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Final Draft:

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

A Preliminary Analysis of Yosemite Creek

Abstract

The San Francisco Public Utilities Commission (SF PUC) 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. Yosemite Creek in southeastern San Francisco's McLaren Park has been identified as a potentially feasible site in which to pilot a daylighting project, which could provide insight into other San Francisco projects and/or into a citywide daylighting policy. Drawing upon lessons learned from similar creek daylighting projects in similar cities elsewhere - as enumerated in Part I (Smith 2007) - Part II recommends a demonstration daylighting program in McLaren Park, sized to contain the 100 year storm. Clear goals and incorporation of monitoring and maintenance costs into the initial budget will be critical to the ability of the project to both inform future projects and adapt over time to meet goals over the long term.

Introduction

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 (Webster 2007). Part I of this report discusses in greater detail the definition of creek daylighting within the broader context of river restoration (Smith 2007).

Why Daylight in San Francisco?

In addition to the regulatory pressures reviewed in Part I, the city of San Francisco also faces three pressing economic challenges that can begin to be addressed through low impact development practices like stream daylighting. Specifically, the city's existing combined system is over a century old and beginning to fail, compliance with future, more stringent water quality regulations may be costly, and funding for conventional wastewater management solutions is scarce. First, "seventy-one percent of the collection system is over 65 years old and one-third of all sewers are more than 100 years old. As the 'normal' life expectancy of sewer pipes is 50-100 years, a pro-active repair and replacement program is essential in all future programs" (Metcalf and Eddy, 2006). Sheer replacement of these sewer pipes is estimated at up to $2 million per mile, excluding system upgrades or improvements in technology (Metcalf and Eddy, 2006).

Second, San Francisco already invested approximately $1.4 billion in the 1970s to comply with the federal Combined Sewer Overflow (CSO) Control Policy, taking over 20 years to construct a ring of storage structures around its perimeter that could detain winter storm flows until the municipal treatment plants could treat these flows to meet required water quality standards (Figure 1) (Brown and Caldwell 2004). Not keen on repeating this costly process to meet future water quality standards, the SF PUC is interested in assessing the effectiveness of LID, decentralized treatment, and alternative wastewater treatment technologies (Brown and

Caldwell 2004, Crites et al 2007, McGovern 2007). Sewer separation, an option considered in other cities in the United States such as Seattle, Portland, has been deemed infeasible due to high costs – between $2 and $4 billion - with marginal benefit to overall water quality[1] (Metcalf and Eddy 2006).

Third, a 1998 citizen initiative, Proposition H, enacted a voter-approved retail water and wastewater rate freeze from 1998 to 2006, limiting the ability of the SF PUC to fund infrastructure improvements. Proposition H allowed rate increases only for emergencies and repayment of revenue bond debt; as a consequence, water and sewer rates barely kept pace with regional inflation rates (SF PUC 2007). Faced with the potential of increased regulatory oversight of discharge water quality, and a lack of federal and local money to upgrade the existing system using conventional and expensive engineering solutions like concrete structures and energy- and chemical-intensive treatment facilities, low impact development is becoming an increasingly attractive solution.

Ongoing Stormwater Planning Efforts

Initial outreach efforts by the San Francisco Public Utilities Commission (SF PUC) to promote a low impact development (LID) approach to urban stormwater management has received citizen support in the context of a city-wide stormwater planning charrette. The SF PUC, which manages city water, wastewater, and public power, operates a Green Stormwater Management Division within its Clean Stormwater Program in the Wastewater Enterprise. In September 2007, this group within the SF PUC hosted an Urban Stormwater Planning Charrette, in which approximately seventy city residents gathered for five hours to brainstorm ways in which low impact development could reduce peak flows and volume of stormwater runoff in four of San Francisco's eastern Bayside watershed basins. A charrette is a collaborative and creative design session in which a group of designers, planners or engineers draft a range of spatial

1 As an artifact of its combined sewer system, San Francisco currently treats nearly all of its stormwater to secondary treatment standards, along with its wastewater. According to Metcalf and Eddy (2006), if separated, stormwater flows would become subject to a new host of water quality regulations, requiring significant investment in new treatment infrastructure for stormwater in addition to new conveyance infrastructure.

solutions to a particular design problem, usually in a limited amount of time (Webster 2007). This exercise is an effective way of generating a range of interdisciplinary ideas that can be eventually refined and implemented.

From this stormwater planning charrette, participants identified stream daylighting as a preferred option in several areas of the city, including the Yosemite Basin where this report will focus. Currently, consultants for the SF PUC are assessing the feasibility of daylighting as well as several other recommendations proposed during the charrette, and will produce a modeling report using InfoWorks and SWMM by Summer 2008 that will quantify the stormwater peak flow and volume reduction benefits attainable through these different LID strategies (Scott Durbin, Metcalf & Eddy, personal communication, 10/19/07). This effort is part of a larger process within the SF PUC to release a Sewer System Master Plan, in which a stormwater management component will recommend ways to reduce surface runoff into the combined system.

In addition, numerous other sources have identified opportunity areas for future daylighting projects throughout San Francisco, with Yosemite Creek being one potentially feasible site in which to pilot a creek daylighting demonstration (Kennedy and Jencks 2006, Braswell 2006, Greg Braswell, San Francisco Department of Public Works, personal communication 11/9/07; Rosey Jencks, SF PUC, personal communication 8/07-12/07, Jencks and Leonardson 2004, Griffith 2006).

Problem Statement

Given a demonstrated interest by citizens of San Francisco to daylight Yosemite Creek, how and where could this be achieved? Drawing upon lessons learned from precedent stream daylighting projects in similar urban contexts worldwide (Smith 2007), this report presents a preliminary hydrologic analysis of the needs and specifications of a proposed Yosemite Creek daylighting project, which could guide future implementation by the SF PUC of this and other daylighting projects. The following specific research questions were initially posed by the SF

PUC (Kennedy and Jencks 2006), and are used in this report as a framework in which to conduct a preliminary Yosemite Creek daylighting feasibility study:

1. How much flow historically and currently would be available for the creek channel?
2. Is the creek spring fed or does is convey storm runoff?
3. Does the creek flow perennially or with a more seasonal pattern?
4. What regulatory issues would be triggered? If the creek conveys stormwater runoff, would it be covered under Phase II regulations? If the water is sufficiently clean, would it be permissible to discharge directly to the Bay, ocean or lake?
5. What is the condition of the historical flow path? Has it been developed? Is there space (i.e., a right-of-way or purchased properties) to daylight the stream? Or is it feasible to reroute the stream into a separate pipeline?
6. What is the level of local community acceptance in the immediate vicinity of the proposed project?
7. How would SFPUC quantify the various services performed by a pipe as compared to a restored waterway? What are the differences in the operations and maintenance costs and capital investments?

