50,000	Transform abandoned railyard into public park	
Berkeley, CA (1984)	university campus	800-1000 cfs 100-yr					
		peak flow					
Codornices Creek	1.5 sq.mi/ urban	2-6 cfs avg annual flow	400 linear feet		$33,000 plus lots	Stop parking lot construction & re-orient new building;	
Berkeley, CA (1994)		800-1000 cfs 100-yr			of donated material	restore creek for salmon and human use	
		peak flow			and labor		
Blackberry Creek	0.3 sq.mi/ urban	15 cfs 1.5-yr peak flow	250 linear feet		$144,000	Remove culvert that flooded schoolyard; reduce	create outdoor classroom and
Berkeley, CA (1995)		220 cfs 100-yr peak				flood damage	provide a better local park
Baxter Creek	0.25 sq.mi/residential	N/A	250 linear feet		N/A	Replace failing stormwater drains	Create open stream in local park
El Cerrito, CA (1996)							
Washington State							
Omak Creek	140 sq.mi/ range	1 cfs seasonal low flow	1,500 linear feet		$788,000 ($300K	Reduce flood hazard caused by a damaged culvert	Improve fish passage and stream
Omak, WA (1998)	land and commercial	30 cfs bankfull flow			for arch culvert)	and reopen a closed, flood-damaged lumber mill	function; incremental flow
	forestry	900 cfs 100-yr peak					introduction techniques
Valley Creek	4.2 sq.mi/ forested	15 cfs avg base flow	490 linear feet	introduced a 2.8 acre open	$1 million	Fill a defunct log moving pond and restore original	Create new habitat and
Port Angeles, WA ('97)	and urban	120 cfs 2-yr peak		water estuary		estuary, saving $150,000 per year	recreational park around estuary
		545 cfs 100-yr peak					
LOCATION	**Watershed**	**Flow rates**	**Length daylighted**	**Additional stream length**	**Costs**	**Primary Objectives**	**Secondary Objectives**
West Coast							
Washington State							
Jenkins Creek	1.6 sq.mi/ rural and	3.3 cfs mean annual	800 linear feet		$645,000, incl.	Remove pipes that prevented fish passage; improve	Reduce flooding and control
Phase I	mid-density suburban	39 cfs avg peak flow			easement purchase	stream habitats for spawning salmonids	flow from additional developments
Maple Valley, WA ('94)		55 cfs 100-yr peak					
Washington State							
Jenkins Creek	0.6 sq.mi/rural and	1.7 cfs mean annual	700 linear feet		$400,000	Remove pipes that prevented fish passage; improve	Daylight stream channel in
Phase II	low-density suburban	6.8 cfs avg peak flow				stream habitats for spawning salmonids	county park; educate residents

Maple Valley, WA ('96)		24 cfs 100-yr peak					about proper stream vegetation
		* low summer flows *					and lawn maintenance practices
Midwest							
Illinois							
Kilgoblin Wetland	1.2 sq. mi/ rural and	N/A; perennial flow	300 linear feet		$55,000	Daylight a tributary to Flint Creek; improve water	Create a small wetland near an
Barrington, IL (1995)	urban					quality downstream; remove existing culverts	industrial area
Embarrass Creek	<1 sq. mi/suburban	N/A; ephemeral in	~4,000 linear feet		N/A	Deliberate creation of a park with a newly dug stream	Remove drain tiles from old
Urbana, IL (early 1970s)		dry summers				channel in drained farm fields; re-established some	agricultural lands
						of the headwaters of Embarass Creek	

