Brooke Ray Smith

December 13, 2007

Final Draft

Assessing the Feasibility of Creek Daylighting in San Francisco, Part I:

A Synthesis of Lessons Learned from Existing Urban Daylighting Projects

Abstract

The San Francisco Public Utilities Commission is investigating the feasibility of daylighting historical urban creeks to mitigate flooding and combined sewer overflows in an attractive and multi-functional way in San Francisco. Examining the successes and shortcomings of existing creek daylighting projects in similar cities elsewhere in the world can provide valuable insight for potential future daylighting projects in San Francisco. The following daylighting projects share similar hydrologic, geographic, and/or urban characteristics with San Francisco: Berkeley, El Cerrito, and Albany, California; Seattle, Washington; and Zurich, Switzerland. In general, the projects in the United States were initiated by citizens, while in Zurich a city-wide daylighting program was the primary impetus. The projects reviewed tended to be located in the most economically, politically, or geographically feasible areas, representing "low-hanging fruit." They were most often sized to accommodate the 100 year storm event. Capital costs ranged from $30-3,000 per linear foot. Community acceptance varied, but generally increased over time. In the US examples, a general lack of sufficient monitoring and maintenance pervaded

Introduction

What is Creek Daylighting?

"Daylighting is the act of removing streams from underground pipes and culverts, restoring some of the form and function of historic streams" (Pinkham 2000). Daylighting can restore full or partial flows to a waterway, and can naturalize the restored waterway to varying degrees, using either natural soil, rocks, or concrete to line a creek channel (Kennedy and Jencks 2006). In the context of urban stormwater management, stream daylighting can be a valuable way to reduce peak flows and improve water quality in urban areas, as well as provide multiple benefits to surrounding human and ecological communities. Stream daylighting is an example of low impact development (LID), also called best management practices (BMPs), soft water path development, green stormwater management, or green infrastructure (Figure 1) (Webster 2007).

Daylighting versus Restoration

Whether or not stream daylighting can be equated with stream restoration is debatable. Some believe that, "Daylighting is the most profound form of stream restoration, recreating a surface waterway where 'nothing' exists now" (Pinkham 2000). However, others describe urban stream daylighting as a diversion or a type of sewer separation, in which surface and stormwater runoff is diverted away from sewer pipes along separate conduits, either in pipes or in open channels (Webster 2007). In this sense, because many stream daylighting projects occur in highly urbanized contexts that are often ecologically and hydrologically degraded, full restoration of a stream's natural processes may be exceedingly difficult or impossible. However, daylighting can yield other important benefits including: reduced property damage from flooding, increased access to urban green space for recreation, education, and aesthetic enjoyment, and reduced combined sewer overflows into receiving waters like the San Francisco Bay (Jencks and Leonardson 2004).

Why Daylight?

In San Francisco, creek daylighting and other LID practices can help address significant challenges facing the city's water and wastewater infrastructure management today. Specifically, San

Francisco regularly experiences flooding and combined sewer overflows in wet weather due to its combined sewer system, in which sanitary sewage and stormwater runoff share the same pipe network. During wet weather, stormwater runoff can exceed the capacity of the municipal combined system, sending minimally treated wastewater into the San Francisco Bay as combined sewer overflow (CSO). The federal CSO Control Policy requires cities with combined sewer systems to limit their CSO events, and urban stormwater management can significantly reduce the volume of storm runoff that contributes to these CSOs.

Political opinion in San Francisco is favorable towards a low impact development (LID) approach to urban stormwater management, both from local government and from citizens. The San Francisco Public Utilities Commission (SF PUC), which manages city water, wastewater, and public power, hosted an Urban Stormwater Planning Charrette in September 2007. At this event, approximately seventy citizens gathered for five hours to brainstorm ways in which low impact development (LID) could reduce peak flow and volume of stormwater runoff in four of San Francisco's eastern bayside watershed basins. One preferred LID option identified in this exercise was creek daylighting in several areas of the city.