Methods

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 SF PUC plans, reports, and memoranda as well as Internet research. See Part I for precedent case study selection and data analysis (Smith 2007).

Daylighting Site Analysis

Yosemite Basin is the focus watershed for this analysis for several reasons. This watershed has been identified as an opportunity area for urban stream daylighting, in part because its headwaters are located in an existing open space called McLaren Park (Kennedy and Jencks 2006, Braswell personal communication, Jencks personal communication). Yosemite Basin is a relatively small watershed of 1,469 acres, and is primarily single-family residential in its land use (Figures 2 and 3). The Basin also experiences an average of two combined sewer overflows (CSOs) per year, which exceeds the limits stated in the federal CSO Control Policy. Ongoing research efforts are assessing the feasibility of using constructed wetlands to mitigate these CSOs in Yosemite Basin (Smith, unpublished research). Combining upstream and downstream green infrastructure could be an exciting and as yet untested strategy for San Francisco in its quest to mitigate combined sewer overflows.

Design Calculations

In order to assess where and how a daylighting project could occur in Yosemite Basin, I compiled spatial data using the San Francisco Department of Public Works Geographic Information System (GIS) database. The data layers were: land use, zoning, sewer system, natural hydrologic features, historic hydrologic features, transit lines, street trees, parks and open space, land ownership, schools, neighborhoods, blocks, streets, and watershed basins. I overlayed these data layers to identify potential areas in which daylighting might be most feasible and appropriate within the Yosemite Basin. I also obtained existing data from the SF PUC about sewer pipe dimensions, estimated flow rates, flood-prone areas, and rainfall data. Dividing the historical Yosemite Creek path into four reaches based on land use, ownership, and urban condition, I compiled these data into a matrix to help identify which reaches might be most feasible to daylight (Table 1, Figure 4). For a more detailed discussion of how these factors contributed to site selection, see Part I of this report, under separate cover. These data inform a conceptual site design for the dimensions and flow path of a daylit Yosemite Creek, taking into consideration existing buildings and infrastructure.

Results Part II: Yosemite Creek Daylighting Analysis

Yosemite Basin Research Findings

Despite modeling estimates indicating otherwise, San Francisco does not quite meet its regulatory water quality discharge requirements in Yosemite Basin. The federal Combined Sewer Overflow Control Policy allows one CSO per year in the Yosemite Basin. Based on modeling software, the Yosemite Basin should experience approximately 0.94 CSO events per year, each lasting about two hours and discharging about five million gallons of minimally treated combined sewer-stormwater into the San Francisco Bay via three CSO outfall points in the

Yosemite Slough area (Figure 5). However, based on actual data from 1983-2002, the Yosemite Basin, also called South Basin, experienced an average of two CSOs per year with a maximum of eight in the unusually wet winter of 1997-1998 (Table 2). Though CSO data more recently than 2002 have been unavailable, the National Resources Defense Council (NRDC) releases an annual report of when and why public beaches have been closed due to health risks. In San Francisco in 2006, CSOs caused public advisories or closures in the Candlestick Point area just south of Yosemite Slough for a total of six days in December 2006. The Candlestick Point Sunnydale Cove closed from December 12 to 15, 2006, and the Candlestick Point Windsurfer Circle closed from December 12 to 17, 2006 (NRDC 2007). Thus, there is still a need to continue to develop ways to reduce CSOs to the San Francisco Bay, and LID measures like stream daylighting can contribute significantly towards achieving this goal.

Yosemite Creek Daylighting Analysis

Kennedy and Jencks (2006) identified Yosemite Creek within McLaren Park as a potential daylighting project site, but acknowledged that several research questions would have to be answered first. Specifically their recommendations for further study included the following questions, which guide the rest of this report.

1. <u>How much flow historically and currently would be available for the creek bed?</u>

The historic flow of Yosemite Creek is difficult to ascertain, but historic creek lengths can be estimated using GIS, which in turn was based on historical hand-drawn maps from the 1800s (Sowers 2007). The Oakland Museum has produced an excellent map showing both historic and existing conditions, in which historical creeks and marshes (circa 1850) are shown in green, and the existing sewer system is shown in red dotted lines (Figure 6).

From a GIS analysis, I determined that approximately 14,981 linear feet (2.8 miles) of primary creek channel is thought to have existed in Yosemite Basin (Figure 7). Today, however, no major creek segments exist in the basin, and only 1,425 feet (0.27 miles) of “minor creek” can be found in the upper reaches of the watershed, mostly in McLaren Park. For definitions of the terms used in Figure 7, see Appendix A. Citywide, an estimated 27 miles of historical creek may have once flowed through San Francisco until the late 1800s (Table 3, Figure 8).

The design storm for this project, which is typically used by the SF PUC, is the five year three hour design storm, which produces approximately 1.32 inches of rain with an intensity of 0.44 inches per hour (Appendix B). However, based on a review of existing projects elsewhere, evaluated in Part I of this report, many urban daylit creeks are sized for the 100 year storm. In San Francisco, a 100 year, three hour storm generates 2.08 inches of rain at 0.69 inches per hour. The average runoff coefficient given to Yosemite Basin is 0.6, and a rainfall factor of 1.05 accounts for local differences from the citywide average rainfall estimates (Brown and Caldwell 2004).

I used the rational method (Q = C x I x A) to calculate peak stormwater discharge from the watershed, incorporating the Yosemite Basin rainfall factor. Q_{100} is the peak flow from the 100-year design storm in cubic feet per second (cfs), C is a unit-less runoff coefficient, I is rainfall intensity in inches per hour, and A is area in acres.

$$Q_{100} = 0.6 \text{ x } 0.69 \text{ in/hr x } 1.05 \text{ x } 1{,}469 \text{ acres} = 611 \text{ cfs}$$

To determine the total volume of stormwater flowing through the Yosemite Basin during a 100 year three hour storm, a simple volume calculation is used (V = C x A x Rd) where V is volume in cubic feet, C is the runoff coefficient, A is area in square feet, and Rd is rainfall depth in feet.

$$V = 0.6 \text{ x } 63{,}989{,}640 \text{ ft2 x } 0.17 \text{ ft x } 1.05 = 6{,}853{,}291 \text{ ft3}$$

Converting cubic feet to gallons, this means that over a three-hour storm with a five-year recurrence interval, 51.2 million gallons of stormwater could fall on the Yosemite watershed.

Averaged out over a day, however dry weather combined sewer flows in Yosemite Basin are approximately 3.05 million gallons per day (mgd), with wet weather flows at 4.44 mgd (Brown and Caldwell 2004). This is interesting because it means that in wet weather, an average of 1.39

mgd of stormwater enters the system in addition to the base sanitary sewer flows. This represents over 30% of total wet weather flow in the Yosemite Basin, so if the stormwater component could be removed from the sewer system via daylighting and other low impact development strategies, it could constitute significant reductions in overall loading volume to San Francisco's aging combined system.