APPENDIX A: INDIVIDUAL CASE STUDIES

LOCATION	Watershed	Flow rates	Length daylighted	Additional stream length	Costs	Primary Objectives	Secondary Objectives
Midwest							
Kansas							
Cow Creek	1.5 sq.mi/urban	<30 cfs design flow	800 linear feet		$1.25 million for	Reduce pending costs of replacing a bridge that ran	Created a new urban park and
Hutchinson, KS (1997)		>700 cfs 100-yr peak			stream/park	directly on top of Cow Creek	bike path
Michigan							
Arcadia Creek	7.4 sq.mi/ urban	<5 cfs seasonal low flow	1,550 linear feet	stormwater basin built	$7.5 million	Flood relief and downtown business redevelopment	Park and canals in a CBD
Kalamazoo, MI (1995)		1,015 cfs 100-yr peak					
Michigan							
Grand River Cap Removal	163 sq. miles	n/a	300 linear feet		$1,100,000	Prevent drowning deaths	Promote 'waterfront' development
Jackson, MI (1998)							to attract more businesses
Minnesota							
Phalen Creek	2.4 sq.mi/high-	2 cfs controlled flow	2,100 feet	includes surface pond	N/A	Create stream amenity for a park by removing a	Built several sediment/ detainment
St. Paul, MN (1987)	density residential	(base flow unknown)				culvert destroyed by a storm	ponds along stream's length
	and industrial						("diversion structure")
							Partial-flow daylighting done
South							
Georgia							
Shoal Creek Trib (1994)	0.15 sq.mi/ medium	1.5 cfs seasonal low flow	200 linear feet		$14,500	Remove collapsed culvert & restore small section	
DeKalb County, GA	density residential	225 cfs 100-yr peak				of stream	
Virginia							
Pimmit Run Trib	0.03 sq.mi/forested	ephemeral creek	50-100 linear feet		N/A	Remove undersized pipe that overflowed in storms	
McLean, VA (mid-90s)	** RESIDENTIAL **	<0.02 cfs seasonal				and erode the gravel driveway	
		>7 cfs large storms					
LOCATION	**Watershed**	**Flow rates**	**Length daylighted**	**Additional stream length**	**Costs**	**Primary Objectives**	**Secondary Objectives**
South							
Virginia							
"The Dell"	150 acre/suburban	1.25 cfs base flow	1,200 linear feet		~ $700,000	Create campus amenity; allow new stream to	Use site as a floodplain
Charlottesville, VA (2004)	** college campus **	190 cfs 100-yr peak				deposit sediment on site, slow major flows	
Massachusetts							
West Ox Pasture Brook	0.35 sq.mi./suburban	small perennial stream	85 linear feet		$1,200	Backyard stream restoration; riparian habitat creation	Saved money on a home septic
Rowley, MA (1999)		on residential property					system

New York							
Darbee Brook Roscoe, NY (1996)	1.5 sq.mi/agriculture and residential **SCHOOL SITE **	0.5 cfs seasonal low flow 30-40 cfs annual peak	330 linear feet (this was removed culvert length)	160 feet of new channel (this is the total length of stream that is daylighted)	$9,000	Remove deteriorating culvert that prevented fish passage and damaged school playing fields; FEMA provided funds after huge flood damage occurred, to "prevent damage from any future flooding"	New environmental science summer camp at site; HS level water chemistry class started; other science curricula additions

