FINAL

SAUSAL CREEK WATERSHED ENHANCEMENT PLAN

SUMMARY

Sausal Creek "Restoration Reach" in 2003

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For

Friends of Sausal Creek

March 2010

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SAUSAL CREEK WATERSHED ENHANCEMENT PLAN
Summary

In the middle of urban Oakland lies a series of parks which shelter Sausal Creek and create a green ribbon through the city. Unlike so many urban streams now flowing lifeless through pipes hidden beneath city streets, Sausal Creek has a natural channel over much of its length. Hikers can follow Sausal Creek and its tributaries from the top of the watershed on Skyline Boulevard down through Palo Seco and Dimond Canyons and past Interstate 580 before the natural creek channel is resigned to a culvert in the Oakland flatlands. Although the effects of its cemented urban drainage are everywhere, Sausal Creek is alive and inspiring. Native trees line the creek in many places and there is a small number of rainbow trout residing in its waters. These remnants of the natural world, gone from most of Oakland, make Sausal Creek a good candidate for enhancement actions, as well as community involvement and education.

The Friends of Sausal Creek (FOSC) formed in 1996 to focus community activities to learn about, protect, and enhance the creek and its watershed. FOSC has completed projects using volunteers to remove invasive non-native plants, install native plants, monitor water quality, control erosion, and complete a major creek habitat enhancement project. The Friends recognize that citizen participation is critical for building a long-term commitment to protecting Sausal Creek as a natural resource for the greater Oakland community. FOSC operates a native plant nursery at Joaquin Miller Park. FOSC worked with Laurel Marcus & Associates (LMA), a consulting firm specializing in watershed planning, to raise grant funds to complete a plan for the Sausal Creek watershed. Funding for this plan was provided by the State Water Resources Control Board and the San Francisco Foundation.

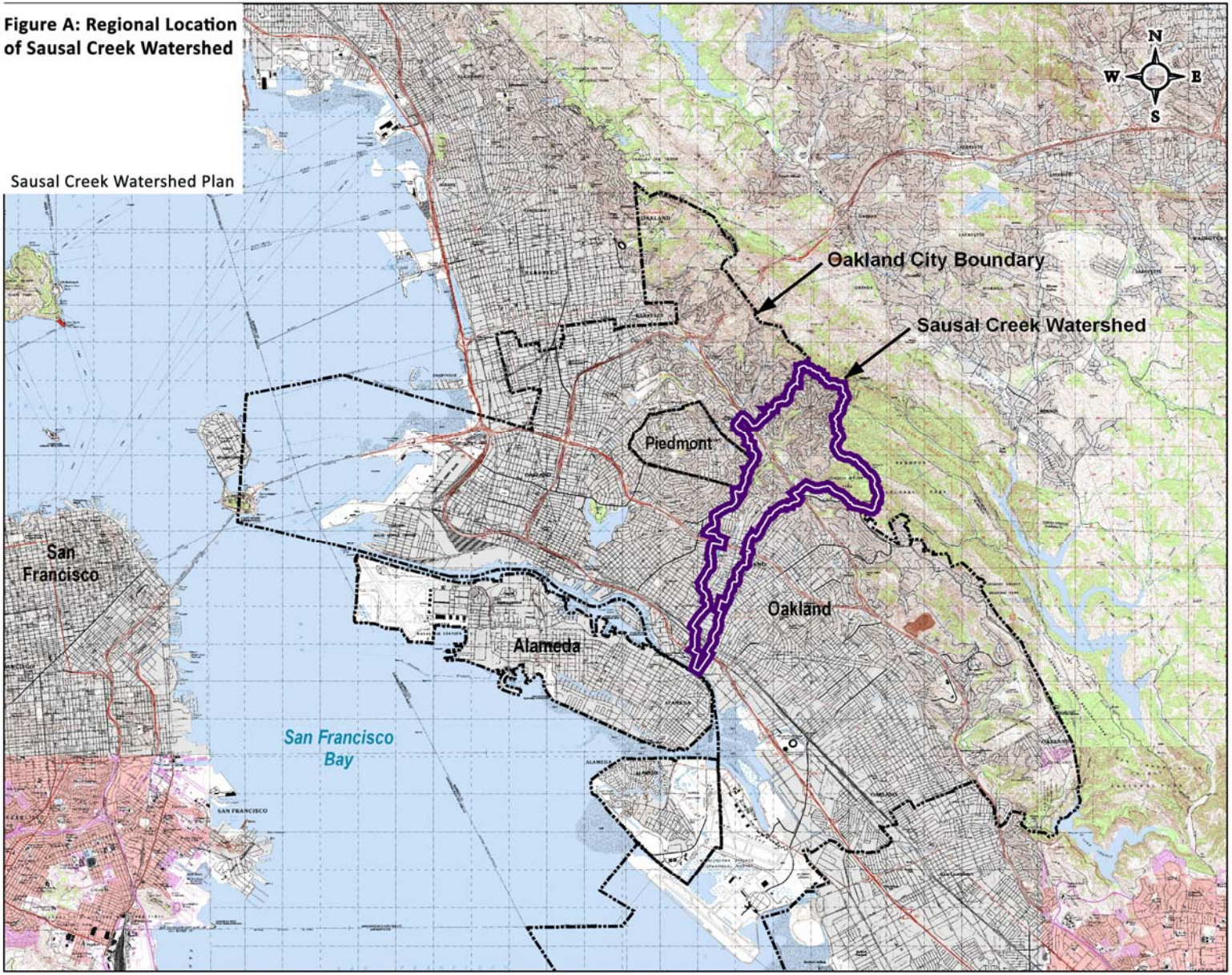
The Sausal Creek watershed covers 4.5 square miles (2,777 acres) in Oakland (Figure A). Most of the watershed has been developed for residential and commercial land uses. This development has changed the volume and rate of stormwater runoff. Impervious surface associated with development is the primary culprit, resulting in faster runoff and lower infiltration rates. The runoff is also collected in the pipes of a storm drain system and discharged into creeks. This urbanization process results in peak flood flows well in excess of the natural conditions that formed the creek. These effects of urbanization are further exacerbated by the steep slopes of the upper Sausal Creek watershed.

This plan characterizes the hydrology of the Sausal Creek watershed in order to document a baseline of flow, sediment loading, and channel conditions. From this baseline the impacted hydrological and ecological conditions of the channels, and the watershed processes that resulted in that degraded condition, can be identified. In highly urban watersheds, many factors that adversely impact the creek are intrinsic parts of the developed landscape. Successful restoration or revegetation of urban creeks depends upon evaluation of the larger watershed and implementation of projects that will most offset the effects of urbanization. This plan describes projects to address the conditions that are adversely impacting Sausal Creek and its tributaries, and their aquatic habitats and water quality. Enacting a long-term plan to repair and improve the watershed will sustain Sausal Creek for future generations.

This plan for the Sausal Creek watershed will:

- Document the hydrology of the Sausal Creek watershed and identify watershed-based projects that, to the greatest extent feasible, mitigate the effects of urban runoff on Sausal Creek, its habitats and water quality;

Figure A: Regional Location of Sausal Creek Watershed



- Collect and analyze existing water quality and aquatic insect monitoring data
- Document erosion problems in the urban storm drain system and recommend improvements to reduce this erosion;
- Discuss the location and extent of non-native invasive plants on parklands and evaluate measures to eradicate these plants and revegetate with appropriate native plant species;
- Identify locations where riparian habitat enhancement can be implemented;

The Sausal Creek watershed extends from the Oakland Hills to the San Francisco Bay. Three tributary creeks make up the upper watershed—Shephard Creek, Cobbledick, and Palo Seco Creeks (Figure B).

HUMAN HISTORY

Prior to European arrival the Huichin Ohlone, a group of Native Americans, lived at very low densities in the East Bay including the Sausal Creek watershed and managed the landscape using fire, selective gathering of food plants, and hunting. In 1775-1776, the Spanish Anza expedition explored the Bay area and soon thereafter established missions in the area. The Spanish restricted the burning practices of the Ohlone and brought non-native European annual grasses to California. Americans were active in the watershed beginning in the 1840s when the San Antonio redwoods were logged. With statehood in 1850, American settlement of the East Bay expanded. Urbanization of the Sausal Creek watershed began in the flatlands and extended into the hills during the 1930s and 1940s. Sausal Creek watershed has been significantly altered with culverts, storm drain systems, and impervious surfaces in its drainage.

NATURAL RESOURCES

Geology and Soils

Sausal Creek is located along the eastern periphery of the San Francisco Bay. The steep hills on both sides of the bay were formed primarily through tectonic processes. The San Andreas Fault zone on the San Francisco side of the bay is one of a series of faults which dissect the Bay Area. The faults are areas of earth movement along the continental plates.

Sausal Creek watershed reflects this regional geology with very steep hills in its upper watershed. These hills are made up of a variety of rock types. The Hayward Fault is a major geological feature which created the valley where Highway 13 is located. Downstream of the Hayward Fault on the flatter lands, Sausal Creek spreads out depositing material eroded from the highly sheared rock in the fault zone and the steep upper drainage.

The soil types of the upper watershed have a high to very high erosion rating. Urbanization of these areas has created erosion problems by producing higher volumes of stormwater running off roofs, roads, and paved areas into steep ephemeral creek channels and onto highly erodible slopes. Ephemeral creeks only carry water immediately after a rainstorm. These steep channels, if not covered in dense vegetation or rock, will erode when urban development increases runoff volumes.

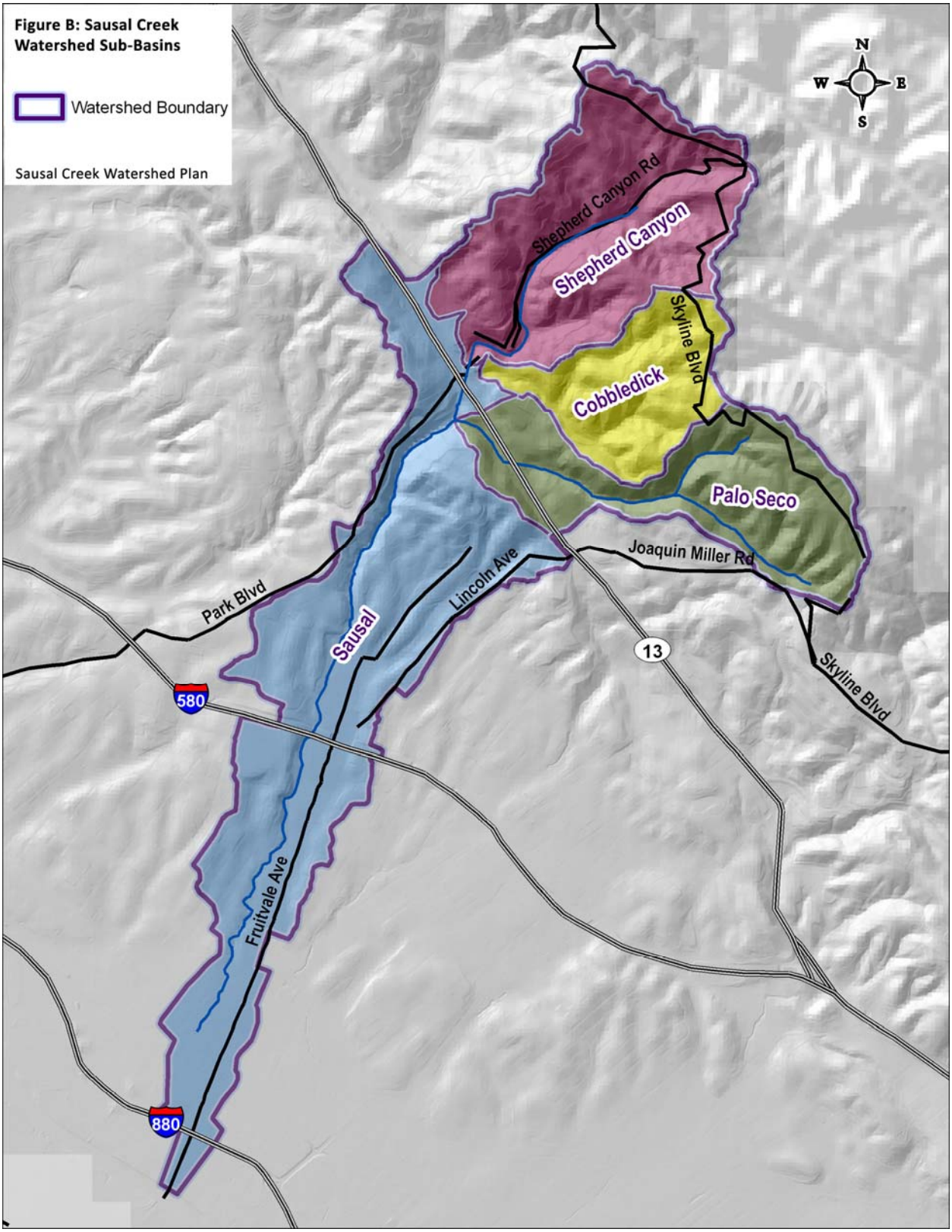


Figure B: Sausal Creek Watershed Sub-Basins
Watershed Boundary
Sausal Creek Watershed Plan
N
W
E
S
Shepherd Canyon Rd
Shepherd Canyon
Skyline Blvd
Cobbledick
Palo Seco
Joaquin Miller Rd
Lincoln Ave
Park Blvd
Sausal
13
Skyline Blvd
580
Fruitvale Ave
880

Hydrology

A hydrologic analysis was completed in order to develop a watershed model that would simulate the rainfall-runoff processes for 1-year through 100-year frequency storm events over the watershed. The model was developed at a level of detail that would allow for the evaluation of measures designed to reduce the peak discharge to Sausal Creek and its tributaries. A series of 33 hydrologic sub-basins were delineated for use in the model (Figure C). Six precipitation gages in the area were evaluated. The Environmental Protection Agency's Storm Water Management Model (SWMM) computer model was used which allows for the analysis of stormwater runoff from multiple linked basins with various runoff characteristics.