2. Is the creek spring fed or does is convey storm runoff?

Based on aerial photographs and anecdotal information, Yosemite Creek appears to have a small marsh called Yosemite Marsh at its headwaters (Figure 9) (Braswell personal communication). However, surface runoff during rain events would most likely contribute the majority of flows to a daylit Yosemite Creek, given that up to 1.39 mgd is currently entering the combined sewer system in wet weather (Brown and Caldwell 2004).

3. Is it a perennial or seasonal creek?

Yosemite Creek is classified as having been perennial, based on the Oakland Museum map data (Kennedy and Jencks 2006).

4. What regulatory issues would be triggered? If the creek conveys stormwater runoff, would it be covered under Phase II regulations? If the water is sufficiently clean, would it be permissible to discharge directly to the Bay, ocean or lake?

Since a daylighting project along Yosemite Creek is in an existing combined sewer area, it would likely be subject to the Federal CSO Control Policy rather than NPDES MS4 Phase II requirements. This means that the creek could not discharge to the Bay without a new discharge permit, which the SF PUC would prefer to avoid where possible (Arleen Navarrett, SF PUC, personal communication, 11/2/07). Daylighting a small upstream segment in McLaren Park but returning flow to the combined sewer system may represent a feasible and attractively conservative initial pilot study for the PUC. As discussed in Part I of this report, partial daylighting is a common practice in other combined sewer cities worldwide such as Seattle and

Zurich (Smith 2007). In the future, further incremental daylighting projects along more reaches of Yosemite Creek could eventually lead to complete daylighting, under a citywide green stormwater management scenario.

5. What is the condition of the historical flow path? Has it been developed? Is there space (i.e., a right-of-way or purchased properties) to daylight the stream? Or is it feasible to reroute the stream into a separate pipeline?

Figure 10 shows several areas where daylighting may be feasible based solely on land use considerations. The red circles indicate where historical Yosemite Creek flowed beneath land that is currently open space, vacant, or public non-residential land. The existing combined sewer pipes in the upper Yosemite Basin range from 42 to 84 inches in diameter (Figure 11). However, a more detailed hydraulic analysis of pipe dimensions and cost would be needed to assess the feasibility of diverting the stream completely from the combined sewer system. This analysis will be carried out in Spring 2008 by a SF PUC consulting team (Jencks, personal communication).

6. What is the level of community acceptance?

This would need to be determined through a series of local Yosemite-Basin-specific community workshops, surveys, and participatory design exercises, as follow-ups to the initial Urban Stormwater Planning Charrette held by the SF PUC in September 2007. Positive response from the September charrette participants suggests that at least a contingent of the city's community supports the idea of creek daylighting. Citizen support has been instrumental in the success of creek daylighting projects in Seattle, and thus is likely to be similarly important in San Francisco (Peggy Gaynor, Gaynor Inc., personal communication 11/6/07). See Part I of this report for more detail about the role of community support in existing urban creek daylighting projects (Smith 2007).

7. How would SFPUC quantify the various services performed by a pipe as compared to a restored waterway? What are the differences in the operations and maintenance costs and capital investments?

It is estimated that sheer replacement of aging sewer pipes in San Francisco could cost up to $2 million per mile, or $378 per linear foot (Brown and Caldwell 2004). Separating the combined system into sewer and stormwater pipes is estimated at $2-4 billion, which is infeasible for the city today (Metcalf and Eddy 2006). However, neither replacement nor separation provides ancillary benefits that often require non-market valuation tools to try to quantify. For example, willingness to pay is a way of measuring how much a particular ecosystem service, such as stream daylighting is valued. One study of restored urban streams in California found that areas with improved streams experienced property value increases from $4,500 to $19,000 after restoration measures (Streiner and Loomis 1995, in Mahan 1997). Further research into non-market valuation could provide useful economic data to more accurately assess the benefits and costs of urban stream daylighting.

CONCLUSION

Supported by successful precedents for creek daylighting projects and programs in other cities similar to San Francisco, San Francisco should pursue urban creek daylighting as an economically and politically feasible strategy for reducing the frequency of flooding and combined sewer overflow in the city. Despite its density and extensive build-out, significant parcels of vacant land, open space area, and public land exist in San Francisco, as evidenced by the analysis of Yosemite Basin land use in this report. As corroborated by several existing studies and reports, daylighting segments of Yosemite Creek within McLaren Park as a pilot study could be feasible (Kennedy and Jencks 2006, Braswell 2006, Braswell personal communication, Jencks personal communication, Brown and Caldwell 2004). Such a demonstration project could also be instrumental in helping San Francisco formulate a city-wide creek daylighting policy similar to the Creek Concept in Zurich, Switzerland, discussed in Part I (Smith 2007). More detailed hydrologic modeling is required before an actual project could be implemented, but this report provides some initial estimates of approximate locations and capacity requirements of a potential Yosemite Creek daylighting demonstration project.

By reviewing lessons learned from existing case studies in geographic regions that share important characteristics with San Francisco (Part I), and by providing rationale for the need and means to daylight a creek in the San Francisco context (Part II), this report provide a solid foundation for future hydrologic and planning analyses of the practicalities of stream daylighting in highly urban areas like the City and County of San Francisco.

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Figures and Tables

Table 1: Yosemite Creek Daylighting Analysis: Four Potential Reaches (See Figure 4)

Daylighting Reach	Zone	Land Use (Current)	Zoning (Future)	Ownership	Sewer Infrastructure
McLaren Park	Headwaters	Open Space	Public Use	SF Parks & Rec	Engineered Channels, Minor Creeks
Woolsey Street	Upper - flood reduction target area	Single Family Residential	Single Family Residential	DPW (ROWs), Private	Main Underground Pipe (>24")
Industrial	Lower - flood prone area	Industrial, Vacant	Light Industrial	DPW (ROWs), Private	Main Underground Pipe (>24")
Yosemite Slough	Mouth	Vacant	Public Use	State Parks	Transport Storage Structure

Table 2: Combined Sewer Overflow Data for San Francisco, 1983-2002 (in Brown and Caldwell 2004)

Table 3-6. Wet Weather Discharge History

Year	Westside		Bayside			
	Rainfall (inches)	Discharges	Rainfall (inches)	Discharges		
				Northshore	Central Basin	South Basin
1983-84			22.0	2	12	
1984-85			20.0	5	11	
1985-86			28.7	8	21	
1986-87			12.2	1	11	
1987-88	16.8	1	14.0	0	13	
1988-89	16.4	4	11.7	1	5	
1989-90	10.4	1	12.1	2	5	
1990-91	14.3	2	12.8	1	7	1
1991-92	17.1	5	15.9	1	7	0
1992-93	22.4	4	23.3	3	14	1
1993-94	12.6	2	15.9	2	7	0
1994-95	27.3	4	34.7	3	15	1
1995-96	22.4	9	25.0	4	15	3
1996-97	20.8	8	18.6	6	15	3
1997-98	41.1	14	39.8	7	21	8
1998-98	18.9	7	17.0	1	13	0
1999-2000	23.2	7	20.9	3	12	1
2000-01	13.8	3	15.8	0	8	0
2001-02	22.2	7	19.3	2	9	2
Average	**20.0**	**5**	**20.0**	**3**	**12**	**2**
Max	41.1	14	39.8	8	21	8
Min	10.4	1	11.7	0	5	0
Design Criteria		**8**		**4**	**10**	**1**