APPENDIX A: INDIVIDUAL CASE STUDIES

LOCATION	Hydrologic Studies	Design Elements	Monitoring	Evaluation Method	Key Contacts	Comments	Park
West Coast		sedimentation basin					
California	flood frequency tables	recontoured floodplain	conducted every year by high	vegetation counts	Lewis Armin-Holland	sediment basin has been dredged several	Yes
Jolly Giant Creek	channel engineering	new channel geometry	school and local university	fish spawning counts	Redwood Community Action Agency	times since its construction; reported	
Arcata, CA (91, 95, 97)	revegetation plans	stormwater detention basin	biology students		(RCAA)	improved flood control and erosion control	
				none reported;			
Strawberry Creek	analyzed channel width,	upland hillocks	None officially reported;	considered a success	Douglas Wolfe & Gary Mason,	City officials initially resistant and fearful;	Yes
Berkeley, CA (1984)	depth, and meander	swales (what type?)	maintenance program using low-	for humans and	Wolfe Mason Associates (LAR's)	Today's technology will probably not allow	
	upstream; soil analysis	in-stream boulders	income high school students in	property; not known	Urban Creeks Council	for rip-rap stabilization and concrete slabs	
		rip-rap bank protection	job training program	about ecology	ASLA - Design Merit Award, 1995	left in-channel; no followup monitoring	
Codornices Creek	none reported	original meander used	None officially reported;	None reported	Urban Creeks Council	Project not possible w/o thousands of hours	Yes
Berkeley, CA (1994)		small floodplain installed	volunteers maintain plantings;		Waterways Retoration Institute	of volunteer labor; catalyst for future upstream	
		new vegetation planted	various birds and macroinvert's		Ecocity Builders (Richard Register)	and downstream daylighting that will get	
			seen, along with some mature		Wolfe Mason Associates (LAR's)	rid of some culverts for fish passage	
			steelhead upstream; frogs, snakes				
Blackberry Creek	upstream reach measure-	4 shallow rock weirs;	None officially reported;	None reported	Urban Creeks Council	"Success" defined by popularity of newly	Yes
Berkeley, CA (1995)	ments: velocity, bankfull	fascines, brush layering,	elementary school children identify		Waterways Restoration Institute	created park and tot-lots adjacent to new	
	discharge, original	pole cuttings, and erosion	organisms in the restored creek		City of Berkeley Land. Architect	stream; no indication if flood reduction has	
	stream meander	fabrics; boulders on outer	and learn about its connection to		Wolfe Mason Associates (LAR's)	occurred since daylighting	
		edges of meander bends	larger watershed				
Baxter Creek	None reported	meander bends added;	None officially reported;	None reported	Urban Creeks Council	Initial project engineers did a poor design,	Yes
El Cerrito, CA (1996)		"step-pool" construction;	maintenance performed by local		Waterways Restoration Institute	using V-channels, straight lenghts, and	
		fascines, fabric, and	resident volunteers			rip-rap along the banks; all were replaced	
		plantings to control erosion					
Washington State							
Omak Creek	Expedited analysis of	new channel geometry;	None officially reported;	None reported	Colville Confederated Tribes	Woody material for in-stream structures	No
Omak, WA (1998)	reference reaches only	low-flow & bankfull chanels;	No maintenance activities reported		Ridolfi Engineers	provided by damaged lumber mill;	
		re-established a floodplain;				Arch deck ("bottomless culvert") added to	
		23 ft wide steel arch deck				aid fish passage thru a log-loading area	
Valley Creek	None reported	removal of 400 ft of seawall;	Students from Peninsula College	None reported	Parametrix, Inc (Port's engineering	New stream is tidal; some estuary banks	Yes
Port Angeles, WA (97)		excavated 2.8 a in estuary;	have documented increases in		consultant);	are marshes; protection from sea waves and	
		filled log pond with spoils;	number of animal species and		City of Port Angeles;	storm surges required rip-rap protection in	
		shading and beach logs;	salmonid smolts in the estuary		NTI, Polaris, and Lindberg Architects	some locations; sewage pump station also	
		root masses; meander bends				required rip-rap protection to remain	
LOCATION	**Hydrologic Studies**	**Design Elements**	**Monitoring**	**Evaluation Method**	**Key Contacts**	**Comments**	**Park**
West Coast							
Washington State							
Jenkins Creek	Fish habitat survey;	Incorporated daylighted	Required by King County Dept of	Stream structures	Ken Nilsen, King County Surface	Public reaction favorable, incl. golfers;	No
Phase 1	Wetland, weir, detention	waterway as a hazard in local	Development & Environmental	condition report;	Water Management Division	In golf course, gradient was too low for	
Maple Valley, WA (94)	pond, and culvert ID along	golf course;	Services for 3 years;	Vegetation counts	(it alone funded the project entirely	velocities to flush sediments from gravel beds	
	creek;	Arch culverts beneath golf cart		Fish species counts	through a "surface water charge"	in the reach; much of channel designed on	
	Route feasability study;	bridge;			billed semi-annually along with	"50% exceedance flow" that typifies flows at	
	Geotechnical study for	Clay layer added below surface			property-tax assessments.	critical times for salmonids	
	suitability of new bridge;	to keep stream flowing in			Residences pay a flat fee of		
	Hydraulic modeling of	summer; holes added for cool			$84/year (mid-1990's)		
	channel geometries	spring water to trickle in					
Washington State							
Jenkins Creek	see above	re-creation of floodplain	Required by King County Dept of	Stream structures	King County Surface Water	Considerable attention given to optimum	Yes
Phase 11		stream channel development	Development & Environmental	condition report;	Management Division	channel depth and velocity, spawning beds,	