The Sausal Creek SWMM existing conditions model was run using dynamic wave analysis and time steps of 1 second or less for the 1 –year, 2-year, 5-year, 10-year, 25-year, and 100-year storm events. Existing conditions output for the Sausal Creek hydrology model was calibrated to streamflow measurements during significant storm events on October 19, 2009 and November 20, 2009. The SWMM existing conditions model was run with rainfall data of the Sausal Creek watershed from two Oakland gages for the same period as the two storms.

A hydraulic model was developed using surveyed cross-sections of Sausal and Palo Seco Creeks and the Hydrologic Engineering Center River Analysis System, commonly referred to as HEC-RAS. The hydraulic model was calibrated with measurements of high water marks and flow velocities at a known discharge. These calibration measurements were collected during significant storm event on October 19, 2009.

Channel bed and bank stability varies throughout the Sausal Creek watershed, however, in general, the channel bed and banks are likely stable for velocities up to approximately 7 ft/sec and shear stresses up to approximately 2 lbs/ft^2. These values are based on the US Army Corps of Engineers' Engineering Research and Development Center "Stability Thresholds for Stream Restoration Materials" to determine permissible shear strengths reference for selection of stream restoration materials, and a useful guide to assessing the stability of existing stream materials. While conditions vary throughout the watershed, we made the assumption that the system has geomorphic controls such as riffles and artificial grade control structures with cobble and coarser particle sizes and some woody vegetation on the banks. As shown in Table A, the reaches with these characteristics would be stable for velocities up to 7 feet per second and shear stresses up to 2 pounds per square foot. Therefore, portions of the Sausal channel network are at risk of erosion under existing hydrologic and hydraulic conditions, even during the 1-year discharge. Even moderate reductions in peak flows could reduce the frequency and duration of erosive flows and contribute to long-term improvements in creek habitat conditions (Figures D and E)

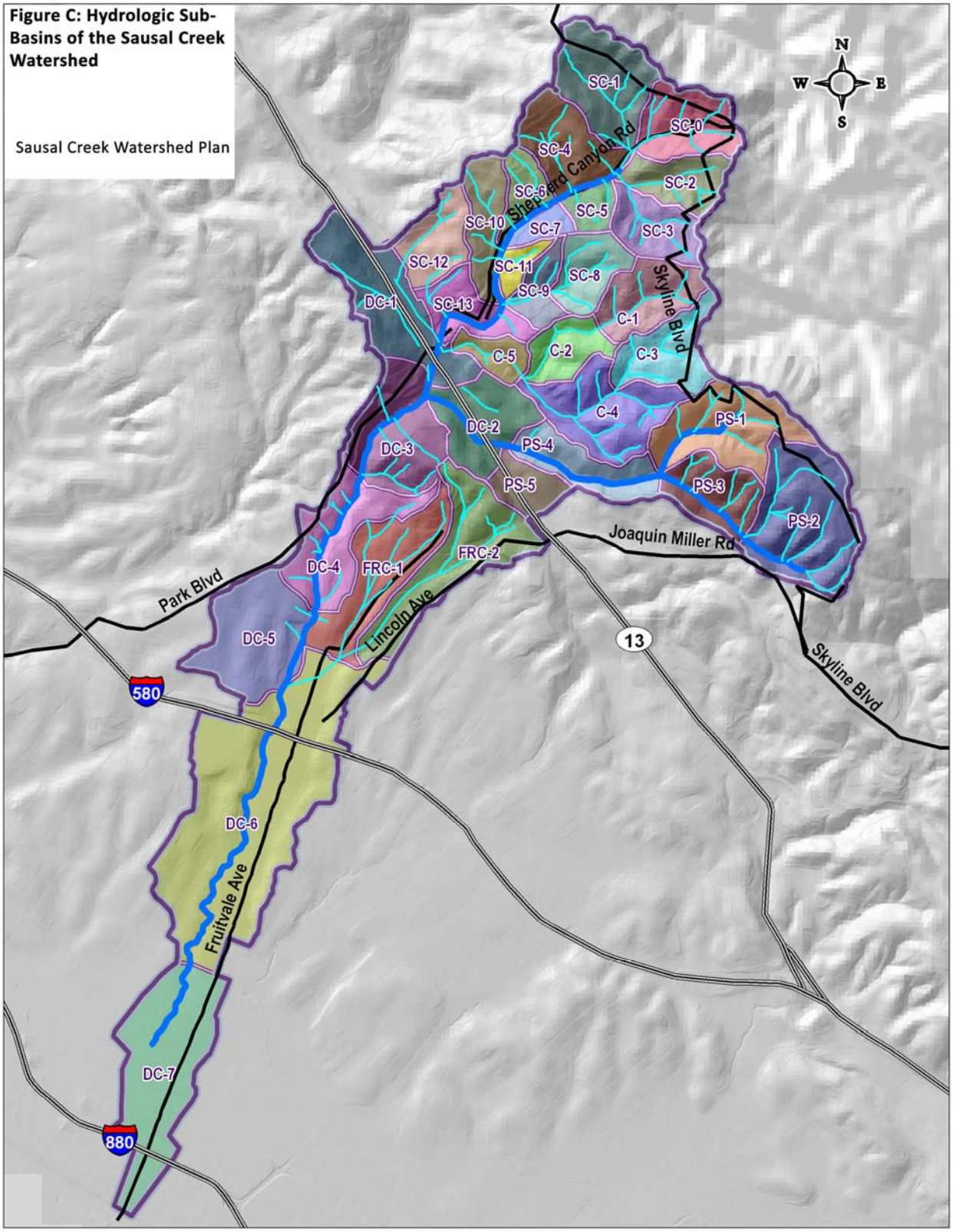


Figure C: Hydrologic Sub-Basins of the Sausal Creek Watershed
Sausal Creek Watershed Plan
N
W
E
S
SC-1
SC-0
SC-4
Shepherd Canyon Rd
SC-2
SC-6
SC-5
SC-10
SC-7
SC-3
SC-12
SC-11
SC-8
Skyline Blvd
SC-9
DC-1
SC-13
C-1
C-5
C-2
C-3
C-4
PS-1
DC-2
PS-4
DC-3
PS-5
PS-3
PS-2
Joaquin Miller Rd
FRC-2
DC-4
FRC-1
Park Blvd
Lincoln Ave
DC-5
13
Skyline Blvd
580
DC-6
Fruitvale Ave
DC-7
880

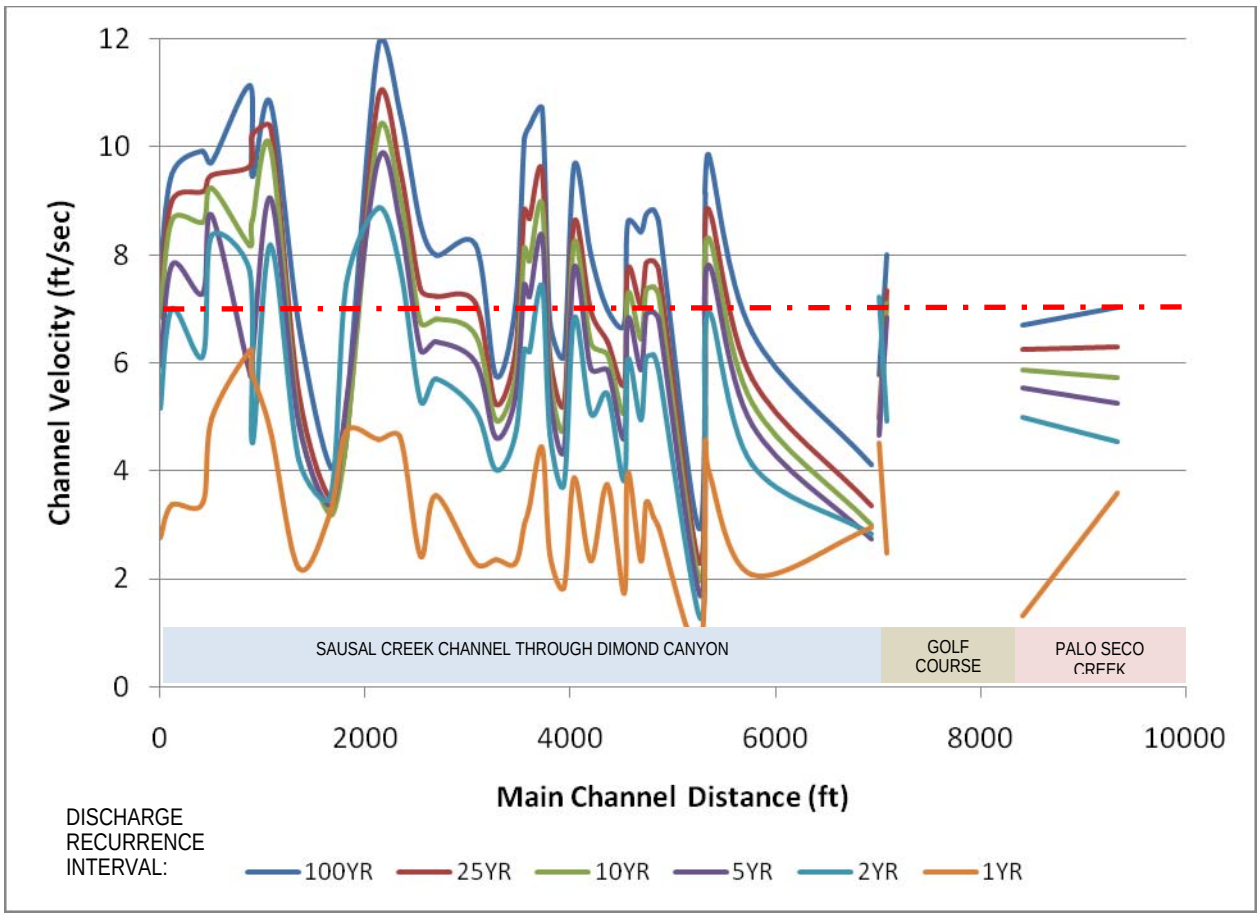


Figure D: Existing conditions longitudinal velocity plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.

Table A: Permissible velocities and shear stresses for channel sediment and vegetation types similar to Sausal Creek (after Fischenich 2001)

Material	Permissible Velocity (ft/sec)	Permissible Shear Stress (lbs/ft^2)
Gravel (2 inch)	3.0 – 6.0	0.67
Cobble (6 inch)	4.0 – 7.5	2.0
Riprap (18 inch)	12.0 – 16.0	7.6
Emergents	n/a	0.1 – 0.6
Grasses	3.0 – 6.0	0.7 – 1.7
Woody Vegetation	3.0 – 10.0	2.1 – 3.1