Table 3: Length of Historical and Contemporary Creeks and Sewers in San Francisco (based on GIS analysis)*

San Francisco Water Conduit Lengths: Creeks vs. Combined Sewer and Storm Drain Pipes*

Summary Table

Type of Flow Path	Length (miles)
Creeks	
Contemporary Creeks	**3.4**
Historical Creeks	**27.0**
Combined Sewer System	
Underground Sewer Drains >40"	**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**

Full Data Table (data derived from GIS analysis, November 2007)

Type of Flow Path	Length (feet)	Length (miles)	Length (meters)	Length (km)
Creeks				
Contemporary Creeks	8,675	**1.6**	2,645	2.6
Contemporary Minor Creeks	9,238	**1.7**	2,817	2.8
SFP Historical Creeks	151,668	**28.7**	46,240	46.2
186x Historical Creeks	133,019	**25.2**	40,555	40.6
Sewer System				
Underground Drains >40"	1,051,223	**199.1**	320,495	320.5
Transport-Storage Structures	56,066	**10.6**	17,093	17.1
Transport-Storage Tunnels	26,450	**5.0**	8,064	8.1
Tunnels	21,659	**4.1**	6,603	6.6
Force Mains	19,328	**3.7**	5,893	5.9
Storm System				
Underground Culverts or Storm Drains	39,907	**7.6**	12,167	12.2
Engineered Channels	4,008	**0.8**	1,222	1.2
Minor Engineered Channels	4,850	**0.9**	1,479	1.5

*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, bsmith@sfwater.org

* Note: This analysis relies solely on available GIS data and may not fully represent the total length of San Francisco's sewer pipes, which are estimated to be on the order of 900 miles in total (Braswell, personal communication, 11/9/07)

Figure 1: San Francisco Combined Sewer System (adapted from San Francisco Bureau of Engineering, 1996)

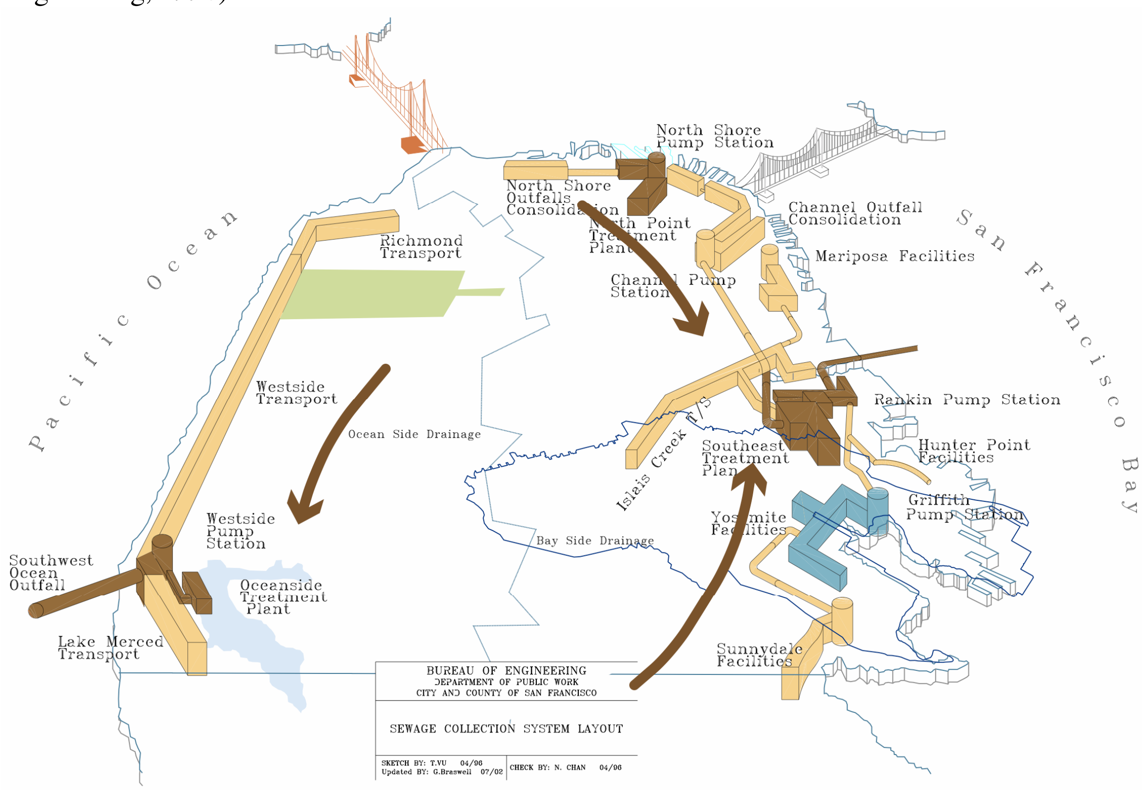


Figure 2: Yosemite Basin Site Map

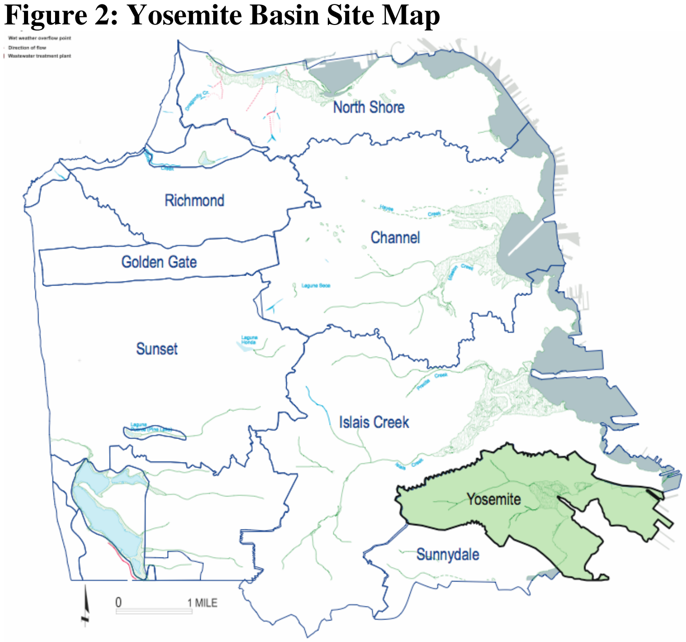


Figure 3: Yosemite Basin Land Use as of 2004 (created by Brooke Ray Smith for SF PUC, September 2007)