Maple Valley, WA (96)		vegetated biofiltration swales	Services for 3 years;	Vegetation counts	(Ken Nilsen, project engineer)	rearing areas, refugia pools, grading of	
		lip above floodplain captures		Fish species counts		pool/glide sequences, appropriate spawning	
		sediments & nutrients from				substrate, root wads, trees, and control logs.	
		golf course					
Midwest							
Illinois							
Kilgoblin Wetland	none reported	graded depression for 1-acre	none reported in wetland;	macroinvertebrate	John Heinz, public works director	At first glance, this appears to be a good	No
Barrington, IL (1995)		wetland; sediment trap at	downstream measures of macro-	measurements	Natural Areas Ecosystems Mgmt.	project; however, out of over 1,800 feet that	
		upper end that can be dredged	invertebrates improved from "fair"	(nothing specific		were supposed to be daylighted, only 300	
		and a weir to control water	to "good".	mentioned)		feet were restored; the 'engineering' of the	
		levels downstream; rip rap				wetland does not appear to be too environ-	
						mentally sustainable, and the tall prairie	
						grasses that were planted are seen as a	
						problem' to be avoided	
Embarrass Creek	none reported	a rough stream channel was	none reported	none reported	Urbana Park District (Robin Hall)	The Park District has its own taxing	Yes
Urbana, IL (early 1970s)		graded in low points of new	maintenance limited to occasional			authorities and self-funded the daylighting	
		park; allowed to meander and	thinning and pruning of plants			project.	
		establish its own channel;				This project restored an old stream channel	
		planted channel banks but				that *was not* placed into pipes originally, but	
		most riparian vegetation is				was simply drained away over time.	
		volunteer colonies					