One daylighting project has already been carried out, at Tennessee Hollow Creek in the Presidio (Storesund et al 2006). Additionally, several other reports and papers identify potential for future daylighting projects throughout San Francisco (Kennedy and Jencks 2006, Braswell 2007, Jencks and Leonardson 2004, Griffith 2006).

Problem Statement

Given a demonstrated interest by citizens of San Francisco to daylight historical urban creeks within the city, how and where could this be achieved? This report examines existing stream daylighting projects in similar urban contexts worldwide, and provides recommendations for the San Francisco Public Utilities Commission (SFPUC) that could guide future implementation of a San Francisco daylighting project. Specific research questions developed by the SF PUC and the author include: 1) Why and how did these projects begin? 2) How were they sited and sized in order to maximize their effectiveness? 3)

How effective have they proven in terms of meeting stated goals and being cost-effective? and 4) what lessons learned can apply to a San Francisco context?

Methods

Case Study Selection

I chose nine case studies in three geographic regions that each share important geographic, hydrologic, political, and/or regulatory contexts with San Francisco: the San Francisco Bay Area, the city of Seattle in Washington, and the city of Zurich in Switzerland. Each case study provides insights for San Francisco, but no single project answers all of this report's research questions.

Specifically, the daylighting projects on Strawberry Creek and Blackberry Creek in Berkeley, on Baxter Creek in El Cerrito, on Cordonices Creek in Albany, and on Tennessee Hollow Creek in the San Francisco Presidio share the most similar climatic and regulatory conditions with San Francisco. In addition, they have also been well documented in post-project appraisal reports (Pinkham 2000, Purcell 2004, Gerson et al 2005, Storesund 2006, Garber et al 2007), and are cited nationwide as successful daylighting precedents (Pinkham 2000). Interestingly, "the highest concentration of 'daylighting' activity in the US can be found in the San Francisco Bay Area" (Mason 2001). However, none of these projects lend insight into San Francisco's combined sewer challenges because they are located in separate sewer areas.

In contrast, Seattle and Zurich both operate combined sewer systems, both have significant experience with urban stream daylighting, and both share many similar physical characteristics with San Francisco (Table 1). Specifically, Zurich, Seattle, and San Francisco all have densely populated urban areas with large areas of impermeable surface and culverted or underground creeks, all have complete or partial combined sewer systems, and all are progressively-minded and interested in a 'softer' or green infrastructure approach to managing stormwater (Ted Holden, Seattle Public Utilies, personal communication 10/19/07; Conradin and Buchli 2004).

In Seattle, four daylighting projects have been successful over the past ten years: Meadowbrook Creek, Ravenna Creek, Madrona Creek, and Thornton Creek. All were designed by the same landscape architect, Peggy Gaynor, with whom I conducted a phone interview on 11/16/07. In Zurich, a citywide creek daylighting program called the "Creek Concept" has successfully completed over forty daylighting projects since its inception in 1988 (Bauer and Brewer 2007). Although no data was available for a specific daylighting project, Zurich provides an excellent model of an effective citywide daylighting program. As a reference, Zurich is particularly appropriate for San Francisco because the two are officially "sister cities" under the San Francisco-Zurich Initiative (http://www.sfzhinitiative.com/). This relationship fosters sharing of insights about innovative urban planning initiatives such as creek daylighting.

Data Acquisition

Data acquisition included primary research, through phone interviews and email correspondence with city officials and stream daylighting experts, and secondary research through review of existing post-project appraisals and written reports as well as Internet research. From these sources, I compiled a matrix of salient characteristics of nine urban creek daylighting projects in Berkeley, Albany, El Cerrito, San Francisco, and Seattle, as well as the Zurich citywide creek daylighting program (Appendix A). Characteristics were selected to provide basic information about a project (date begun, date completed, location, length of daylit reach, stated goals, historical and current condition, project cost, and funding source), and to answer specific questions in which the SF PUC is interested (impetus, siting and sizing determinants, contamination prevention, goal achievement, monitoring, and lessons learned).

Results: Case Study Analysis

Impetus: Why and How Do Daylighting Projects Begin?