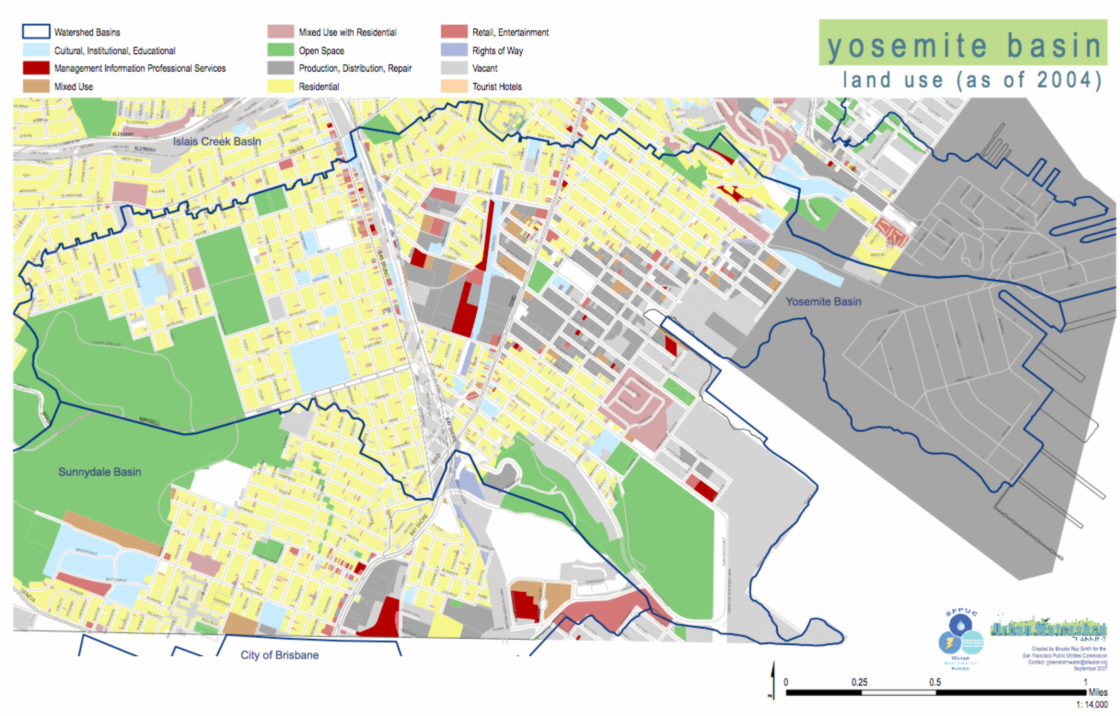


Figure 4: Four Reaches of Yosemite Creek (See Table 1)