APPENDIX A: INDIVIDUAL CASE STUDIES

LOCATION	Hydrologic Studies	Design Elements	Monitoring	Evaluation Method	Key Contacts	Comments	Park
Midwest							
Kansas							
Cow Creek	none reported	10-feet wide concrete channel	none reported	none reported	Hal Munger, City engineer	This project filled in the original creek bed	Yes
Hutchinson, KS (1997)		that is 30 inches deep;	(passes coliform standards for			and replaced it with a new one that is not	
		Cow Creek's low gradient	human contact, but is still posted			really a creek; the result is a highly controlled	
		led city to keep an armored	against entry because of nearby			and heavily built storm water canal and grass	
		bed for sediment scraping	children's water park)			park with ornamental water features.	
Michigan							
Arcadia Creek	none specifically reported	3 blocks of concrete channels	none reported	none reported	Downtown Development Authority	Due to large sediment loads and deposits	Yes
Kalamazoo, MI (1995)	but vaguely referred to	that are 20 ft wide x 12 ft deep			STS Consultants, Ltd (engineering	along the low gradient channel, most	
		open stormwater pond with			firm that led the daylighting portion)	maintenance costs are for sediment and	
		grassy slopes				trash removal); withstands flows of a 500-yr	
		6 weirs @ 1.5 ft deep along				flood now; paid for itself in event revenues	
		channel length					
Michigan							
Grand River Cap Removal	none reported	300 feet of capped culvert was	none reported	none reported	Michigan Department of Environmental	This was an unusual daylighting project for	No
Jackson, MI (1998)		removed; river banks were			Quality	unfortunate reasons; contaminated soils	
		stabilized				found on site increased total costs; new	
						stream' is only a concrete canal	
Minnesota							
Phalen Creek	none reported	2 large underground culverts	none specifically reported;	none reported	St. Paul Garden Club (Olivia Dodge)	Considerable sediment deposits into the	Yes
St. Paul, MN (1987)		open into 3 settling ponds;	Biocide-treated water from brewer		St. Paul Public Works Department	stream and no dredging schedule is known.	
		flow diverter passes a constant	has decreased in quantity since		(Pat Byrne)	This was a very unusual project in a weird	
		flow of 2 cfs into stream	plant closed; macroinvertebrates			location with unique site constraints; but	
			and amphibians reported.			it has initiated several other nearby day-	
						lighting and stormwater filtering projects	
South							
Georgia							
Shoal Creek Trib (1994)	visual assessment of	rock check dams during	none reported;	none reported	DeKalb County Parks Dpt.	Detailed breakdown of project/material costs	Yes
DeKalb County, GA	upstream reaches	construction to catch sediment	Vegetation reported to be doing		Ginna Tiernan	However, no cost comparison b/w doing this	
	(since stream was put	later pushed down to make	well and residents accepted the			and replacing the broken culvert (which was	
	underground in original	weirs; planted bank stabilization	wilder' look of the stream			one of the stated goals - saving money)	
	location, it didn't need	rather than rip-rap					
	relocation)						
Virginia							
Pimmit Run Trib	none reported	series of log check dams;	none reported	none reported	Michael Vergason, L.A.	This was largely an aesthetic design on a	No
McLean, VA (mid-90s)		runnel across pavement;				residential property, including an open	
		existing drain pipes used for				trickling water feature that needed regular	
		overflow events; vegetated				flows to be available	
		swales; plastic lined step pools					
LOCATION	**Hydrologic Studies**	**Design Elements**	**Monitoring**	**Evaluation Method**	**Key Contacts**	**Comments**	**Park**
South							
Virginia							
The Dell	Hydrologic modeling of	new pools and riffles	none officially reported, but	none reported	Nelson Byrd Woltz, Landscape	Kept an existing 48" diameter storm pipe	Yes
Charlottesville, VA (2004)	1-yr and 100-yr events	log vanes in channel	supposedly some local students		Architects: Kennon Williams	in place to capture major storm overflows;	
		stone overflow weir	are looking at it		BioHabitats: Vince Sortman	a 100-year storm has 190 cfs; only 35 cfs	
		2 infiltration rain gardens				are allowed to pass through new stream.	
		ball fields as floodplains				This is probably more of a "partial flow"	
		natural stone boulders at toe				daylighting project	
Northeast							
Massachusetts							
West Ox Pasture Brook	none reported	grading of new stream banks;	none reported	none reported	Tim Purinton (Rowley Conservation	Due to lot configuration, septic system was	No
Rowley, MA (1999)		banks mulched with hay and			Commission)	not relocated, so stream curved away from	
		planted with native species			Parker River Clean Water Association	original course to accommodate this;	

					Betty Lambright, landscape designer	homeowners needed a lot of 'hand-holding' to	
						accept the final outcome	
New York							
Darbee Brook	a few measurements of	shorter length of stream now;	Documented fish entry into the	Electrofishing samples	NY Dept of Environmental	Cost of replacing culvert was estimated at	No
Roscoe, NY (1996)	channel widths for	main channel is 25 ft wide;	main river and use of newly opened		Conservation (DEC)	$45,000-50,000….	
	representative riffles above	in summer, ~ 2 ft wide	channel itself		(Ed Van Put and Jack Isaacs)	New stream is less than ideal because it	
	the culvert				Trout Unlimited (Jack Conyngham)	does not have sufficient meander sinuousity	
					Roscoe Central School Superintend.	or an appropriately sized floodplain	
					(George Will)		

APPENDIX B: DETAILED COST BREAKDOWNS FOR SELECTED CASE STUDIES

Arcadia Creek, Kalamazoo, MI

Total Costs: $7.5 million

$7.5 million - Downtown Development Authority (DDA)

Environmental assessments
Engineering
Construction
* A majority went to soil excavation and replacement

Additional:

DDA issued bonds based on tax-increment financing: those bonds are now being repaid by property-tax revenues from zone
Private philanthropic organizations helped reduce costs to the city by funding certain property acquisitions
DDA pays maintenance costs at about $50,000 per year (remove silt, weeds, algae)
City maintains ownership of the land to protect developers from potential environmental liabilities and problems related to the site.