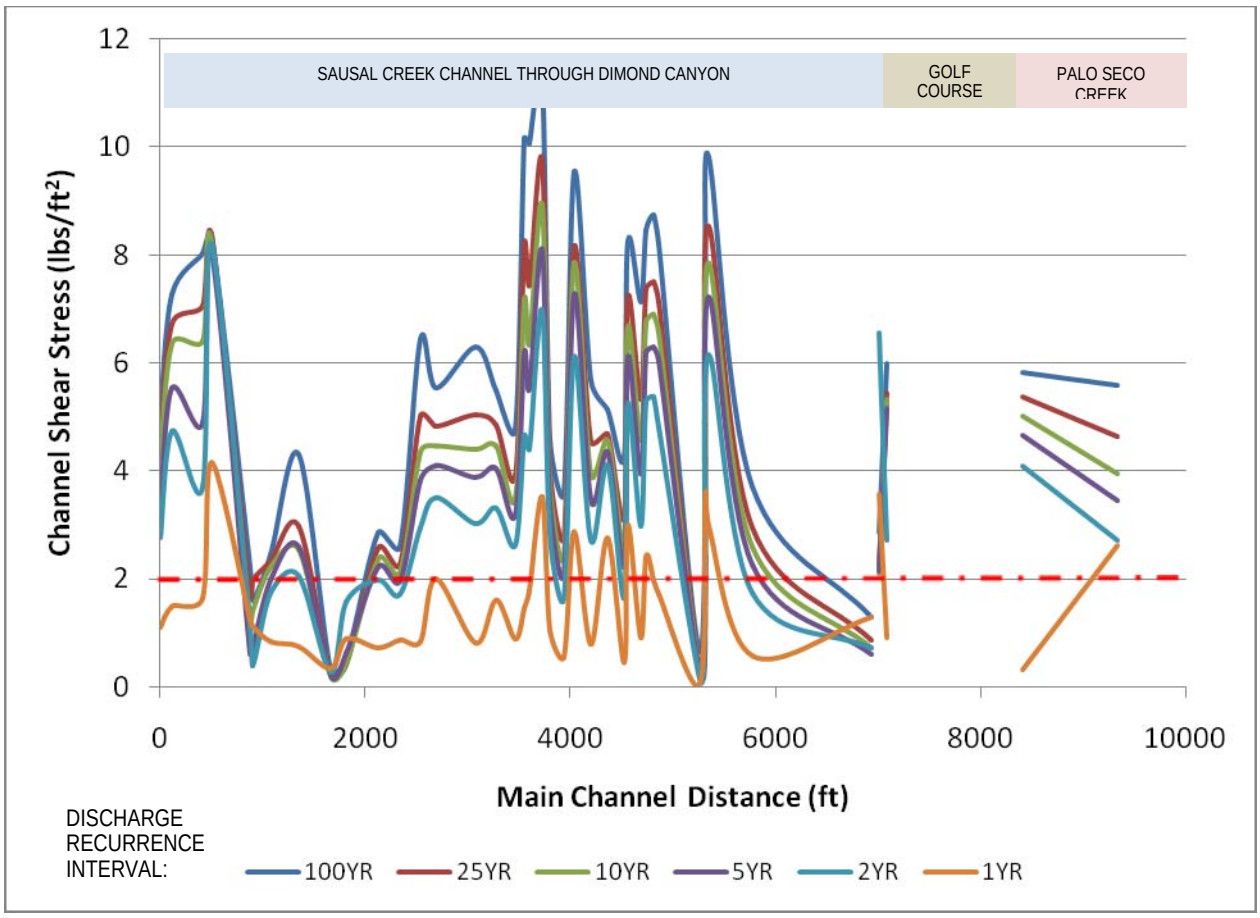


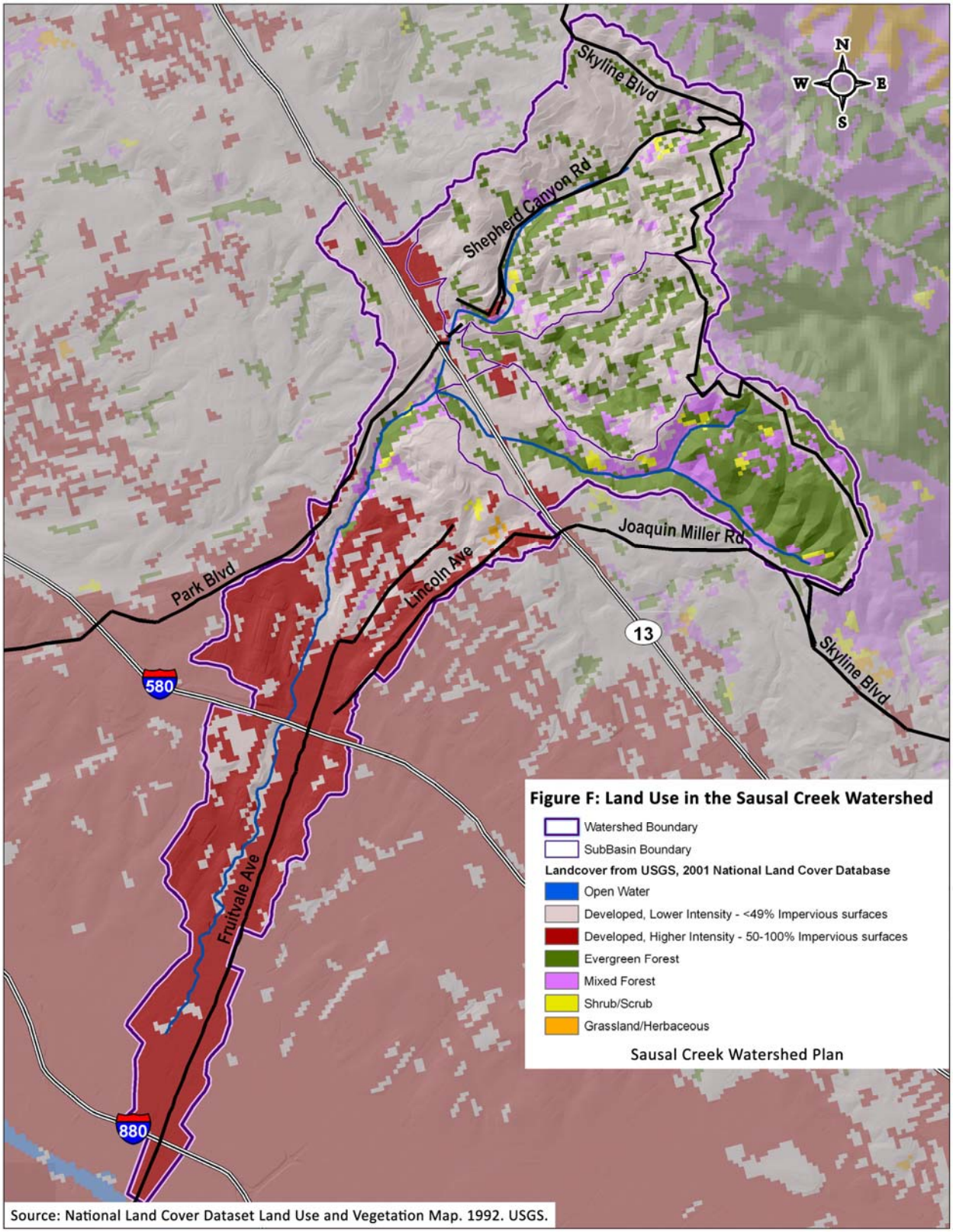
Figure E: Existing conditions longitudinal shear stress plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.

Vegetation

The vegetation growing in Sausal Creek watershed is a combination of native plant species primarily found in parks and ornamental species (including planted natives) surrounding residential and commercial areas. In the upper watershed, evergreen forest dominates the parkland and vegetated areas next to houses, including creek areas.

The upslope area of Joaquin Miller Park in the Palo Seco sub-basin is part of a five square-mile area in the Oakland hills once dominated by redwood forest called the San Antonio Redwoods. Logging of the redwoods started in the late 1840s and all of the trees were cut by 1860. The redwoods in this area are now second-growth. Besides the redwood forest, most early accounts and photographs of the upper Sausal Creek watershed describe large areas of grassland with trees along the ephemeral and seasonal water courses. Following the logging of the redwoods, numerous trees were planted in Joaquin Miller Park and surrounding hill areas, like Piedmont Pines and Oakmore. Planted species included trees native to other areas of California—Monterey pine and Monterey cypress—as well as non-native invasive tree species: Eucalyptus and Acacia. Palo Seco Creek sub-basin holds over 250 acres of this mix of native and non-native trees termed "evergreen forest," mostly focused in Joaquin Miller Park. Cobbledick Creek sub-basin has 110 acres of evergreen forest dispersed between houses. Similarly, Shephard Creek sub-basin has 110 acres of evergreen forest spread out in residential and park areas (Figure F).

The native vegetation areas that remain in the Sausal Creek watershed are under constant threat of invasion and replacement by invasive, non-native plant species. These plants were typically brought to California as garden plants or by the government to provide erosion control along streams or on agricultural lands. Some, such as Eucalyptus, were widely planted in the East Bay hills under the mistaken assumption that Eucalyptus would produce good lumber in California. The spread of invasive non-native plants is a primary cause of the degradation and loss of native habitat in California. Most invasive plants are adapted to rapid germination and growth following ground disturbance. Some produce chemicals which suppress the growth of other native plants, resulting in complete dominance by the invasive species. Most invasive plants do not provide habitat values for wildlife, nor do they have natural predators outside their native land to reduce their rapid spread.


Skyline Blvd
Shepherd Canyon Rd
Joaquin Miller Rd
Park Blvd
Lincoln Ave
Fruitvale Ave
580
880
13
Skyline Blvd
N
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S
Figure F: Land Use in the Sausal Creek Watershed
Watershed Boundary
SubBasin Boundary
Landcover from USGS, 2001 National Land Cover Database
Open Water
Developed, Lower Intensity - <49% Impervious surfaces
Developed, Higher Intensity - 50-100% Impervious surfaces
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Sausal Creek Watershed Plan
Source: National Land Cover Dataset Land Use and Vegetation Map. 1992. USGS.

Figure G: Top: Invasive non-native cape ivy adjacent to a residential area in the Shepherd Canyon sub-basin. Bottom: French broom, a highly flammable invasive plant, is widespread in the Sausal Creek watershed and is seen here as an understory plant in both native vegetation

Replacement of native species by invasives can exacerbate the effects of fires and floods. Most of the invasive plants that cover the understory areas along streams provide little to no erosion control, allowing streambanks to fail in floods. Some invasives are extremely fire-prone; the 1991 Oakland firestorm was spread as Eucalyptus stands exploded, sending burning embers across major freeways to start additional fires.

Typically the approach to invasive species control is to: 1) document the species present and their areal extent; 2) determine the primary dissemination pattern (from upstream to downstream along watercourses, along trails, from parking lots into parkland, etc.); and 3) complete a multi-year strategy for eradication. When the processes of invasive plant dissemination are contained entirely within public lands, this type of approach can be successful if funding is available.

In the Sausal Creek watershed, however, public and private landscapes are intertwined, making eradication of invasives on public lands and along creeks very difficult. Unfortunately, private land in Sausal Creek watershed contains numerous non-native invasive species and serves as a permanent source for dissemination of these plants (Figure G). For the most part, homeowners are largely unaware of invasive plants and can still purchase many of the worst species for their gardens. Although state and local governments fund invasive plant removal, and park and fire districts carry out management to remove these species, the plants have not been banned for sale in the state. This situation creates a never-ending supply of invasive plants to open space areas, while there are limited resources to remove them. Unless the ongoing cultivation of invasive plants by homeowners in the watershed is reduced, invasive non-native plants can never be eradicated on public land and along creeks in the Sausal Creek watershed.

Water Quality

In urban watersheds, rainfall flushes numerous contaminants off of roofs, driveways, gardens, parks, and streets into storm drains and creeks. Rainfall also moves pollutants from the air into storm runoff. Due to the large volumes of runoff in winter, most of these contaminants are transported to San Francisco Bay. During the dry season, however, there are also many sources of pollutants in urban watersheds which may reach storm drains and creeks. Due to the low flows in the creeks in summer there is little dilution and pollutants can have a large effect on aquatic life.

In the Sausal Creek watershed the primary land use is residential with limited commercial areas and some parkland. These land uses produce pollutants including oil and gas residues, trash, pesticides, fertilizers, sediment, dog feces, heavy metals, and other materials. These pollutants are generated by numerous sources in the watershed. One of the only effective methods for reducing pollutants is changing the habits and materials used by urban residents.

Several different programs have measured water quality parameters in Sausal Creek. Friends of Sausal Creek (FOSC) has carried out a volunteer monitoring program for a number of years for basic water quality parameters in several locations.

The San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) completed comprehensive water quality, sediment quality, and aquatic insect monitoring in Sausal Creek in 2004-2005 at five stations (Figure H).