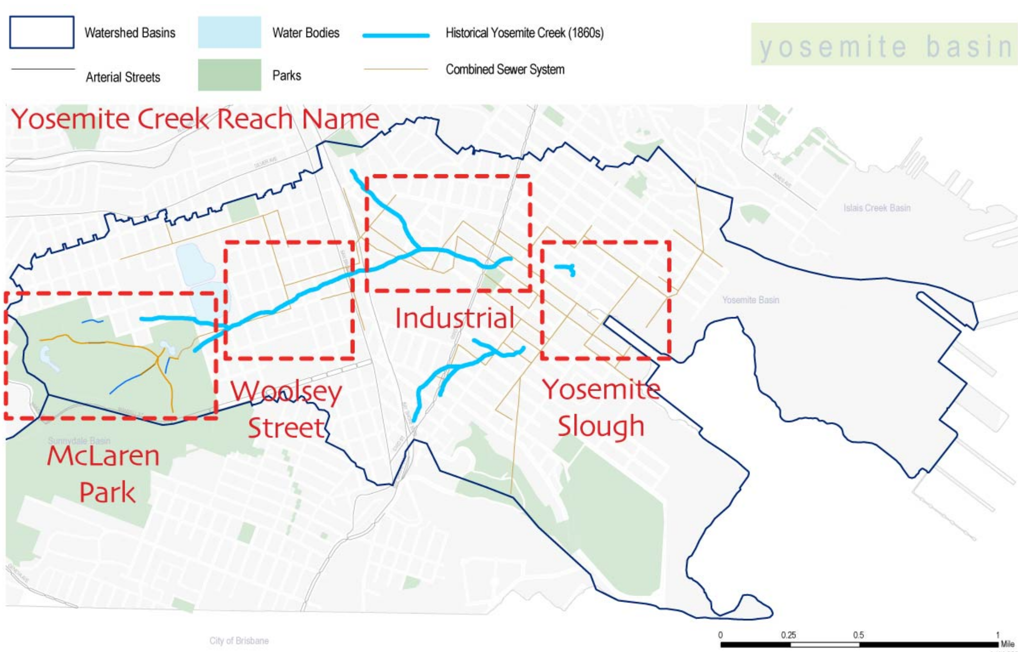


Figure 5: Yosemite Basin Combined Sewer System

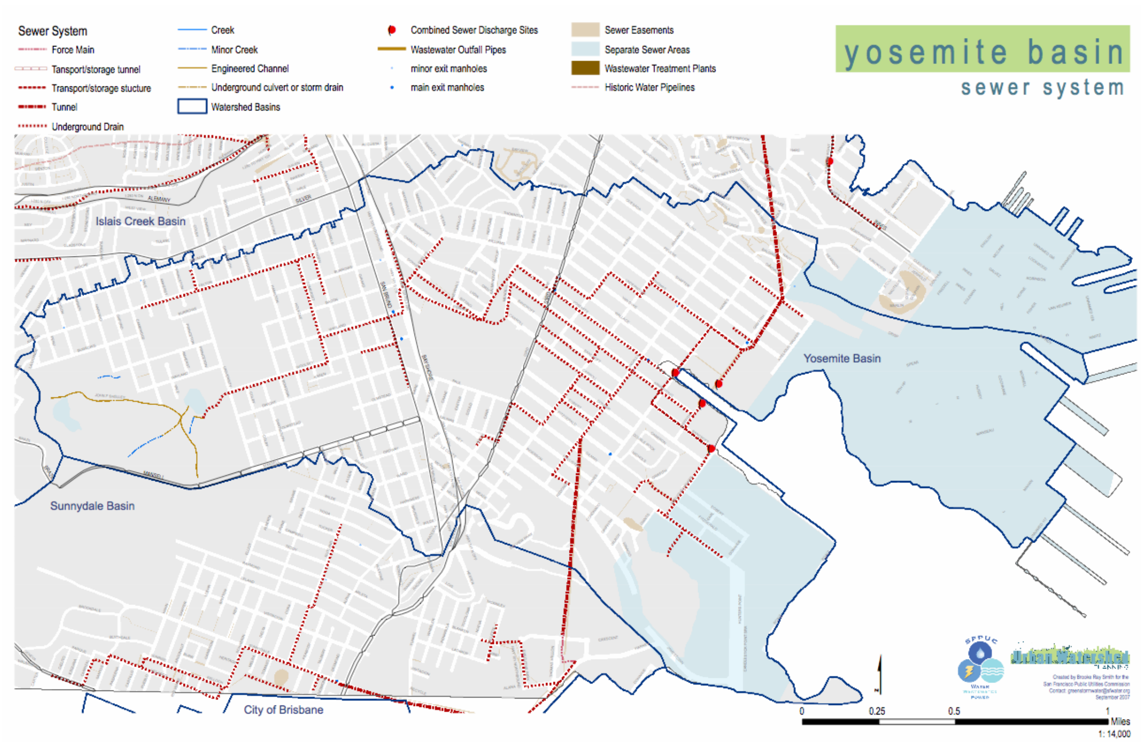


Figure 6: Current and Historical Hydrologic Features of Yosemite Watershed (from Ramirez-Herrerra, Teresa, Janet Sowers, and Christopher Richard. 2006. Creek and Watershed Map of San Francisco. William Lettis & Associates, Inc, Oakland Museum of California, and the San Francisco Estuary Institute)

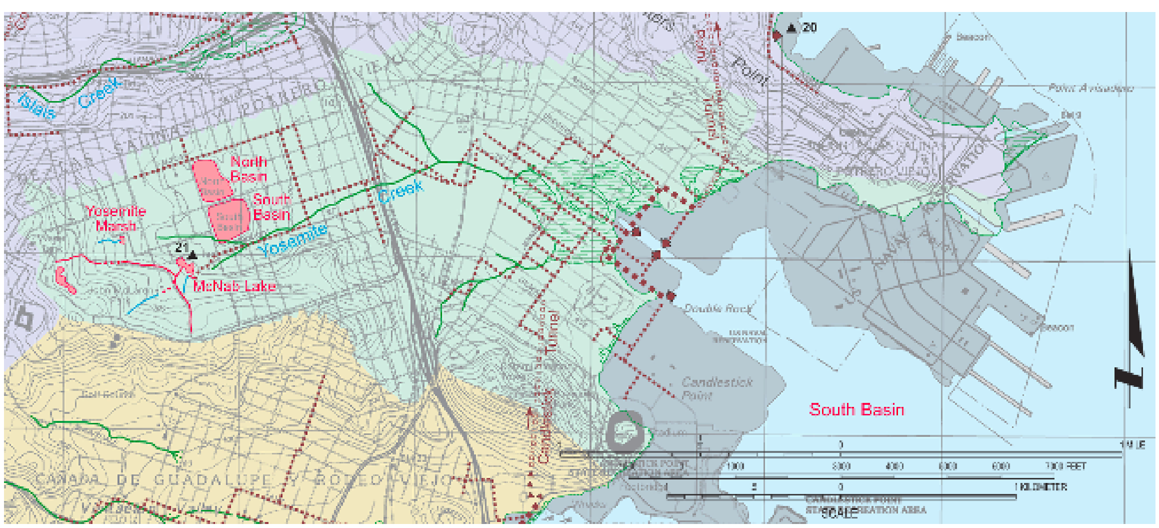


Figure 7: Estimated Historical Yosemite Creek Dimensions

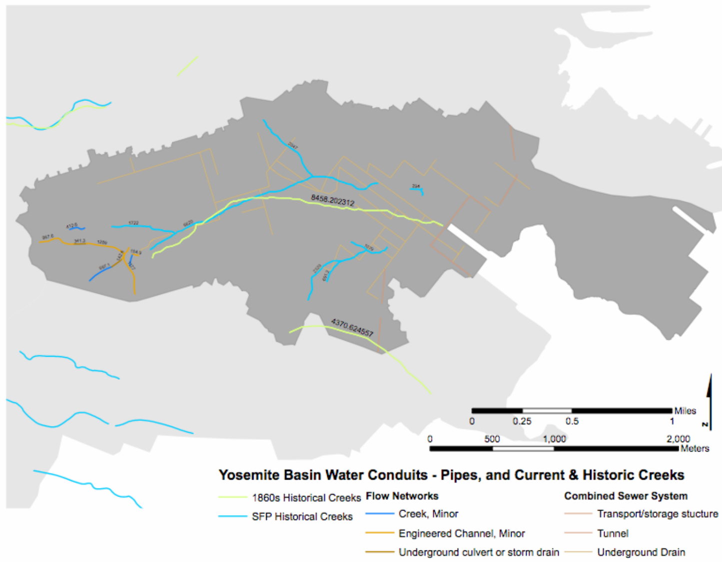


Figure 8: San Francisco Historical Creek and Contemporary Sewer Flow Paths

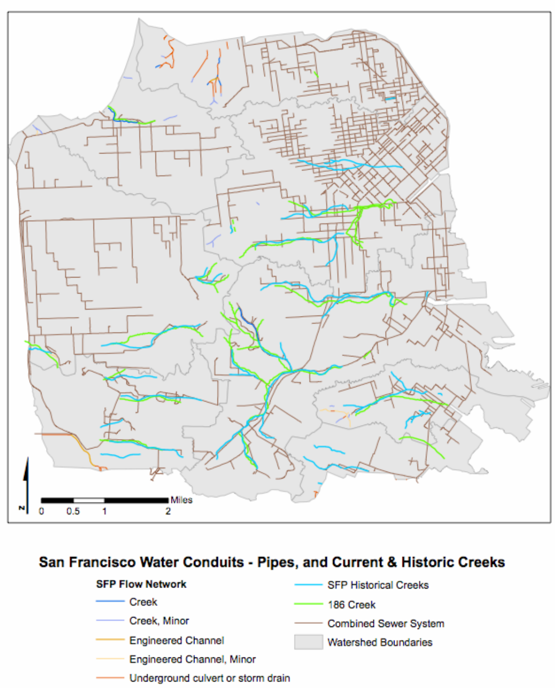


Figure 9: Google Earth Aerial Image of Yosemite Creek Headwaters

Figure 10: Potential Yosemite Creek Daylighting Project Sites Based on Existing Land Use