Blackberry Creek, Berkeley, CA

Total Costs: ~ $200,000

$144,000 (CA Dept. of Water Resources Urban Stream Restoration Program)

Planning
Permitting
Grading
Hauling away fill
Burying excavated culvert on site
Irrigation installation
Conservation corps labor

$8,000 (Thousand Oaks Elementary School District)

Fencing at top of steep sections and at headwalls

$15,000 (City of Berkeley, CA)

Concrete work
Drainage
Playground sand
Staircase down to creek

Additional:

A few thousand dollars in donated money for plants from local businesses
Design fees “reduced” but not listed specifically

Cow Creek, Hutchinson, KS

Total Costs: $4 million – Intermodal Surface Transportation Efficiency Act (ISTEA); Bridge Replacement & Transportation Program

$1.25 million - (ISTEA)

Concrete channel and walking path
Grassy amphitheater
Stage
Water play area, fountains, water features

APPENDIX B: DETAILED COST BREAKDOWNS FOR SELECTED CASE STUDIES

Darbee Brook, Roscoe, NY

Total Costs: $9,000

$9,000 - Trout Unlimited

Earthwork
Revegetation
Fencing

Additional:

Outdoor Life magazine donated money to cover nursery trees and shrubs, supplied at cost by Haledon Nursery in New Jersey

"The Dell", Charlottesville, VA

Total Costs: ~ $700,000

Source of funding: n/a
Detailed breakdown: n/a

$100,000 for original design study and plantings conducted by University Landscape Architecture Committee

Grand River Cap Removal, Jackson, MI

Total Costs: ~ $1,100,000

$1,038,000 - Clean Michigan Initiative (CMI) Fund

Cap cutting and removal
Excavation of soil along river

$62,000 - CMI Funds

Removal and disposal of contaminated soils found during construction

Jenkins Creek, Maple Valley, WA

Total Costs, Phase I: $645,000
Total Costs, Phase II: $400,000

Phase I

$289,000 for design, permitting, and right-of-way acquisition
$335,200 for earthmoving, labor, channel and landscape materials, other construction expenses

Phase II

$159, 300 for design and permitting
$240, 700 for construction

All paid for by the King County Surface Water Management Division, which is self-funded by a "surface water charge" billed to residents along with property-tax assessments.

APPENDIX B: DETAILED COST BREAKDOWNS FOR SELECTED CASE STUDIES

Jolly Giant Creek, Arcata, CA
Total Costs: $120,000
Arcata High School Project
$25,000 grant - CA Department of Water Resources Urban Stream Restoration Program
Upstream Mill
$50,000 grant - CA Department of Water Resources Urban Stream Restoration Program
Downstream Mill
$45,000 grant - CA Department of Water Resources Urban Stream Restoration Program;
U.S. Fish and Wildlife Service Challenge Cost-Share Program
Earthmoving
Various materials
Additional:
The city of Arcata contributed up to $40,000 worth of equipment, materials, and staff time
The National Tree Trust provided many trees for free

Pimmit Run, McClean, VA
Total Costs: n/a

West Ox Pasture Brook, Rowley, MA
Total Costs: $1,200
$800 - U.S. Fish and Wildlife Service Partners for Wildlife Program
$400 - Rowley Conservation Commission
Detailed breakdown not available
Plants provided by the Parker River Clean Water Association

Appendix C: Sources of Funding by State (as listed in case study literature)

California

- CA Department of Water Resources Urban Streams Restoration Program
- CA Department of Fish and Game
- City of Berkeley, California

Georgia

- U.S. Environmental Protection Agency grant – Clean Water Act Section 319 (h) Program
- DeKalb County Roads and Drainage Department – residents' drainage-improvement fund

Illinois

- Illinois Environmental Protection Agency
- Illinois Department of Natural Resources

Massachusetts

- Rowley Conservation Commission
- Parker River Clean Water Association
    - Essex County Ecology Center
    - Massachusetts Riverways Program
    - Massachusetts Environmental Trust

Michigan

- Michigan Department of Environmental Quality - Clean Michigan Initiative (CMI) Fund
- Kalamazoo Downtown Development Authority – bonds issued on tax-increment financing