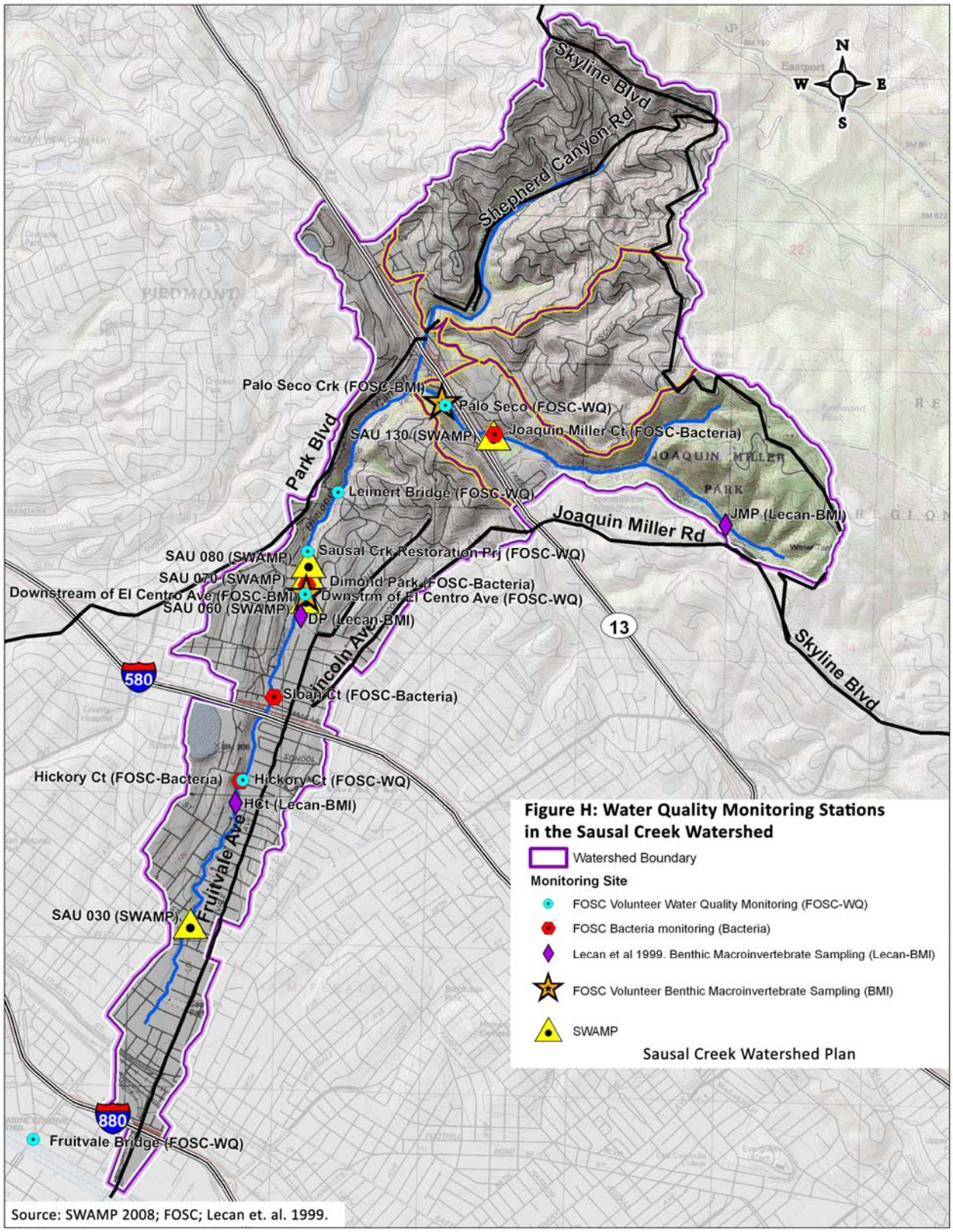

Skyline Blvd
Shepherd Canyon Rd
N
W
E
S
Palo Seco Crk (FOSC-BMI)
Palo Seco (FOSC-WQ)
SAU 130 (SWAMP)
Joaquin Miller Ct (FOSC-Bacteria)
Park Blvd
Leimert Bridge (FOSC-WQ)
JMP (Lecan-BMI)
Joaquin Miller Rd
SAU 080 (SWAMP)
Sausal Crk Restoration Prj (FOSC-WQ)
SAU 070 (SWAMP)
Dimond Park (FOSC-Bacteria)
Downstream of El Centro Ave (FOSC-BMI)
Dwnstrm of El Centro Ave (FOSC-WQ)
SAU 060 (SWAMP)
DP (Lecan-BMI)
13
Skyline Blvd
580
Lincoln Ave
Sloan Ct (FOSC-Bacteria)
Hickory Ct (FOSC-Bacteria)
Hickory Ct (FOSC-WQ)
HCt (Lecan-BMI)
Fruitvale Ave
SAU 030 (SWAMP)
880
Fruitvale Bridge (FOSC-WQ)
Source: SWAMP 2008; FOSC; Lecan et. al. 1999.
Figure H: Water Quality Monitoring Stations in the Sausal Creek Watershed
Watershed Boundary
Monitoring Site
FOSC Volunteer Water Quality Monitoring (FOSC-WQ)
FOSC Bacteria monitoring (Bacteria)
Lecan et al 1999. Benthic Macroinvertebrate Sampling (Lecan-BMI)
FOSC Volunteer Benthic Macroinvertebrate Sampling (BMI)
SWAMP
Sausal Creek Watershed Plan

Table B: SWAMP Program Comparison of Nutrient Concentrations in Years 4 and 5 Samples to Water Quality Benchmarks (WQB) for Sausal Creek

Station	Season	Ammonia as N (mg/L)	qual	pH	Temperature (°C)	Unionized Ammonia as N (mg/L) (WQB=0.025)	Unionized Ammonia Exceedance Factor	Nitrate as N (mg/L) (WQB=0.16)	Nitrate Exceedance Factor	Phosphorus as P, Total (mg/L) (WQB=0.03)	Total P Exceedance Factor
SAU030	1/10/05	0.097	J	7.84	11.5	0.001	0.04	2.27	14.2	0.07	2.3
SAU030	4/12/05		ND	7.56	12.8			1.41	8.8	0.06	2.1
SAU030	6/14/05	0.05	J	7.68	15.5			1.25	7.8	0.08	2.7

* ND=not detected. "J" is defined as 'estimated'; the analyte was detected but the value is below the Reporting Limit

Table C: SWAMP Metal Concentrations in Comparison to Quality Benchmarks for Sausal Creek

Station	Aluminum (mg/Kg)	Arsenic (mg/Kg)	Cadmium (mg/Kg)	Chromium (mg/Kg)	Copper (mg/Kg)	Lead (mg/Kg)	Manganese (mg/Kg)	Mercury (mg/Kg)	Nickel (mg/Kg)	Silver (mg/Kg)	Zinc (mg/Kg)
SAU030	15552	4.2	0.16	66.5	12.4	12.7	250	0.243	44.3	0.11	50
Threshold Effect Concentration Values:		9.79	0.99	43.4	31.6	35.8		0.18	22.7		121

Table D: FOSC/EPA E. coli Monitoring in Sausal Creek (in MPN/100ml)

Date	Palo Seco Creek	Sausal Creek		
	Joaquin Miller Ct.	Dimond Park	Sloan Ct.	Hickory Ct.
3/10/1999-4/7/1999	400	7800	7800	1900
9/8/1999-10/6/1999	150	1500	12000	1900

* MPN=Most Probable Number

Table E: SWAMP Total Coliform Counts and *E. coli* Counts (MPN/100ml) in Sausal Creek in Years 4 and 5

Station: SAU060	7/20/04	7/27/04	8/3/04	8/10/04	8/17/04	Median
Total Coliform	7300	5500	1800	17000	1200	5500
E. coli	260	120	160	150	160	164

* Counts are Most Probable Number per 100 milliliters (MPN/100ml). Values in red exceed the limit for freshwater recreation (126 MPN for the geomean).
Tables from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

These stations include:

- Sausal Creek at E. 22nd Street (SAU030)
- Sausal Creek near Lions Pool in Dimond Park (SAU 060)
- Sausal Creek at El Centro Ave. (SAU070)
- Sausal Creek in Dimond Park (SAU080)
- Palo Seco Creek (SAU130)

The SWAMP program monitored for a range of persistent pollutants typical of urban contaminants. The results of the SWAMP monitoring found excessive levels of nutrients (nitrate and total phosphorus), slightly high water temperatures, and a few low dissolved oxygen measurements. Water and sediment samples were tested for a number of persistent pollutants including metals, pesticides, PCBs, and PAHs. Sediment samples from the downstream area of Sausal Creek had concentrations of chromium, mercury, and nickel that exceed threshold effect concentrations (TEC). Water samples did not show any high contaminant levels. Bioassays on water and sediment found no acute toxicities, but sediment sample tests found hindered growth in the test organism (Tables B and C).

Bacterial data was collected by FOSC in 1999 and analyzed by the EPA, and shows high *E. coli* levels in all locations sampled. SWAMP bacterial monitoring in 2004 found lower *E. coli* levels, but levels still exceeded water contact recreation standards (Table D and E).

AQUATIC AND RIPARIAN HABITATS

The Sausal Creek watershed, unlike most urban areas, has many open, unculverted creek channels. In the Sausal Creek watershed, aquatic habitat consists of the stream channel bottom and banks in the creeks with perennial and intermittent, or seasonal, flow. Riparian habitat consists of the vegetation bordering the low flow channel and covering the adjacent floodplain. Riparian vegetation is dependent on a source of summer water. Willows and alders are the most abundant riparian plants along Sausal Creek and are considered “pioneer” species. Both species are able to rapidly colonize deposited sediment, stream banks, and channel edges. Other common plants found along streams in the watershed include trees: coast redwoods, California bay laurel, and big-leaf maple, and understory plants: Pacific dogwood, nine bark, and native blackberry. Uncommon riparian species in the Sausal Creek watershed include elk clover, red alder, box elder, rushes and sedges, California wild rose, and red elderberry.

An important concept in the ecology of riparian systems is ecological succession. The diversity of riparian vegetation species varies over a continuum of the conditions created by flood events and associated changes in stream channel morphology. Willows and alders, as pioneer species, occur near the active channel in alluvial streams or along the edges and among rocks in confined channels. Their reproductive and adaptive strategy is tuned to a highly variable physical environment. Farther away from the channel, other species occur on the floodplain that are still riparian in nature but are adapted to less physical variation. These include big-leaf maple, California bay laurel, and coastal redwood.

<u>Effects of Urbanization of the Watershed on Riparian and Aquatic Habitats</u>

The urbanization of Sausal Creek began along the lower creek where the land is flat, and eventually extended up into the headwaters and onto steep slopes. Only one tributary—Palo Seco Creek—retains a largely undeveloped drainage basin. Shephard and Cobbledick Creeks have less intensive urban development than Sausal Creek, but are still highly impacted by runoff from impervious surfaces.

Creeks in a natural state are formed and changed by flood events. Each watershed has a unique set of features, including size and shape of the basin and stream network, topography, geology, vegetative cover, land use, and rainfall patterns. Over time, the creek's size, shape, and condition reflect watershed conditions. For example, large-scale grading, road building, and land disturbance for residential development in upper Sausal Creek watershed likely increased soil erosion, including landslides in wet years, resulting in large volumes of sediment being delivered to Sausal Creek. The creek channel might have had increased over-bank flooding and reduced aquatic habitat due to the sedimentation. Once large areas of the watershed were paved and many creek channels replaced with storm drains, Sausal Creek experienced larger volumes of runoff over a shorter time and a decreased sediment supply. Erosion of the sediment stored in the creek bed and banks occurred, resulting in incision or entrenchment. Once the channel is incised, storm flows are confined to the channel and increase erosion. In addition, urbanization typically involves channelization of creeks to reduce the area the creek occupies in order to maximize buildable land.

During the urbanization process, the riparian habitat is eroded out as the creek channel incises. As the channel bottom erodes, the former floodplain is isolated from frequent inundation. The entrenched channel has high flow velocities precluding much sediment deposition and the germination of riparian trees. The habitat in the new incised channel is limited in area and diversity. As the channel deepens, the banks fail, eroding habitat remaining on the original floodplain.

Aquatic habitats are affected by the high flow velocities. Channel scour and frequent gravel movement decrease the abundance and diversity of aquatic insects. Sand transport can shred the insects. High water temperatures caused by the loss of riparian shading, persistent urban pollutants, and fine sediments also limit aquatic insects.

To revegetate the riparian corridor and achieve conditions which support natural ecosystem processes of succession and diversity, the effects of urbanization on flow volumes, velocities, and channel form have to be mitigated. Willow, the species most adapted to high velocity flows, can withstand a flow velocity of up to 7 ft./sec. and shear stresses of 2 lbs./ft^2. Sausal Creek typically exceeds these conditions during the 1-year frequency event (Figures D and E).

Benefits and Limitations of Creek Restoration

Urban creek restoration typically means changing the stream channel by grading and possibly adding rock or removing a culvert and recreating a channel. A narrow band of vegetation, usually willows, is installed on the newly graded channel banks. The creek usually remains in the same area. Due to space limitations of urban areas it is uncommon for a floodplain to be created where storm flows can spread out and slow down. The footprint of the riparian corridor is rarely wide enough to support ecological processes, or a diversity of plant species. The restored urban stream may continue to have physical conditions such as frequent high velocity flows, which scour the channel and reduce the abundance and diversity of aquatic insects and riffles and pools for spawning and rearing fish. By restoring only one reach of an urban creek, the habitat benefits that can be achieved are limited to what can be changed in this very limited area. A broader approach, integrating improvements in the watershed with creek projects to mitigate the effects of urbanization, offers the possibility for changing both the creek and the processes which have caused the degradation of the creek. A focus on watershed restoration instead of just creek restoration requires a greater level of analysis but has the potential to produce higher quality, more sustainable environmental conditions in habitat areas.

A number of studies have looked at the long-term changes in aquatic habitat conditions in restored urban creeks. One of these studies focused on changes in aquatic insect assemblages in a creek in the East Bay. A restored section of Baxter Creek in Poinsett Park was evaluated in 1999 and in 2004 (Purcell et. al. 2002; Purcell 2004). The creek was removed from a culvert, a new channel was graded and stabilized with rock, and willows were planted. The size of the new creek channel was restricted by adjacent urban development and no floodplain was created as part of the project.

Aquatic insects were monitored in 1999 and again in 2004. Samples were taken after the project was completed and were evaluated for taxa richness, number of taxa of EPT (pollutant intolerant taxa), and family richness. Habitat areas were also evaluated.

The restored reach was compared with an unrestored reach of Baxter Creek and a high quality habitat area of Strawberry Creek deemed "best attainable conditions." The same sampling design was applied to all three creek reaches. The study found that the "restored" reach of Baxter Creek had slightly improved aquatic habitat conditions over the unrestored reach of Baxter Creek but showed no significant improvements in aquatic habitat between 1999 and 2004, and had lower quality habitat than the Strawberry Creek site. The study attributed the lack of improvement in aquatic habitat in the restored reach to the continued urban runoff and high velocity flows in the channel.