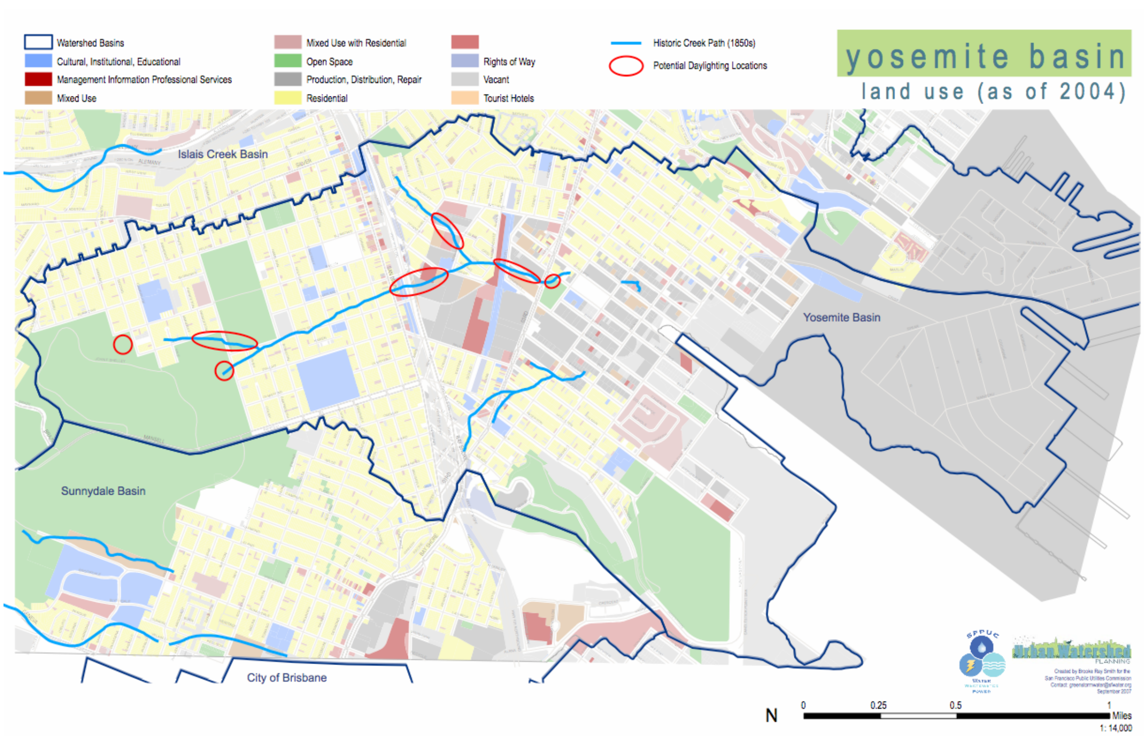
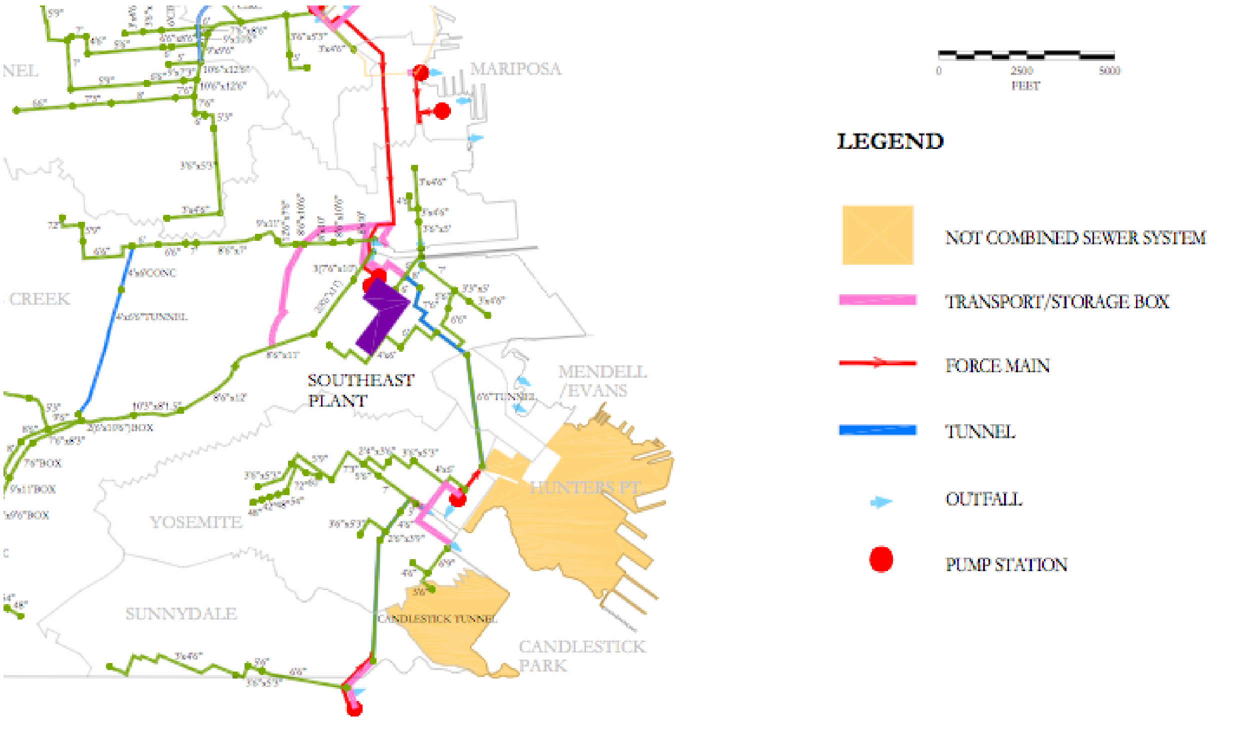


Figure 11: Existing Combined Sewer Pipes in Yosemite Basin (in Brown and Caldwell 2004)


0
2500
5000
FEET
LEGEND
NOT COMBINED SEWER SYSTEM
TRANSPORT/STORAGE BOX
FORCE MAIN
TUNNEL
OUTFALL
PUMP STATION
MARIPOSA
CREEK
SOUTHEAST
PLANT
MENDELL
/EVANS
HUNTERS PT
YOSEMITE
SUNNYDALE
CANDLESTICK TUNNEL
CANDLESTICK
PARK

APPENDICES

- Appendix A: Definitions of San Francisco Watershed Features (from Sowers 2007)
- Appendix B: San Francisco Design Storm Rainfall Intensities and Depths
- Appendix C: Potential Planting Palette (from Storesund 2006, Plant Community Design section)

Appendix A: Definitions of San Francisco Watershed Features (from Sowers 2007)