Daylighting projects in the Bay Area, Seattle, and Zurich have arisen due to citizen action, due to city policy, or as an added part of a previously planned construction project (Appendix A). In Seattle's four daylighting projects, grassroot organization and political support was one of the most significant factors in funding and implementing the projects (Peggy Gaynor, Gaynor Inc., personal communication 11/16/07). Citizens groups such as the Ravenna Creek Alliance, the Friends of Madrona Woods, and the Thornton Creek Legal Defense Fund in Seattle, and the Urban Creeks Council and Parent Teacher Associations in the Bay Area all contributed substantial amounts of time, money, and political pressure on city governments to daylight urban creeks, with successful results.

Alternatively, city policies can encourage creek daylighting, such as the Zurich Stream Daylighting Concept or "Creek Concept." This citywide policy has orchestrated over ten miles of daylighting projects since the program began in 1988 (Bauer and Brewer 2007). These daylighting or revitalization projects associated with the Creek Concept plan have occurred on approximately 40% of all of the city's non-forested urban watercourses (Figure 2). As of 2004, these urban projects have diverted 300 liters per second (L/s), or 10.6 cubic feet per second (cfs) of surface runoff from the combined sewer system. This volume equals about 37% of the total stormwater and surface runoff input to Zurich's wastewater treatment network (800 L/s, 28.2 cfs), representing a significant reduction in loading to the combined sewer system (Conradin and Buchli 2004). Other citywide policies in Portland, Oregon are discussed in Kennedy and Jencks 2006.

Finally, several daylighting projects occurred in the context of other construction or redevelopment efforts. Blackberry Creek was daylit as part of an earthquake retrofit at Thousand Oaks School; Tennessee Hollow Creek was daylit as part of a soil remediation and old landfill removal project in the San Francisco Presidio; and Thornton Creek will be revitalized as part of a redevelopment of a mixed-use residential-commercial private development on an old mall parking lot.

Siting and Sizing Determinants

The location of most of these stream daylighting projects is primarily on public land, in undeveloped or open space areas such as schools, parks, and parking lots, and most often along a historic or culverted creek path (Appendix A). According to Peggy Gaynor, these areas represent "low-hanging fruit," meaning they may be the least costly geographically, politically, and economically for a stream daylighting project. Similarly, in Zurich, daylighting projects are prioritized in areas that are most feasible for separating storm and sewer pipes, such as places where roof runoff could easily enter a daylit stream (Kohler, personal communication, 11/1/07).

In Berkeley, Zurich, and the San Francisco Presidio, daylighting projects are generally sized to accommodate the 100-year storm peak flows (Pinkham 2000; Harry Kohler, Stadt Zurich, personal communication, 11/1/07; Mark Frey, Presidio Trust, personal communication, 11/26/07). A common tool for determining creek dimensions is a regional hydraulic geometry relationship between channel size and drainage area, such as the one created by Dunne and Leopold (Dunne and Leopold 1978). In addition to quantitative engineering and hydraulic calculations, qualitative analyses are also employed in order to effectively design an urban stream daylighting project. Historical photographs or an existing upstream healthy reach provide important reference conditions for channel morphology (Purcell 2004; Gaynor, personal communication, 11/16/07). As Peggy Gaynor stated in an interview, “the creek will tell you what it wants” (Gaynor, personal communication, 11/16/07).

Effectiveness in Meeting Goals

Have these daylighting projects achieved their stated goals? In general, the answer seems to be “yes,” but as with any stream restoration or modification project, the time frame for evaluating success is variable and often unclear. Several recent post-project appraisals of older daylighting projects suggested that it can take up to ten years to realize achievement of goals, which may not have been recognized in the first several years after project completion (Gerson et al 2005; Purcell 2004). The majority of daylighting projects included several categories of goals: hydrologic goals such as daylighting an underground watercourse, flood reduction, and erosion control; ecological goals such as improving fish habitat, species diversity, and habitat corridor connectivity; and social goals such as creating a community educational and recreational amenity. In general, most daylighting projects succeeded in increasing plant and animal species, and over time fostered community acceptance and appreciation of the creek as a local amenity (Appendix A). In two cases, the community did not fully appreciate the project until five to ten years after project completion (Gerson et al 2005, Purcell 2004).