Studies of stream restoration in Australia (Walsh et. al. 2005) concluded:

> "Restoration of streams degraded by urbanization has usually been attempted by enhancement of instream habitat or riparian zones. Such restoration approaches are unlikely to substantially improve instream ecological conditions because they do not match the scale of the degrading process. Recent studies of urban impacts on streams in Melbourne, Australia, on water chemistry, algal biomass and assemblage composition of diatoms and invertebrates, suggested that the primary degrading process to streams in many urban areas is effective imperviousness (EI), the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater drainage pipes. The direct connection of impervious surfaces to streams means that even small rainfall events can produce sufficient surface runoff to cause frequent disturbance through regular delivery of water and pollutants; where impervious surfaces are not directly connected to streams, small rainfall events are intercepted and infiltrated…Alternative drainage methods, which maintain a near-natural frequency of surface runoff from the catchment were identified as the best approach to stream restoration in urban catchments…"

Studies of urban stream restoration in the Seattle area (Booth 2005) found:

> "Undoing harm by catchment urbanization on stream channels and their resident biota is challenging because of the range of stressors in this environment. One primary way in which urbanization degrades biological conditions is by changing flow patterns; thus, re-establishing natural flow regimes in urban streams demands particular attention if restoration is to have a chance for success. Enhancement efforts in urban streams typically are limited to rehabilitating channel morphology and riparian habitat, but such physical improvements alone do not address all factors affecting biotic health. Some habitat-forming processes such as the delivery of woody debris or sediment may be amenable to partial restoration, even in highly disturbed streams, and they constitute obvious high-priority actions. There is no evidence to suggest, however, that improving

non-hydrologic factors can fully mitigate hydrologic consequences of urban development."

This plan focuses on changing the watershed processes which have the largest effects on streams and are the result of the high level of urbanization in the Sausal Creek watershed.

Description of Stream Conditions

Cobbledick Creek

Most of Cobbledick Creek and its tributaries have open channels with seasonal flow. With the exception of two areas, however, this sub-basin is private residential land. In addition, in many areas of this sub-basin homes border the creek or have foundations or deck piers next to or in the creek. In these private creeks, control and eradication of invasive plants such as broom, Himalayan blackberry, cape ivy, Algerian ivy, and blue periwinkle will reduce the spread of these problem plants into downstream habitat areas. Erosion control and bank stabilization may also be needed. Native shrubs and trees such as toyon, manzanita, oaks, and madrone occur as natural vegetation.

Cobbledick Creek 1 (CC1)
This reach along Larry Lane is bordered with houses. The channel is semi-confined between hillslopes and much of the former floodplain is filled with houses. Mixed conifers line the creek and Eucalyptus, Algerian ivy, and broom are common. A sediment/detention basin blocks the channel near the Ascot Road crossing. The dam creating this basin was overtopped and eroded portions of the dam and Larry Lane road fill. Downstream from this basin the creek channel consists of fill with a culvert and has a house on the fill. There is erosion at the outlet. Downstream of the Ascot Rd. crossing the creek channel is filled and the creek goes through a culvert under Joaquin Miller Elementary/Montara Middle schools.

Cobbledick Creek 2 (CC2)
This reach is Cottonwood Creek, which flows through Beaconsfield Canyon. The channel is semi-confined between hillslopes and the channel bed is mostly fine sediment with some gravel. Black cottonwoods line the creek and broom and Himalayan blackberry make up the understory. The downstream end of this reach has a rapidly eroding inlet where the creek drops into a storm drain.

Cobbledick Creek 3 (CC3)
This reach is made up of ephemeral creeks in an undeveloped but private 15-acre area. There are willows, elk clover, and dogwoods growing along one of the creeks.

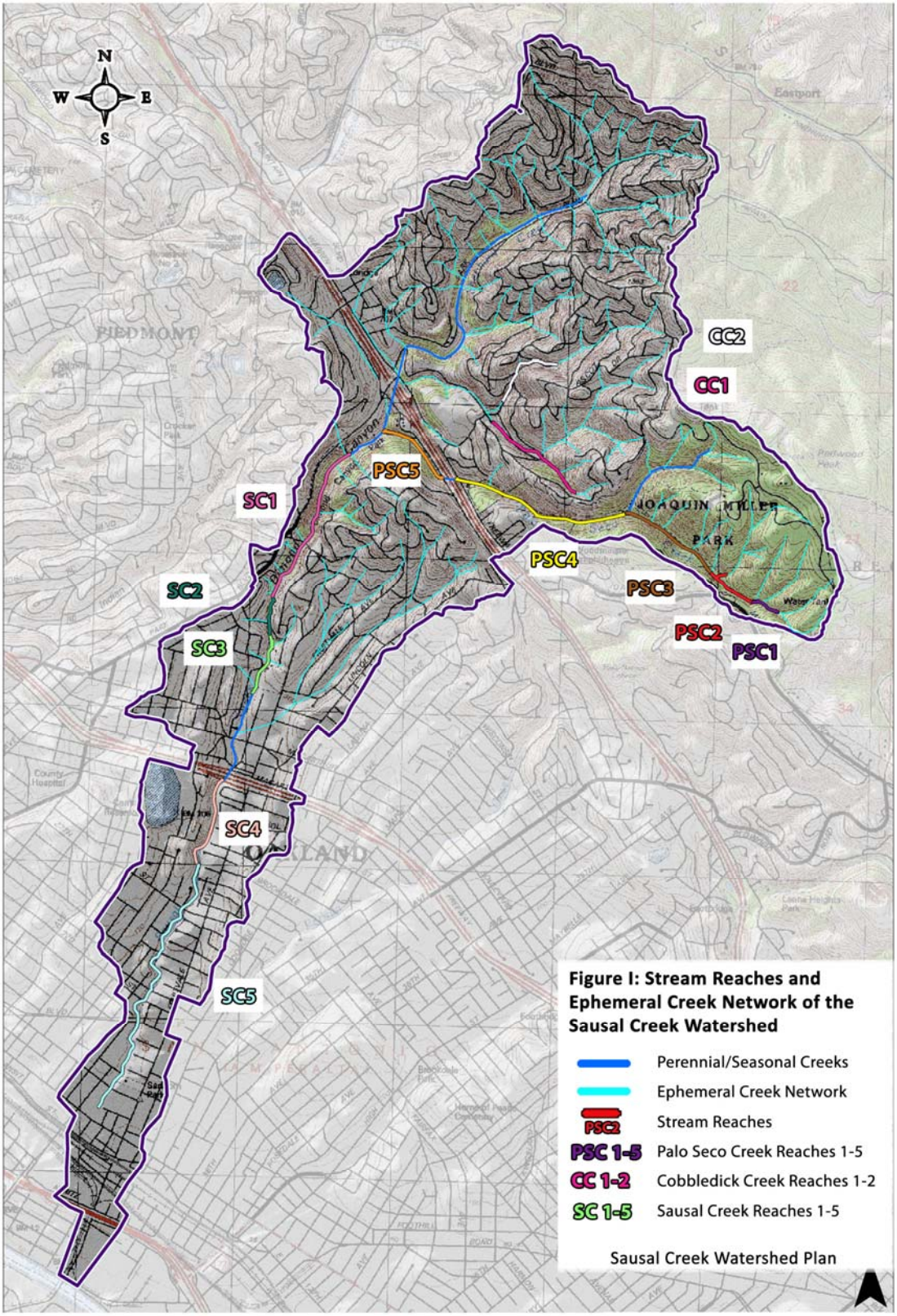

N
W
E
S
CC2
CC1
PSC5
SC1
PSC4
PSC3
SC2
PSC2
SC3
PSC1
SC4
SC5
Figure I: Stream Reaches and Ephemeral Creek Network of the Sausal Creek Watershed
Perennial/Seasonal Creeks
Ephemeral Creek Network
PSC2
Stream Reaches
PSC 1-5
Palo Seco Creek Reaches 1-5
CC 1-2
Cobbledick Creek Reaches 1-2
SC 1-5
Sausal Creek Reaches 1-5
Sausal Creek Watershed Plan

Figure J: Houses line the tributary channels in the Cobbledick Creek sub-basin. House and deck foundations are located within the area of the channel that is subject to bank erosion and failure.

Cobbledick Creek 4 (CC4)
This reach extends from the outlet of the culvert underneath the Joaquin Miller Elementary/Montara Middle schools to the confluence with Shephard Creek. The channel is lined by live oaks and Eucalyptus and has erosion in many locations with undercut trees.

Palo Seco Creek

The Palo Seco Creek sub-basin is the least developed area of the Sausal Creek watershed.

Palo Seco Creek 1 (PSC1)
This reach is the upper meadow area of Joaquin Miller Park. Dominant trees are coast redwoods and willows with an understory of Himalayan blackberry. The channel appears to have been relocated to one edge of the meadow area. Currently the meadow serves as a floodplain (Figure K). A drop inlet into the culverted section of creek (PSC2) occurs at the downstream end of this reach.

Palo Seco Creek 2 (PSC2)
This reach of creek was culverted to create a meadow. This reach was likely lined by redwoods prior to clearcutting in the 1860s and park development projects in the 1930s and 1940s. This reach includes the confluence with Fern Ravine Creek, which is culverted from a picnic area to its confluence with culverted Palo Seco Creek. The drop inlet for Fern Ravine Creek frequently fills with bedload, and water creates an overland course to meet the open channel of Palo Seco Creek.

Palo Seco Creek 3 (PSC3)
This reach of Palo Seco Creek stretches from the culvert outlets at the downstream end of the meadow to the confluence with Cinderella Creek. The slope of the creek bed increases over this reach and contains several knickpoints. The creek channel is incised below these knickpoints and several trees have been undercut on the banks. Aquatic insect monitoring showed good aquatic conditions (Figure L).

Palo Seco Creek 4 (PSC4)
This steep rockbound channel is lined by redwood and California bay laurel trees. Many trees, however, are covered with parasitic Algerian ivy and numerous invasive non-native holly trees are growing in the redwood forest.

Palo Seco Creek 5 (PSC5)
This reach stretches from the Highway 13 culvert outlet to the confluence with Sausal Creek. The channel is confined with hillslopes, and the channel bed is mostly fine sediment with gravel. The density of vegetation is high, dominated by coast redwoods with Algerian ivy, Himalayan blackberry, and American elm. Since 2003, FOSC has been working to re-create the understory vegetation under the redwoods along the switchback trail. An erosion control project consisting of a swale was installed to divert flow from a storm drain outlet.

Figure K: Palo Seco Creek (PSC1) overflows onto a grassed floodplain and trail during larger flow events This reach could be easily restored.

Figure L: Top: Palo Seco Creek (PSC3) in the Jan. 1, 2006 flood event. Bottom: Small trail bridge with culverts serves as a grade control structure for Palo Seco Creek. Small trash rack visible upstream is also a grade control structure. Note sediment runoff from adjacent trails.

Shephard Creek

Shephard Creek has very little riparian or aquatic habitat and few feasible opportunities for native revegetation exist on the main creek. Controlling invasive non-native plants (Eucalyptus, broom, Acacia, pampas grass) in tributaries and on hillslopes will benefit downstream creek areas. This sub-basin has a large number of storm drains and most of the main creek channel has been culverted. Shepherd Canyon Park was once an open creek channel. A large amount of fill and a pipe was placed in the creek to create a flat area for the park. Escher Creek is an ephemeral tributary to Shephard Creek which was relocated to flow along the edge of Shepherd Canyon Park, and has been cleared of invasive plants and planted with native plants by the Shepherd Canyon Homeowners Association. Downstream of this park, the creek has an open channel up to Highway 13 and the confluence with Cobbledick Creek.

Sausal Creek

Sausal Creek extends from the confluence of Palo Seco Creek and Shephard Creek to San Francisco Bay.

Sausal Creek 1 (SC1)
SC1 extends from the confluence of Shephard and Palo Seco Creeks to the restoration project. The creek is confined in a relatively deep canyon lined by California bay laurels and white alders covered by parasitic Algerian ivy. Grade control structures, culverts, and cement lining cover most of the creek channel. Cobble dominated substrate has built up behind the stair steps of grade control structures. A major sewer line borders the creek and runs down the channel. There are numerous erosion sites from storm drains which outlet on the slopes of the canyon (Figure M)

Sausal Creek 2 (SC2)
This is the 600-foot reach where a restoration project was completed in 2001. It begins one-quarter mile upstream from the El Centro culvert. Several grade control structures were removed and the sanitary sewer pipe in the middle of the creek was replaced. A series of rock weirs were installed along with some riprap at the base of the banks. Overstory California bay laurel trees were cut and willows and other native species were planted along the channel banks. Thousands of native plants were installed in the narrow riparian corridor and adjacent slopes (Figure N).

Sausal Creek 3 (SC3)
This reach stretches from just upstream of the El Centro culvert through Dimond Park. The Sausal Creek channel would be unconfined with a floodplain if it were not channelized and culverted. The area downstream of the El Centro culvert is lined by white alders. There are few alder seedlings and no regeneration of the riparian corridor. Along the downstream section, the right bank is residential with various types of revetments to protect against erosion. The left bank is parkland with native and ornamental trees. The channel is entrenched and eroding in this downstream area. The City of Oakland is planning to change this reach by daylighting part of the creek out of the culvert west of Wellington Street, protecting the private property downstream on the right bank and installing native vegetation on the left bank.