ELEMENT	DESCRIPTION
Creek (major and minor)	Open channel in a fairly natural condition following its historical alignment. At least two of the three sides must be natural. One side may be revetted. To qualify for inclusion, creeks must have a minimum watershed of 0.2 sq-km. The upstream beginning of any creek line on the map is determined by estimating the watershed area by eye on a topographic map, and placing a dot on the map at the point where the watershed size criterion is met. The line begins at this dot, which can be considered precise plus or minus 200 feet.
Former creek, buried or drained	Historical creek or creek segment that no longer carries water, or carries minimal water. The main flow of the creek is now carried by an engineered channel or storm drain. The creek bed may be filled and buried, or open.
Engineered channel	Open channels that either: a. Are significantly reinforced natural channels, having at least two of three sides lined with concrete, rip rap, gabions, or other hard material, OR, b. Are artificially dug, their alignment not coincident with any natural or historical creek. Some engineered channels built in recent years are designed to mimic natural channels.
Underground culverts and storm drains	Underground pipes and culverts that carry storm runoff. For inclusion on the map, pipe or culvert diameter must be 24 inches or larger, or be fed by a creek that meets the minimum watershed requirement.
Flood control channel	Those engineered channels that are greater than 200 feet in width, therefore more appropriately depicted by a polygon than a line. These wide channels are bounded by levees and typically contain an interior low flow channel. In the case of Coyote Creek, the historical channel is the low flow channel
Water spreads over the ground	At this fork symbol, the flow exits the channel or pipe and spreads over the ground. For natural creeks, either modern or historical, this point is called the *distributary point*. Here the flow divides into multiple channels and sediment is deposited in lobes on the piedmont slope, radiating out from the distributary point. The point is approximately located, and is expected to move somewhat through time.
Artificial bodies of water	Reservoirs, detention basins, landscaping ponds, and lagoons that are artificially constructed, or are artificially enlarged or reshaped. Does not include artificial water bodies that lie within the boundaries of historical tidal marsh AND currently receive tidal flow. Does include waste ponds and detention ponds.
Freshwater marsh	Inland marshes not affected by tidal waters. The boundaries of these marshes vary seasonally. Some may dry the summer.
	Tidal marsh along the shore of the San Francisco Bay or Pacific

Tidal marsh	Ocean. The primary data source is a compilation by the San Francisco Estuary Institute that relies heavily on the 1850 to 1900 U. S. Coast Survey maps (1998 EcoAtlas).
Bay fill	Artificial fill that creates land, located in areas shown on the SFEI EcoAtlas to have been open bay circa 1850.
Present watersheds	Present-day watersheds of major creeks or engineered channels. Watersheds are defined either by point-of-entry into the bay, or by a junction with a trunk stream. Trunk streams are limited to the larger creeks and include Coyote Creek, Guadalupe River, Alameda Creek, and Arroyo de la Laguna (Pleasanton map). If watershed color overlies former tidal marsh, the marsh has been filled and is now land.
Willow groves	Willow groves circa 1850 as delineated by the San Francisco Estuary Institute on the 1998 EcoAtlas.

Appendix B: San Francisco Design Storm Rainfall Intensities and Depths

Typical San Francisco Design Storm highlighted in yellow: 5-year 3-hour storm

San Francisco Rainfall in Inches per Hour

Return Period (years)	Duration							
	5 min	**10 min**	**15 min**	**30 min**	**1 hrs**	**2 hrs**	**3 hrs**	**6 hrs**
	0.083	**0.167**	**0.25**	**0.5**	**1**	**2**	**3**	**6**
100	***4.8***	***3.42***	***2.8***	***1.88***	***1.28***	***0.88***	***0.69333***	***0.48***
50	***4.32***	***3.12***	***2.52***	***1.7***	***1.15***	***0.795***	***0.627***	***0.433***
25	***3.84***	***2.76***	***2.28***	***1.52***	***1.03***	***0.71***	***0.557***	***0.387***
10	***3.36***	2.4	1.96	1.31	0.9	0.62	***0.49***	***0.33***
5	2.904	2.07	1.712	1.156	0.79	0.555	0.44	0.297
2	2.364	1.74	1.4	0.954	0.66	0.4575	0.373	0.245
1	1.968	1.428	1.176	0.8	0.562	0.39	0.323	0.21
0.5	1.56	1.152	0.96	0.66	0.47	0.325	0.27	0.177
0.25	1.164	0.864	0.736	0.516	0.372	0.26	0.213	0.14

San Francisco Rainfall in Inches per Indicated Duration

Return Period (years)	Duration							
	5 min	**10 min**	**15 min**	**30 min**	**1 hrs**	**2 hrs**	**3 hrs**	**6 hrs**
100	***0.4***	***0.57***	***0.7***	***0.94***	***1.28***	***1.76***	***2.08***	***2.88***
50	***0.36***	***0.52***	***0.63***	***0.85***	***1.15***	***1.59***	***1.88***	***2.6***
25	***0.32***	***0.46***	***0.57***	***0.76***	***1.03***	***1.42***	***1.67***	***2.32***
10	***0.28***	0.4	0.49	0.655	0.9	1.24	***1.47***	***1.98***
5	0.242	0.345	0.423	0.578	0.79	1.11	1.32	1.78
2	0.197	0.29	0.35	0.477	0.66	0.915	1.12	1.47
1	0.164	0.233	0.294	0.4	0.562	0.78	0.97	1.26
0.5	0.13	0.192	0.24	0.33	0.47	0.65	0.81	1.06
0.25	0.097	0.141	0.184	0.258	0.372	0.52	0.64	0.84

Italic:	From the California State Department of Water Resources (CSDWR) Developed by Jim Goodridge using Federal Rainfall Records in SF
Plain:	Developed by the CWP (CAP) using City Gage 23 records from 1972 through 1986 and smoothing out data plots to conform to CSDWR data for the longer return periods

CAP Jul 27-90 revised
7/30/90

Appendix C: Sample Planting Palette for San Francisco Creek Daylighting Projects (from Storesund 2006, Plant Community Design section for Tennessee Hollow Creek)

Plant community descriptions:

• Bulrush wetland community- Dominated by emergent vegetation in open water and small-stature plants in saturated soils (height: 2-3 feet). Rushes (*Juncus* spp.) will likely dominate, but the community will also include sedges (*Carex* spp.), spikerushes (*Eleocharis* spp.) and bulrushes (*Scirpus* spp.). Rooting depth is 0-20 inches. This zone of emergents will be 1 to 10 feet across. The lowest spots are open water or saturated soils.

• Arroyo willow community- Large shrubs and small trees dominate (overstory height: 5-25 feet). Willows (Salix spp.), young oaks (*Quercus agrifolia*), wax myrtles (*Myrica californica)*, and red-osier dog wood *(Cornus sericea* ssp. *sericea*?) dominate the shrub layer and Freshwater Wetland vegetation grades into the understory and open areas. Rooting depth is 10-20 inches but may increase to 36 inches in Colma.

• Coast live oak community- An oak (*Quercus agrifolia*) dominated hardwood assemblage (height 10-25 feet),where species requiring shallow groundwater do not thrive. Other common woody species include California buckeye (*Aesculus californica*), California bay (*Umbellularia californica*), and holly-leaved cherry (*Prunus ilicifolia*). Rooting depth is above 36 inches.

• Coyote brush community- A mix of many shrub and sub-shrub species including coyote brush (*Baccharis pilularis*), toyon (*Heteromeles arbutifolia*), yarrow (*Achillea millifolium*) dominate (height mostly 2-5 feet with occasional small trees <15 feet). An upland habitat, rooting depths not considered.