Hydrologically, stream daylighting projects have the potential to significantly reduce urban stormwater flows. In Seattle, Washington, the Ravenna Creek daylighting project diverts an estimated 1.3 to 3.2 million gallons per day (mgd) of surface runoff away from the city's combined sewer system in dry and wet weather respectively. In Zurich, Switzerland, stream daylighting projects totaling over 11 miles have diverted 4.5 million gallons per day from the city's sewer system (Kennedy and Jencks 2006).

Cost Effectiveness

Though the costs of stream daylighting projects vary widely by geographic region, project scope, and degree of community or volunteer support, a few general estimates can be found in the literature. One source estimates $100 per square foot (Webster 2007); others claim that stream daylighting generally costs $1,000 per linear foot, or $5.28 million per mile (Pinkham 2000). However, in the six case studies for which I was able to find data on costs and project length, the average cost per linear foot ranged from under $40 to over $3,000 (Figure 3). For reference, in San Francisco, replacement of aging combined sewer pipes with new pipes is estimated to cost about $2 million per mile, or $394 per linear foot; however, sheer replacement neither mitigates combined sewer overflows nor provides additional benefits beyond wastewater conveyance (Metcalf and Eddy 2006; Brown and Caldwell 2004). Alternatively, constructing more storage structures might equate to about $1,325 per linear foot, assuming 200 miles of sewers in the city and a $1.4 billion cost to construct San Francisco's transport-storage network in the 1970s (Figure 4) (RWQCB 2002). These cost alternatives indicate that daylighting can be cost-comparable with conventional, infrastructure- and material-intensive engineering solutions to San Francisco's flooding and combined sewer overflow problems. Potential funding sources for creek daylighting projects in California are listed in Appendix B.

Conclusions

Lessons learned from urban stream daylighting projects in other densely urban, politically progressive cities with combined sewer systems could help San Francisco develop its own stream daylighting program. In synthesizing these case studies, several important trends emerge regarding how and why creek daylighting projects are initiated, and what factors determine their location and dimensions.

First, the drive to initiate a creek daylighting project can come from the bottom up through grassroots efforts, from the top down through city policy, or from private sector development interests. The four daylighting projects in Seattle indicate that energy and interest from the community is critical in getting a daylighting project started. Because community groups can advocate for a particular project and can help raise awareness, interest, and funding, they may be able to secure more resources for a project than a city government would normally allocate. Local government can be most effective when carrying out policies for which constituents have expressed strong support. Viewed from a citywide perspective, programs such as the Zurich Creek Concept may enable a wastewater utility to systematically prioritize the most feasible project sites within the urban fabric, as well as provide capital and maintenance funding. These benefits are often difficult to achieve in grassroots projects that must seek funding on a case-by-case basis. In San Francisco, a combination of community activism and SF PUC policy could be an effective way to target the most economically and politically feasible opportunity areas in which to daylight historical urban creeks. San Francisco's vocal residents could help identify priority areas from the "bottom up," as they did in the recent SF PUC Urban Stormwater Planning Charrette, and citywide program could provide feasibility analyses, policy support, and funding to selected projects that meet the goals of both citizens and the SF PUC.

Second, regardless of whether they are community-driven or city-government-driven, projects are most often located in areas that require minimal capital expenditure, and tend to be designed for the 100 year storm event. In Seattle, two of its four daylighting projects are located in isolated sub-watersheds which, though highly urban, receive little or no urban street runoff (Gaynor personal communication 11/16/07). In Zurich, the daylighting projects are preferentially located in areas where sewer separation would be feasible without extensive construction and excavation costs (Kohler personal communication 11/6/07). Despite a high density and perceived full build-out in San Francisco, significant parcels of vacant land, open space area, and public land exist where historical creeks used to flow, such as McLaren