New York

- Trout Unlimited, New York chapter

Washington

- Congressionally funded state salmon restoration program
- King County Surface Water Management Division – "surface water charge"

Appendix C: Sources of Funding by State (as listed in case study literature)

Federal / Private Sources

- American Forests
- Clallam County Physicians (WA)
- Federal Emergency Management Agency (FEMA) – only when flood damage is a problem
- Intermodal Surface Transportation Efficiency Act (ISTEA)
- National Fish and Wildlife Foundation
- National Park Service - Rivers & Trails Program
- Natural Resources Conservation Service
- National Tree Trust
- Orvis Company (fishing equipment manufacturer)
- Prospect Hill Foundation
- Trout and Salmon Foundation
- Trout Unlimited (state and local chapters)
- U.S. Fish and Wildlife Service - Challenge Cost-Share Program
- U.S. Fish and Wildlife Service – Partners for Wildlife Program
- Virginia Mason Hospital Association (WA)

APPENDIX D: PROPOSED DAYLIGHTING PROJECTS

LOCATION	Watershed	Additional Site Info	Length daylighted	Additional stream length	Costs	Primary Objectives	Secondary Objectives
West Coast							
California							
Derby Creek	0.25 sq.mi/ highly	UC Berkeley campus	350 ft to be	100 extra feet added	~$500,000	UC Berkeley campus amenity; hydraulic performance	
Berkeley, CA	urbanized		removed				
Strawberry Creek	1.4 sq.mi/campus	Encompasses much	6 blocks upstream		N/A	Add to existing Strawberry Creek daylighted portion	
Berkeley, CA		of Univ. of California	from original 1984				
		campus	Strawberry Creek				
Colorado							
Westerly Creek	1,900 acres	Lowry Air Force Base	1.2 miles, either	0.6 miles dechannelized	N/A	Establish an ecological and recreational corridor	
Denver, CO	4,500 acres	Stapleton Int. Airport	fully or partially	and restored		along Westerly Creek on old air force base and old	
			daylighted			airport	
Midwest							
Idaho	n/a; urbanized	Downtown business	5 city blocks to	A total of 6 acres of new	$9 million	Catalyst for downtown revitalization in the historic	Restore creek for community trail
Indian Creek	Population: 31,000	district	be removed	habitat and greenbelt in the		district	system and annual creek festival
Caldwell, ID	150 cfs base flow			center of downtown			
				Caldwell; 3.2 miles of trails			
Illinois							
South Branch of the	2.5 sq. mi	Bridge & culvert site	*Replace a culvert		N/A	Reduce water quality impacts of culvert	Remove fish passage barriers
Waukegan River			with a bridge*				
Waukegan, IL (1999)							
Minnesota							
Bassett Creek	100 acre	Housing project site	N/A		N/A	Remove damaged buildings from poor soil area and	Create a central stream corridor
Minneapolis, MN (2000)	redevelopment site					allow some flow from water tunnels to flow again on	and new park
						the surface	

APPENDIX D: PROPOSED DAYLIGHTING PROJECTS

LOCATION	Watershed	Additional Site Info	Length daylighted	Additional stream length	Costs	Primary Objectives	Secondary Objectives
South							
North Carolina							
Rocky Branch	N/A	College campus site	250 feet minimum	6,100 feet of restored	$5 million	Campus greenway and stream restoration project	Replace 3 culverts under roads
Raleigh, NC (2000)				stream geometry, banks…		(connect to city greenway system)	with bridges for sub-grade crossing
							for people and wildlife
Northeast							
Massachusetts							
Muddy River	N/A; Boston area	Muddy River runs thru	N/A; culverts at		N/A	Prevent future flooding caused by pre-Olmsted	
Boston, MA (1999)		Boston's "Emerald	3 sites must be			culverting and dense urban development	
		Necklace" park system	enlarged or removed				
Wyckoff Country Club	N/A; on a golf course	Stream will cross a	350 linear feet		projected to be 'low'	Part of golf course's pond and wetland restoration	
Holyoke, MA (2000)		fairway, make a new				projects	
		water hazard					
Connecticut							
Harbor Brook	10 sq.mi/urban and	Located in a 1/2 mile	2,000 linear feet	Restore 4 miles of river	$30 million	Address flood threats to several hundred commercial	Build a new floodplain at lower
Meriden, CT (1999)	suburban	double box culvert under				and industrial buildings	elevation than natural one
		downtown Meriden					
Additional Projects Not Yet Researched (discussion stages as of 2000)							
Berkeley, CA	Village Creek						
San Luis Obispo, CA							
Bristol, CT							
Cambridge, MA							
Foxboro, MA							
Worcester, MA							
Providence, RI	Waterplace Park	Already completed					
Philadelphia, PA							
Portland, OR							
Salt Lake City, UT	City Creek						
Janesville, WI							