Sausal Creek 4 (SC4)
This reach extends from the Highway 580 culvert to 27th St. The creek channel would be naturally unconfined but due to urban development is highly entrenched and culverted. The creek borders an intensively urbanized area and has been affected by the McKillop slide. This slide filled in Sausal Creek in 2006 and undercut several houses. A similar incident occurred in the 1970s and a culvert was installed to

Figure M: These photos are examples of the drop structures in Sausal Creek (SC1) in Dimond Canyon.

Figure N: Top: California bay laurel trees were trimmed to open up the creek corridor to more light and allow for willow growth as part of the restoration project in SC2. Bottom: The project in 2003 shows the riparian corridor and trail.

Figure O: Top: Sausal Creek at Logan Road. Bottom: Sausal Creek at E. 22nd St (SC5).

direct the creek away from the slide through William D. Wood Park. At the downstream end of the culvert a pump operated by Alameda County Flood Control lifts water up to the creek channel downstream.

Sausal Creek 5 (SC5)
This reach extends from 27th St. to the culvert at the most downstream end of Sausal Creek. The creek channel would be naturally unconfined but due to urban development is highly entrenched and culverted. Houses line the creek. The streambed holds little gravel and has eroded down to clay hardpan. Banks are vertical and tall in many locations. Riparian vegetation is limited and primarily consists of non-native species, and shade canopy is sparse. One SWAMP station is located in this reach (Figure O).

Aquatic Insects

An indicator of both the health of the aquatic ecosystem and water quality is the diversity and abundance of aquatic insects in a creek. Typically aquatic insects are monitored in creeks with perennial flows. Some families of aquatic insects are more tolerant of pollution than others. The term EPT refers to *Ephemeroptera*, *Plecoptera*, and *Trichoptera*, three orders of aquatic insects. Within the EPT are particular taxa that are highly sensitive to pollutants. If the number of taxa of EPT sensitive to pollution is high in a creek, then the pollutant levels may be low. If pollution-sensitive taxa are missing, then it is likely that water pollution, poor habitat conditions, or excessive channel scour is occurring.

In 1999 a benthic macroinvertebrate (BMI) study in Sausal Creek was completed (Lacan et.al. 1999) Three stations were sampled: Palo Seco Creek upstream of the creek canyon, Sausal Creek in Dimond Park, and Sausal Creek at Hickory Court. Pebble counts, streamflow measurements, channel cross-sections, and evaluation of riparian canopy were done at each sampling site. Basic water quality parameters—pH, water temperature, dissolved oxygen, and specific conductivity—were also measured during the sampling as instantaneous measurements. This study found a significant difference between the Palo Seco Creek station and the two stations on Sausal Creek in terms of taxa richness, percent of dominant taxon, and indices of functional feeding groups. These results show that the Palo Seco Creek station has a healthy aquatic habitat, while the two Sausal Creek stations have low quality habitat. The authors state that the Sausal stations are highly affected by urbanization. Riparian forest canopy is inadequate to shade the creek at the Sausal Creek stations and the gravel substrate is frequently scoured, turning rocks and moving smaller gravel. The study cites channel incision, which increases flow velocities, steepens stream banks and often erodes riparian trees, along with the higher velocities of urban runoff, as major causes of the lack of healthy aquatic habitat at the Sausal Creek stations.

The San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) completed BMI sampling at three stations in April 2005. These included SAU030 (Sausal Creek at E. 22nd Street), SAU080 (Sausal Creek in Dimond Park), and SAU130 (Palo Seco Creek) (Figure H). For stations SAU030 and SAU080, the BMI assemblages were in poor condition. Taxonomic richness was low and sensitive EPT taxa were largely absent. These conditions were found for the majority of urban creeks in Oakland and Berkeley and are considered indicators of poor water quality and the high scour conditions in urban creeks. The sampling site on Palo Seco Creek (SAU130) demonstrated far better conditions. Taxonomic richness and percent sensitive EPT were much higher, with many pollution-intolerant taxa present.

BMI results from the 2005 SWAMP study and the 1999 Lacan study found similar results: low taxonomic richness and a near absence of sensitive EPT taxa at all the Sausal Creek stations. Stations on Palo Seco Creek showed significantly better conditions with higher taxonomic richness and a moderate percentage of sensitive EPT taxa. These results demonstrate the poor water quality conditions in the urban areas of Sausal Creek and the relatively good conditions on Palo Seco Creek, the only non-urban tributary.

A small number of rainbow trout have been observed in Sausal and Palo Seco Creeks. These fish are at risk from scouring flows and pollutants. The current levels of information don't identify whether the fish successfully reproduce and where they find refuge during floods. The broken areas of the grade control structures in Sausal Creek may serve as areas of lower velocity during floods.

EVALUATION OF WATERSHED EROSION SITES

A focused evaluation of several types of erosion sites was carried out in the Sausal Creek watershed. Outlets of the stormdrain system were assessed for erosion. The City of Oakland GIS layer of storm drain pipes was used to assign letter/number identities to all of the storm drain outlets in the watershed. These outlets were then evaluated to create a list of priority outlets for field inspection. Priorities included outlets along major open channels, large pipe outlets, outlets in extremely steep areas, and outlets of storm drains which drain a large land area. The primary purpose of the field inspection was to identify major erosion problems associated with concentrated flow at outlets of storm drains. A number of features of each outlet was recorded—size and shape of pipe, pipe material, conditions of outlet, whether the culvert was plugged and, if so, by what percentage; whether the outlet was undercut and the number of feet of undercut, the material in the impact zone of outlet, the drop height from the outlet to the impact zone, the condition of the impact zone, the condition of the channel, whether a gully was present at the outlet and, if so, the length and depth of the gully; comments on the site, and a photograph.

The results were mapped with categories for the amount of erosion at the outlet: extreme, significant, or little to no erosion. Not surprisingly, most of the erosion at the storm drain outlets occurs in the upper watershed and along Dimond Canyon. Many of the storm drains in the watershed have been in place since the development of the area; however, one of the newest developments in the watershed, the Chabot Space and Science Center, has caused significant erosion to surrounding lands from its storm water outlets. This facility has large parking lots, roofs, and other paved areas which drain to a few outlets. There is significant erosion at these storm drain outlets and further downstream in the creek channels. The affected creeks are all on public property. The Castle Drive erosion site in Joaquin Miller Park appears to have been caused by a storm drain outlet at the ridge top which releases storm water into the park.

Parks in the Sausal Creek watershed have several primary areas of erosion: recreational facilities such as trails and roads, outlets of concentrated flows from adjoining urban lands, and changes to creeks from watershed changes and management actions. Major erosions sites are summarized in Table F. Many of the trails in Joaquin Miller Park date from prior logging activities and were not built for long-term use. There is a general lack of stream crossing culverts, waterbars, and proper drainage on trails.

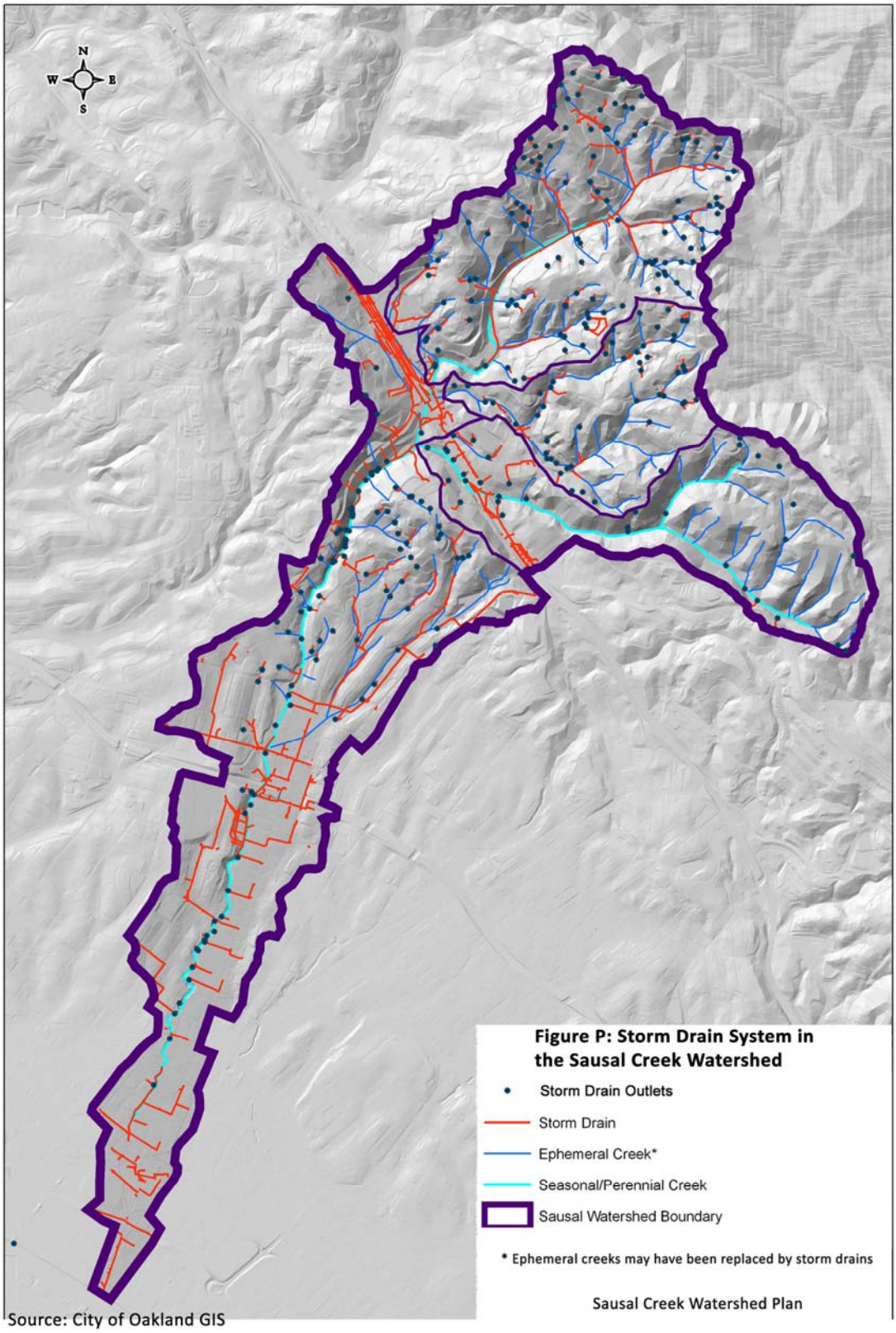

N
W
E
S
Figure P: Storm Drain System in the Sausal Creek Watershed
Storm Drain Outlets
Storm Drain
Ephemeral Creek*
Seasonal/Perennial Creek
Sausal Watershed Boundary
* Ephemeral creeks may have been replaced by storm drains
Sausal Creek Watershed Plan
Source: City of Oakland GIS

Figure Q: Erosion site #2. Lack of a culverted stream crossing causes water to flow down Sunset Loop Trail, eroding the trail and creating a pile of mud on Sunset Trail (bottom)and in Palo Seco Creek.

Figure R: Top: Cinderella Trail is a major erosion site and needs to be re-designed or re-located. Bottom: Casual trails cause soil erosion directly into Palo Seco Creek.

Table F: High Priority Erosion Sites

Priority for Repair	Comments and Recommendations
Joaquin Miller Park	
High – direct delivery to creek; damage to vegetation and trail	The Sunset Loop Trail crosses an ephemeral creek with no culvert and captures the creek flow. Consequently, creek flow courses down the trail, eroding 3-4 inch deep rills and delivering fine sediment to the base of the oak tree on Sunset Trail and into Palo Seco Creek. A culvert needs to be installed to route the stream flow under the trail and back into the creek.
High – direct delivery to the creek	This is the most upstream grade control on Palo Seco Creek and consists of a trail bridge with three 20-inch culverts and an upstream trash rack. Trails at this junction are rilling, particularly Sinawik Loop Trail. In addition, the ephemeral creek on the north side of Sunset Trail is actively eroding from storm drain runoff along Skyline Blvd. directed into this small creek. A major repair will be needed here as major runoff events deepen Palo Seco Creek at the downstream side of the bridge. Trail and ephemeral creek runoff flows down the creek banks, eroding and widening the channel. The channel bed is up to seven feet deeper below the bridge than in the areas upstream of the trash rack. The bridge and trash rack cannot simply be removed, as removal will cause the channel to adjust and undercut numerous redwoods along the creek banks. Any replacement structure should be designed as a grade control structure. Stream banks should be revegetated and the culvert under Sunset Trail between the northern ephemeral creek and Palo Seco Creek replaced with a much larger culvert which will not clog with rocks but will allow for the transport of rock into Palo Seco Creek.
High – direct delivery to creek	This is another major knickpoint in Palo Seco Creek at a casual creek crossing. The knickpoint is over five vertical feet and has eroded approximately five feet upstream in the past ten years. Several tree roots are temporarily preventing the site from further erosion moving upstream. This site should have a rock grade control structure to avoid further upstream migration of this knickpoint. Downstream banks need to be set back to reduce erosive velocities and allow willow sprigging. Large wood debris in the channel should also be retained at this location.
Moderate	Sunset Trail crosses Cinderella Trail and a very large erosion site occurs in the channel of Cinderella Creek downstream of this crossing. The addition of urban runoff from Chabot Space & Science Center greatly increased the level of erosion at this site. The channel downstream of this crossing is over 20 ft. lower in elevation from the upstream side. Unfortunately, a culvert replacement completed in 2007 was installed incorrectly. Stream crossing culverts need to be installed at the same slope as the stream channel. The repair set the culvert at no slope, resulting in a large drop for the water at the outlet. The culvert also appears undersized, with flow overwhelming the culvert during the 2006 flood and flowing over the trail. This site should have a critical dip installed to avoid flow coursing down the trail and causing additional erosion.