Park, Glen Park, and the Lake Merced area (Greg Braswell, San Francisco Department of Public Works, personal communication 11/9/07). Several existing studies and reports have already begun to suggest where and how creek daylighting projects could be feasible (Kennedy and Jencks 2006, Braswell 2007, Braswell personal communication, Jencks personal communication, Brown and Caldwell 2004). Next steps beyond this report should be to examine in greater detail one or several of these recommended target areas for daylighting identified. Such an analysis should locate the historic creek path within the existing land use context of the study watershed, identify opportunity areas for daylighting, calculate the peak flow and volume of expected runoff in the proposed daylighting area for a San Francisco design storm (five year three hour storm) and for a 100-year storm, and size the channel accordingly. A projected cost-benefit analysis would compare capital and maintenance costs to SF PUC savings from reduced flooding and CSO events. These analyses have already been initiated for a conceptual daylighting project along Yosemite Creek in southeastern San Francisco (Smith 2007). Additionally, the SF PUC is also currently compiling the most promising LID proposals resulting from its September 2007 Urban Stormwater Planning Charrette, and will conduct hydrologic modeling analyses to determine the costs and benefits of these stormwater management strategies, with an ultimate goal of implementation (Rosey Jencks, San Francisco Public Utilities Commission, personal communication).

By reviewing lessons learned from existing urban case studies, and by providing rationale that supports the concept of creek daylighting in San Francisco, this report provides a foundation for future hydrologic and planning analyses of the practicalities of stream daylighting in highly urban environments like San Francisco.

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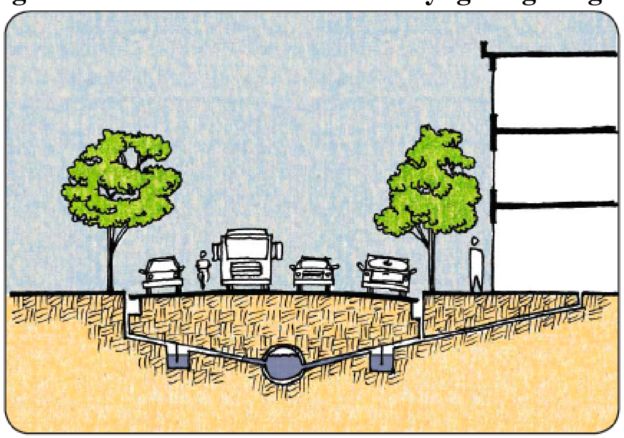
Tables and Figures

Table 1: Comparison Between Cities with Urban Stream Daylighting Programs and San Francisco[1]

City	City Area (sq.mi.)	Popu-lation	Sewer System	Historical Creeks (miles)	Current Creeks (miles)	Daylighting Projects
Zurich	35.5	690,000	80% combined	99	67	50 projects since 1988, 10 miles
Seattle	83.7	570,000	30% combined, 30% partially combined	35	Data not available	Ravenna Creek, Meadowbrook Creek, Madrona Creek, Thornton Creek
San Francisco	46.7	744,000	99% combined	27*	3.4	Tennessee Hollow Creek

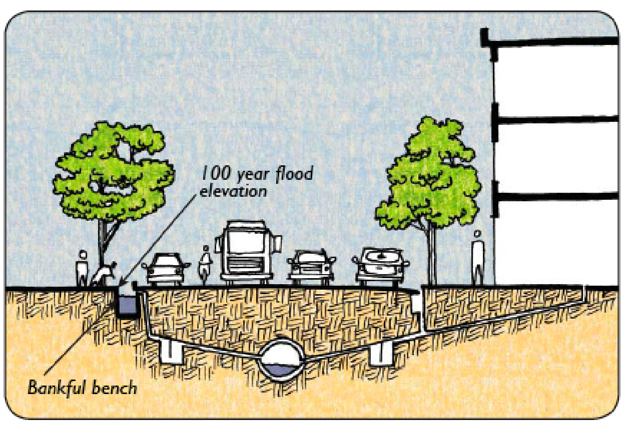
*See Appendix C: San Francisco Water Conduit Lengths: Creeks, Combined Sewer and Stormwater Infrastructure

Figure 1: Stream Diversion and Daylighting Diagrams (from Webster 2007)



Culverted creek

Currently streams are simply combined with the sewer mains



Diverted creek

Creek water runs along the surface towards the Bay or Ocean and the total volume of wastewater flow is decreased - this can be implemented on all or part of the storm flow