APPENDIX D: PROPOSED DAYLIGHTING PROJECTS

LOCATION	Hydrologic Studies	Design Elements	Monitoring	Evaluation Method	Key Contacts	Comments	Park
West Coast							
California							
Derby Creek	not reported	not reported, but retention of	none reported	none reported	Wolfe Mason Associates		
Berkeley, CA		lawn and existing trees listed			Waterways Restoration Institute		
Strawberry Creek							
Berkeley, CA	yes, but not specified	see writeup for "5 Scenarios"	none reported	none reported	Wolfe Mason Associates		
		design options			City of Berkeley, CA		
Colorado							
Westerly Creek	none reported	keep an existing 0.6 mile-long	none reported	none reported	City of Denver redevelopment		
Denver, CO		culvert at a detention basin,			authorities (no one specific listed)		
		remove several other culverts					
		below basin that flood					
Midwest							
Idaho	none reported	not yet specified but includes	none reported	none reported	National Park Service's Rivers &	Partnership launched in 2003; first	Yes
Indian Creek		a greenway / trail system			Trails Program	restoration phase completed in 2005;	
Caldwell, ID						$225,000 grant awarded to Caldwell to	
						construct the first 3.2 miles of trails and	
						bike lanes connecting downtown services	
Illinois							
South Branch of the	none reported	natural stream bottom restored	none reported	none reported	Waukegan Park District		
Waukegan River		natural channel restored			Illinois EPA		
Waukegan, IL (1999)		fish ladder upstream of road			US EPA		
Minnesota							
Bassett Creek	none reported, but master	not specified, but runoff that is	none reported	none reported	City of Minneapolis,	Combines daylighting w/ high density	
Minneapolis, MN (2000)	planning for the entire site	currently directed into the pipes			Near North Side Neighborhood	development; stormwater infiltration systems	
	took place	will be sent to the surface			Redevelopment Project	and other runoff methods will be incorporated	
		stream instead				into the private properties	

APPENDIX D: PROPOSED DAYLIGHTING PROJECTS

LOCATION	Hydrologic Studies	Design Elements	Monitoring	Evaluation Method	Key Contacts	Comments	Park
South							
North Carolina							
Rocky Branch	not specified, but	restore proper channel geometry	none reported	none reported	North Carolina State University		Yes
Raleigh, NC (2000)	probably done	bioengineer stream banks			"Rocky Branch Greenway Project"		
campus design		expand floodplain					
		riparian buffer zone					
		stormwater BMP's in watershed					
Northeast							
Massachusetts							
Muddy River	yes, but not specified	Some combo of dredging,	none reported	none reported	US Army Corp of Engineers	Citizen groups promoting restoration of	
Boston, MA		culvert enlargement, and			FEMA	the Emerald Necklace are highly interested	
		daylighting			Boston Water & Sewer Commisison	in the daylighting option the most	
Wyckoff Country Club	none reported	none specified	none reported	none reported	Wyckoff Country Club		
Holyoke, MA (2000)							
Connecticut							
Harbor Brook	none reported, but	new floodplain; new bankfull	none reported, however deliberate		Milone & MacBroom		
Meriden, CT (1999)	probably done	channel with instream fish	steps to reduce non-point-source				
		habitat; meanders through	pollution are indicated (which				
		vegetated floodway; recreational	implies monitoring activities)				
		trail; removal of one small dam					
		and removal or non-replacement					
		of 8 bridges					