Table F: High Priority Erosion Sites

Priority for Repair	Comments and Recommendations
High – direct delivery to creek; trail damage	Cinderella Trail borders Cinderella Creek and probably was originally constructed as a skid trail for logs. This trail is very steep and highly eroded. It currently functions as a bucket road: the convex road surface concentrates flow in the low point at the center of the trail and erodes fine sediment in storms. These fines are deposited on Sunset Trail and in Cinderella Creek. This trail needs to be re-graded to an outsloped condition with rolling dips to intercept sheet flow from the road. Several ephemeral tributaries and one spring to Cinderella Creek also course over the trail, adding to the runoff on the trail. These tributaries need culverts to move the water to Cinderella Creek. This trail should be considered for closure due to the high cost to repair and stop the environmental damage it causes.
Moderate	Chaparral Trail has numerous rills and gullies and needs to be rebuilt in sections using new grade control steps to stabilize the trail and reduce erosion.
Moderate – monitor repairs for downstream effects	A storm drain at the top of the ridge on Castle Drive combined with clearcutting of Eucalyptus caused a major erosion site in an ephemeral creek channel. An expensive repair was installed following over 10 years of erosion, ineffective repairs, direct delivery to Palo Seco Creek, and environmental damage. Several temporary repairs, installed prior to current project, failed. Current repair includes a pipe to move runoff through the gully and beneath the trail. The pipe outlets in the ephemeral creek channel just downslope from the trail crossing. This creek has significantly eroded and needs to be carefully monitored to avoid continued erosion. Pipe should be extended to culvert at Palos Colorados Trail to avoid eroding the creek.
Moderate	Palos Colorado Trail is eroding in numerous locations with direct delivery to Palo Seco Creek. Repairs should avoid filling or narrowing the creek to support the trail.
High – direct delivery to creek; trail damage	Stormwater runoff from Chabot Space & Science Center parking lots is eroding the Castle Park Trail. Directly delivers sediment to Cinderella Creek.
Moderate	Gully on Sinawik Trail
Moderate	Rill erosion on short steep trail near Horse Arena
Moderate	Rill erosion on steep section of Fern Ravine Trail
Dimond Canyon	
High	There is extreme erosion at two culvert outlets in Dimond Canyon; the first is the gigantic hole created by the shotgun culvert at Estates Drive on Park Blvd. and the second is near Park Blvd., just south of the Leimert Bridge: water runs down the trail for a considerable distance and has created numerous gullies.
High	The storm drain outlet near San Luis Avenue creates a huge gully in the restoration area.
High	The storm drain outlet at the end of Benevides Ave. has created a small landslide into the creek.
Moderate	There is a significant amount of erosion due to off-trail dogs; they've done a tremendous amount of damage to the native plantings in the El Centro restoration area and there are denuded swaths between Sam's Trail and the creek, and also along the Bridgeview switchbacks.

Table F: High Priority Erosion Sites

Priority for Repair	Comments and Recommendations
Moderate	Montclair Golf Course uses a golf ball vacuum on the lower area of the driving range, creating a sediment source just above the culvert outlet.
Shepherd Canyon and Montclair Railroad Trail Park	
High	The Zinn Drive/trail area is the source of a lot of sediment along the Montclair Railroad Trail. There are two or three shotgun culverts with large gullies below the trail; the deteriorating edge of the fire road has many small landslides; and the very large landslide below Cortez Court has blocked the creek channel, creating rills and gullies for about 150 feet along the fire road. The 500 feet of ephemeral creek channel above is basically an eroding gully, up to 3 feet deep and 5 feet wide.
Moderate	Escher Creek is eroding very quickly: former eroding ephemeral creek channels upstream were culverted a few years ago. Karen Paulsell estimates that the creek has downcut at least 1 foot in about 5 years at one creek crossing.
Moderate	A lot of the steep hillsides above and below Escher Drive are regularly denuded, with a lot of bare soil exposure, partially due to the WPD vegetation management. Erosion continues all the way down the Escher Creek channel, and is high between the restroom and the standpipe at Shepherd Canyon Road.
High	Storm drain outlets SC-4-04 and SC-4-05 join to form a large gully, 6 feet wide by 8 feet deep and at least 100 feet in length.
Moderate	Many homeowners clear like the WPD does: down to bare soil, adding to the silt load.
Cobbledick Creek	
High	A landslide at Haverhill Dr. is affecting Beaconsfield Canyon, with the landslide deposition blocking the creek channel and flow diverted onto the fire road.
Moderate	Upstream from Haverhill Dr., the creek is eroding soil from under the edge of the road.
Moderate	A new and significant gully has appeared in Castle Canyon; a possible cause is a new storm drain installed on private property at the top of the canyon. It is very likely that this gully is responsible for the large amounts of deposition in the channel along Larry Lane.
High	One of the extreme creek channels is located on Holyrood Dr. in the upper part of the watershed; the homes next to this creek channel have soil eroded from underneath their foundations.

LAND USE AND MANAGEMENT

Relevant Plans, Policies, and Permitting

Sausal Creek watershed is home to about 80,000 residents and includes 2127.6 acres of urban land covering 76.5% of the drainage. The density of housing varies between the steep hills of the upper watershed and flatter lands of the lower watershed. Above and just below Highway 13, residential density has less than 49% cover of impervious surfaces. From Dimond Park downstream, high intensity urban areas have 50-100% impervious coverage. Parkland and open space covers approximately 650 acres in the watershed or 23.5% of the drainage.

The City of Oakland has a Creek Protection, Storm Water Management and Discharge Control Ordinance. The purpose of the ordinance is to:

- Eliminate non-storm water discharges to the municipal storm drain system;
- Control the discharge to municipal storm drains from spills, dumping or disposal of materials other than storm water;
- Reduce pollutants in storm water discharges to the maximum extent practicable;
- Safeguard and preserve creeks and riparian corridors in a natural state;
- Preserve and enhance creekside vegetation and wildlife;
- Prevent activities that would contribute significantly to flooding, erosion or sedimentation, or that would destroy riparian areas or would inhibit their restoration;
- Enhance recreational and beneficial uses of creeks;
- Control erosion and sedimentation;
- Protect the public health and safety, and public and private property.

Portions of the Sausal Creek watershed are in the City of Oakland Wildfire Prevention District. The priorities of the Wildfire Prevention District for 2004-2014 are to:

- Establish and implement a strategic, cost-effective, sustainable, environmentally sensitive fuel management plan
- Encourage the involvement of and increase the knowledge of property owners, developers and the public-at-large in fire safe practices

Infrastructure

The sanitary sewer system carries raw sewage from residential and commercial areas to the East Bay Municipal Utilities District (EBMUD) wastewater treatment facility in west Oakland. The maze of sewer lines in the hilly residential areas of Shephard Creek and Cobbledick Creek sub-basins appear to feed into main lines along the major creek courses. This system of sewer pipes from the upper watershed feeds into the main sewer, which follows Sausal Creek through Dimond Canyon. Several major lateral pipes feed into the main sewer in Dimond Canyon. Sewer pipes also cross Sausal Creek at several points in the lower watershed. The route of the main sewer line leaves the Sausal Creek bed at the end of Dimond Park and follows Dimond Avenue and then Fruitvale Avenue. There are several locations where the sanitary sewer system is known to overflow during large rainstorms. Where the main sewer extends down Sausal Creek from Highway 13 to Dimond Avenue, the manhole covers pop off the sewer in large storms and raw sewage flows into Sausal Creek. Sewage also flows out of the sewer manhole into Palo Seco Creek just upstream of the Highway 13 crossing on Joaquin Miller Court. There are likely additional locations where similar problems occur (Figure S).

Figure S: Sanitary sewer overflow following the January 1, 2006 flood

Table G: Summary of Watershed Conditions

Feature	Opportunities	Constraints
Physical Features	Many of the creek channels in the upper watershed are open and unculverted. Most of the Palo Seco Creek sub-basin is undeveloped. Sausal Creek is largely unculverted from the Montclair Golf Course to just below Foothill Boulevard. Palo Seco Creek and a large portion of Sausal Creek are in public parks. Many of the ephemeral creeks in the upper watershed are natural channels.	The Sausal Creek watershed is "built out" as a residential area with some commercial areas. In a built out area it is more difficult to implement creek setbacks, low impact development (LID), stormwater detention, and other facilities to mitigate the pollutant and peak flow effects caused by urbanization than if an area is in the process of being developed. The upper watershed is prone to landslides and erosion due to the steep slopes and highly fractured rock along the Hayward fault. Most of the creeks downstream of I-580 are culverted. Rainstorms of 1 inch precipitation or less cause a 1-year frequency flow event. This frequency flow disturbs aquatic habitats. Trails in Joaquin Miller Park have numerous erosion sites. Storm drains direct additional runoff into hillside ephemeral creeks, increasing erosion at the outlet of the culvert and in the creek channel.
Biological Features	Palo Seco Creek retains high quality aquatic habitat as demonstrated by the diversity, abundance, and pollution-sensitive taxa of aquatic insects sampled in the creek. Although infested with invasive non-native plants in some locations, the parkland of the Sausal Creek watershed supports a diversity of native and rare plant species.	Sausal Creek watershed is 78% urban land uses with intensive development from the El Centro crossing downstream and less intensive development upstream. Residential areas harbor numerous ornamental plants, some of which are invasive and can spread into natural creeks and out-compete native plants. These invasive non-native plants are widespread in the natural lands of Sausal Creek watershed. Urban areas are a never-ending source of infestation. Many invasive plants are fire hazards.

Table G: Summary of Watershed Conditions

Feature	Opportunities	Constraints
	A small population of rainbow trout lives in Sausal Creek and lower Palo Seco Creek. There are a number of city parks in the watershed where projects to improve creeks and habitats can be implemented.	Water quality sampling at the five stations in the Sausal Creek watershed found excessive levels of nutrients, no persistent pollutants, and some negative effects from bioassay tests on sediment samples. Aquatic insect sampling at all the Sausal stations found poor aquatic habitat conditions and limited aquatic insect abundance and diversity, with almost no pollution-sensitive taxa. Bacteria sampling in Sausal Creek and Palo Seco Creek found levels of *E. coli* in excess of standards for water contact recreation in all but one sample.
Planning and Infrastructure	The City of Oakland has a creek protection ordinance. Oakland has a Wildfire Prevention District works with residents to control invasive non-native plants that are also fire hazards. FOSC has implemented a program of invasive non-native plant control and native plant installation involving and educating many residents.	The main sanitary sewer is located adjacent to and in Sausal Creek from below Highway 13 to Dimond Avenue. Raw sewage overflows occur during flood events and *E. coli* sampling indicates leaks may also be occurring. Storm drain outlets in the Sausal Creek watershed create erosion in a number of locations. The control methods used by the Wildfire Prevention District often cut the same vegetation numerous times and is believed to spread invasive plants through inappropriate management actions (FOSC 2010).