[1] http://www.seattle.gov/html/visitor/people.htm, http://www.zpub.com/sf/sf-info.html, http://www.demographia.com/db-zurward.htm

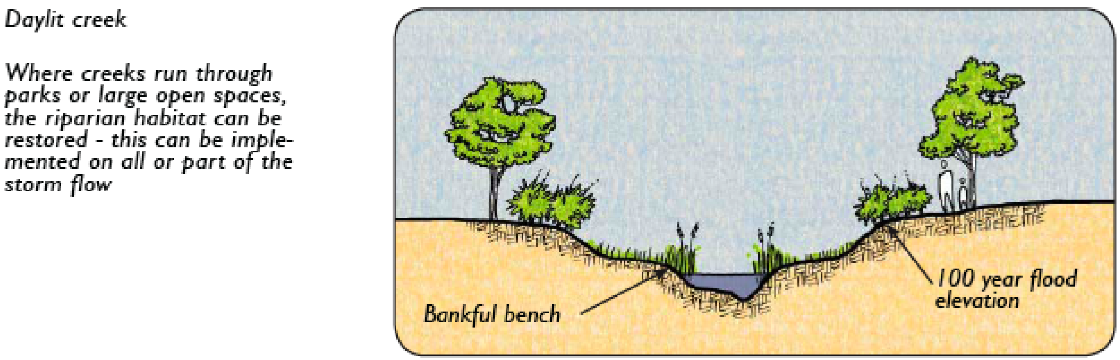


Figure 2: Distribution of Urban Stream Types in Zurich (Stadt Zurich 2007)

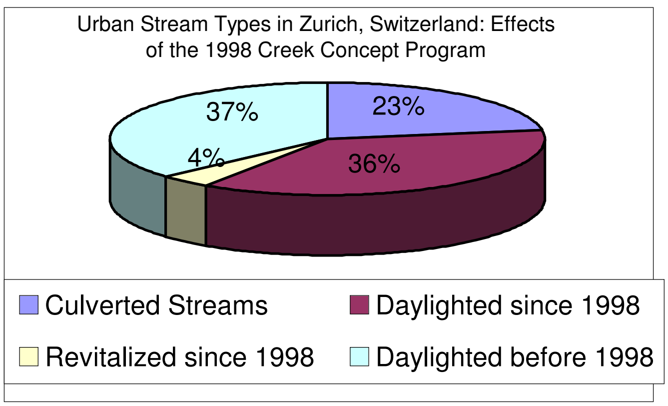


Figure 3: Capital Costs of Stream Daylighting per Linear Foot in the San Francisco Bay Area and Seattle

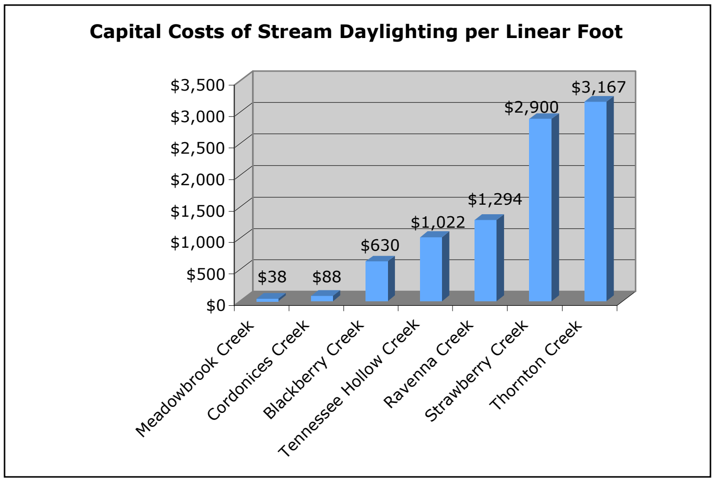
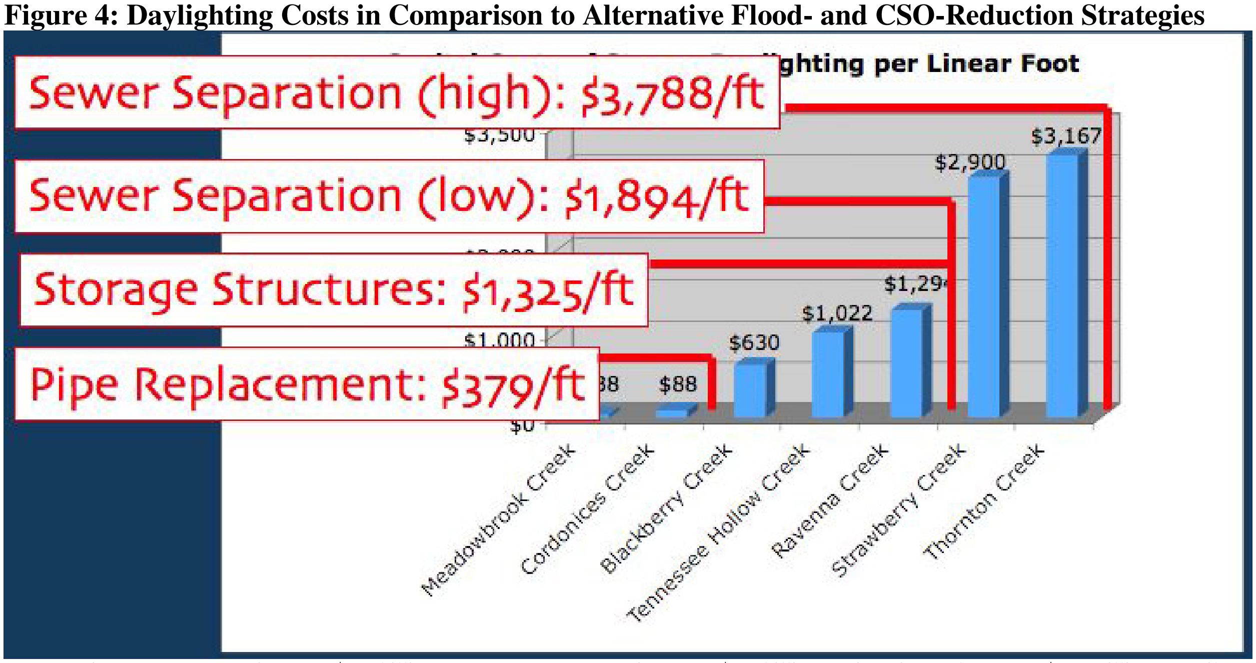


Figure 4: Daylighting Costs in Comparison to Alternative Flood- and CSO-Reduction Strategies



*Assumptions: Sewer separation cost: $2-4 billion. Storage structure cost in 1970s: $1.4 billion. Aging pipe replacement: $1-2 million per mile. San Francisco combined sewer system: 200 miles.

Appendices

Appendix A: Urban Creek Daylighting Projects Lessons Learned
Appendix B: Potential Funding Sources (from Buckholz and Younos 2007)
Appendix C: San Francisco Water Conduit Lengths: Creeks, Combined Sewer and Stormwater Infrastructure

Appendix A: Urban Creek Daylighting Projects Lessons Learned Matrix (attached)

Appendix B: Potential Funding Sources (from Buckholz and Younos 2007)

California

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

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

Appendix C: San Francisco Water Conduit Lengths: Creeks, Combined Sewer and Stormwater Infrastructure[2]

Type of Flow Path	Length (miles)
Creeks	
Contemporary Creeks	3.4
Historical Creeks	27.0
Combined Sewer System	
Underground Sewer Drains	199.1
Transport-Storage Structures	10.6
Transport-Storage Tunnels	5.0
Tunnels	4.1
Force Main Pumps	3.7
Storm System	
Underground Storm Drains	7.6
Engineered Channels	1.7

2 Created using San Francisco Department of Public Works GIS data: SF_Combined_Sewer_length.shp, SFP_flownetwork_cliptoSFmajorwatersheds.shp, SFP_historicalcreek_cliptoSFmajorwatersheds, 186xCreek_projected.shp. Contact Brooke Ray Smith for more source file information, brookeray@berkeley.edu.