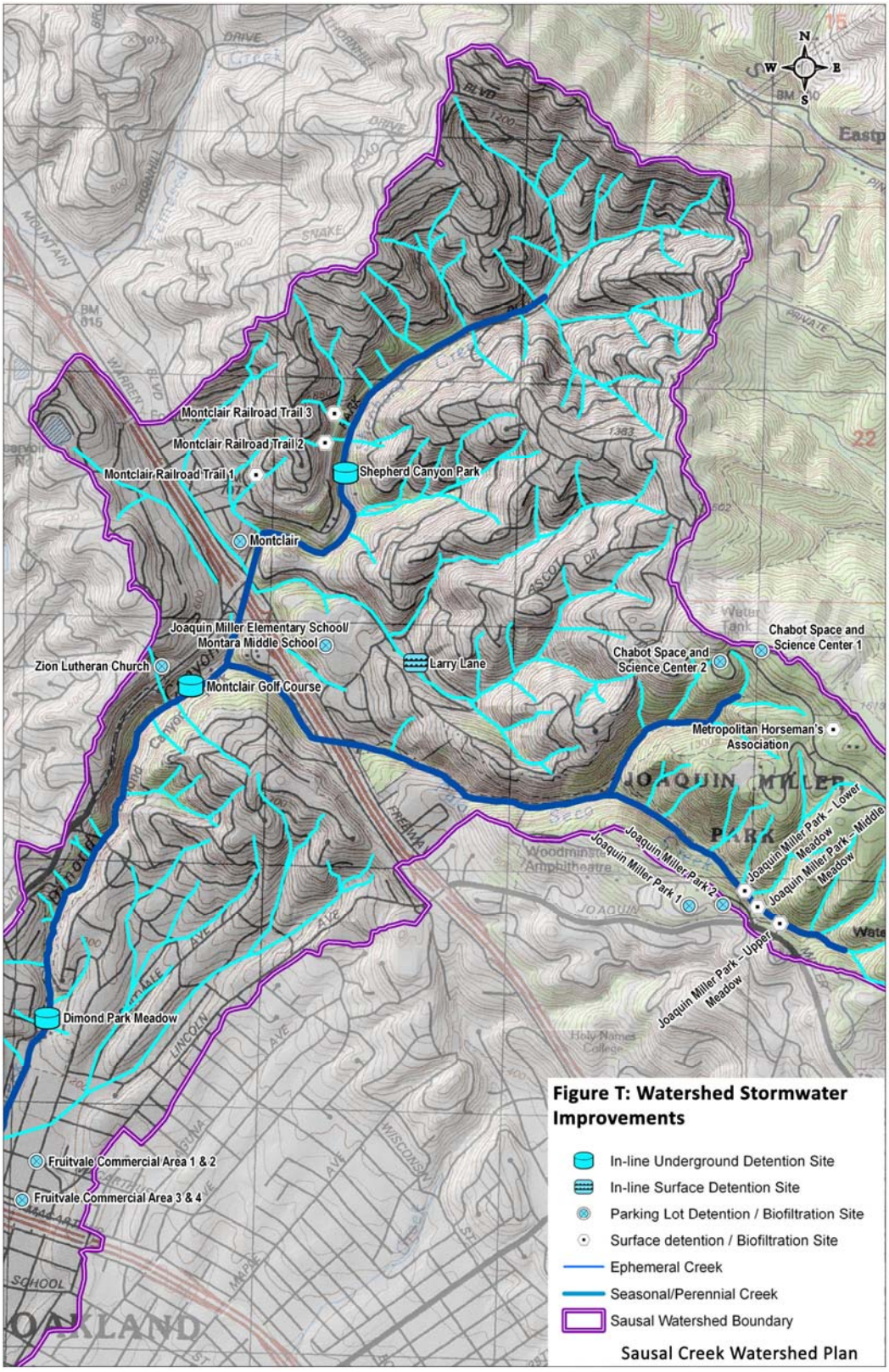
EVALUATING WATERSHED STORMWATER IMPROVEMENTS

The assessment of existing conditions in the Sausal Creek watershed demonstrated that changing the volume and timing of stormwater entering the creek system could reduce the negative effects of urbanization on the aquatic and riparian system.

These conditions include:

- High levels of impervious surfaces (asphalt, cement, buildings) resulting in reduced infiltration of rainfall and increased runoff volumes over a shorter period of time.
- Small increments of rainfall produce larger runoff volumes. For example, a storm event with 0.5 inches of rainfall in a 24-hour period can generate a significant level of runoff.
- Poor habitat conditions for aquatic insects in Sausal Creek but good conditions in Palo Seco Creek, a largely undeveloped tributary basin.
- Frequent runoff events (1-year frequency) are capable of scouring the creek, moving gravel and reducing the ability of the creek to support aquatic insects and aquatic habitats.
- Channel entrenchment and the lack of functional floodplain limits riparian corridors to a narrow width and removes natural regeneration and ecological successional processes.
- Numerous erosion sites from storm drain outlets and erosion in many small creeks in the upper watershed.

The watershed was reviewed for locations where stormwater could be detained or temporarily held and released slowly to reduce the volume of peak flows in Sausal Creek. Figures T and U and Table F depict the locations of a series of watershed improvements.


Montclair Railroad Trail 3
Montclair Railroad Trail 2
Montclair Railroad Trail 1
Shepherd Canyon Park
Montclair
Joaquin Miller Elementary School/
Montara Middle School
Zion Lutheran Church
Montclair Golf Course
Larry Lane
Chabot Space and
Science Center 1
Chabot Space and
Science Center 2
Metropolitan Horseman's
Association
Joaquin Miller Park – Lower
Meadow
Joaquin Miller Park – Middle
Meadow
Joaquin Miller Park 2
Joaquin Miller Park 1
Joaquin Miller Park – Upper
Meadow
Dimond Park Meadow
Fruitvale Commercial Area 1 & 2
Fruitvale Commercial Area 3 & 4
Figure T: Watershed Stormwater
Improvements
In-line Underground Detention Site
In-line Surface Detention Site
Parking Lot Detention / Biofiltration Site
Surface detention / Biofiltration Site
Ephemeral Creek
Seasonal/Perennial Creek
Sausal Watershed Boundary
Sausal Creek Watershed Plan

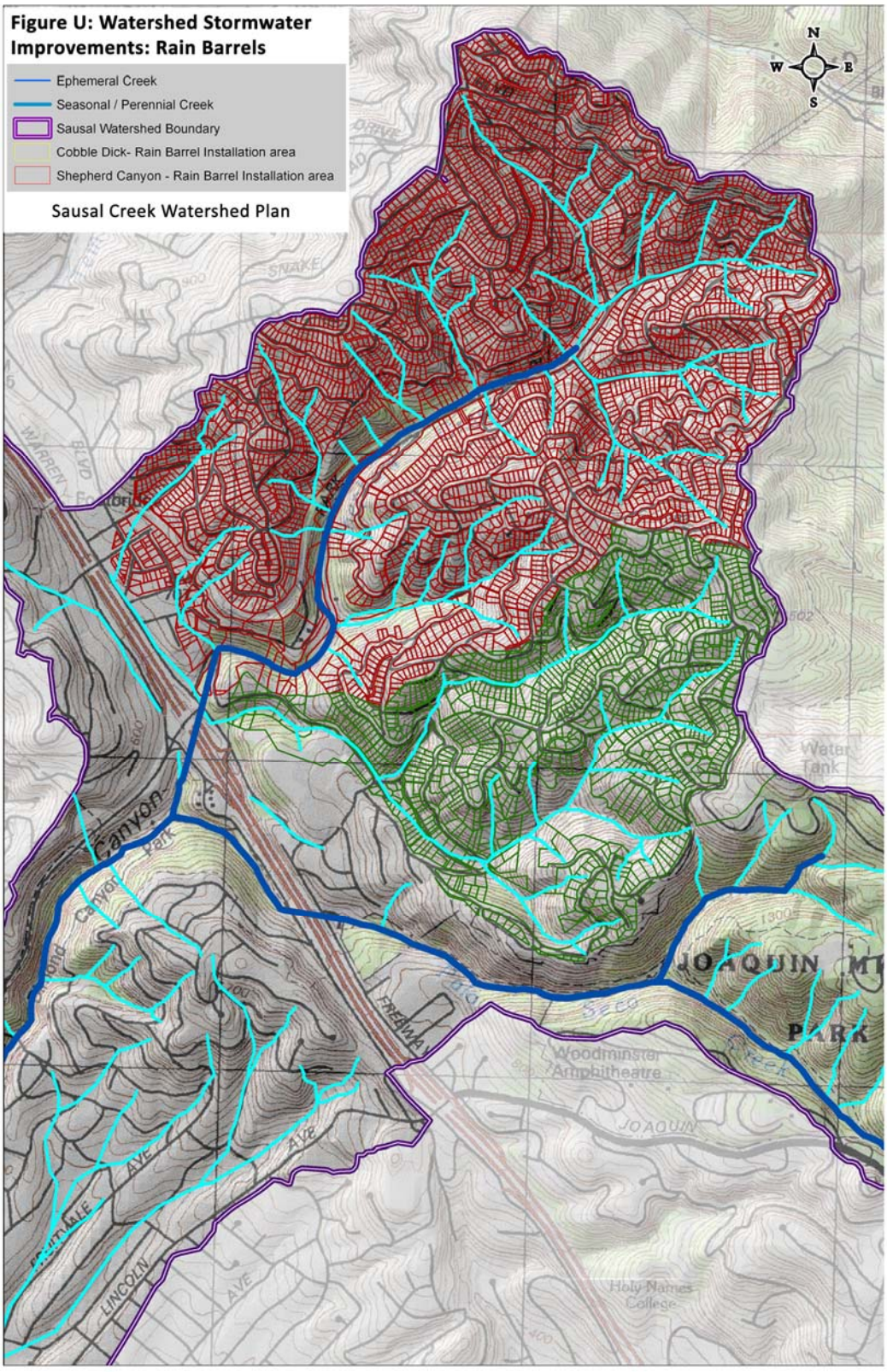


Figure U: Watershed Stormwater Improvements: Rain Barrels
Ephemeral Creek
Seasonal / Perennial Creek
Sausal Watershed Boundary
Cobble Dick- Rain Barrel Installation area
Shepherd Canyon - Rain Barrel Installation area
Sausal Creek Watershed Plan
N
W
E
S
Canyon
Park
Water Tank
Woodminster Amphitheatre
Holy Names College
FREEWAY
LINCOLN
AVE

Table H: Sausal Creek Watershed Stormwater Improvement Sites

Improvement	Scenario 1	Scenario 2	Scenario 3
Rain barrel at each house in the Shephard and Cobbledick Creek sub-basins	✓	✓	✓
Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 1	✓	✓	✓
Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 2	✓	✓	✓
Joaquin Miller Elementary School/Montara Middle School Parking Lot Detention and Biofiltration Site	✓	✓	✓
Montclair Parking Lot Detention and Biofiltration Site	✓	✓	✓
Joaquin Miller Park Parking Lot Detention and Biofiltration Site 1	✓	✓	✓
Joaquin Miller Park Parking Lot Detention and Biofiltration Site 2	✓	✓	✓
Zion Lutheran Church Parking Lot Detention and Biofiltration Site	✓	✓	✓
Montclair Railroad Trail – Stormwater Detention Basin 1	✓	✓	✓
Montclair Railroad Trail – Stormwater Detention Basin 2	✓	✓	✓
Montclair Railroad Trail – Stormwater Detention Basin 3	✓	✓	✓
Joaquin Miller Park – Upper Meadow Detention Site	✓	✓	✓
Joaquin Miller Park – Middle Meadow Detention Site	✓	✓	✓
Joaquin Miller Park – Lower Meadow Detention Site	✓	✓	✓

Table H: Sausal Creek Watershed Stormwater Improvement Sites

Improvement	Scenario 1	Scenario 2	Scenario 3
Metropolitan Horseman's Association Parking Lot Detention and Biofiltration Site	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 1	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 2	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 3	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 4	✓	✓	✓
Shepherd Canyon Park – Underground Cistern		✓	✓
Larry Lane On-stream Detention Pond		✓	✓
Montclair Golf Course – Underground Cistern			✓
Dimond Park Meadow – Underground Cistern			✓

The watershed improvements under Scenarios 1, 2, and 3 for Sausal Creek watershed would result in localized reductions to flow rates and flow volumes in Sausal Creek and tributaries. The hydrology results indicate that while all three scenarios would reduce runoff rates and volumes in the Sausal Creek watershed, the specific types of stormwater facilities and their locations in the watershed have a great bearing on localized hydrologic patterns. Comparing the three scenarios to existing conditions reveals the following trends:

- Stormwater source control practices such as the rain barrels, parking lot detention, and small detention basins simulated in Scenario 1 have a significant effect on reducing flow rates and volumes for the 1-year event. Larger storm events produce larger quantities of runoff, which quickly overflow these facilities; thus reductions in flow rates and volumes are minor for the 2 to 100 year events.

- Cisterns and detention basins significantly reduce flow rates in the reaches below the facilities for the 1-year event, and less so for the larger events. However, as other, uncontrolled

tributaries join the channel downstream of the detention facility, the flow dampening effect becomes less pronounced. Flow volumes are less affected by the detention facilities.

- The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

- In relation to the other sub-basins, Palo Seco Creek is relatively undeveloped. The proposed improvements in that sub-basins included in Scenario 1 reduce flow rates by 14% to 17%, and flow volumes by 15% to 24% compared to existing conditions for the range of storm events. Because the majority of the improvements occur on publicly-owned lands, implementation of these measures may be simpler and less expensive. For these reasons, it is recommended that the Palo Seco Creek sub-basins be considered for a demonstration project.

In an urbanized watershed like Sausal Creek, reductions in peak water depths, velocities, and shear stresses can lead to habitat improvements in the creeks. However, it can be extremely difficult to identify and acquire adequate space to implement measures that can have meaningful impacts on watershed hydrology in an urbanized watershed. The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

As a first step in implementing the watershed stormwater improvements of Scenario 3 the proposed improvements in Palo Seco Creek sub-basin should be completed as a demonstration projects

Biofiltration

An additional water quality benefit can be gained through the installation of biofiltration facilities in the parking lots. Parking lots concentrate oil and grease residues, a persistent pollutant in urban stormwater. With the use of biofiltration facilities, stormwater runs off the parking lot and into biofiltration units before entering the storm drain. Each biofiltration facility has a surface mulch layer which catches particles. Shredded hardwood, pine bark, tree chips, or coarse peat moss are typical mulch materials. Leaf or grass compost is not recommended. Stormwater is directed into the biofiltration facility through a curb cut in the parking lot. Floatable trash is caught on the surface of the device. As the stormwater filters through the mulch layer, trash and particulates are caught. Beneath the mulch are rapid infiltration layers of coarse sand and gravel. It is important to limit clay and silt in

this layer to less than five percent of the total volume. At the base is an underdrain which takes the filtered water to the storm drain system. It is also possible to infiltrate the filtered water if soil types and groundwater levels are appropriate. Each facility has plants, trees, shrubs, and low-growing herbs or rushes which are part of the filtration system. As nutrients such as nitrate fertilizers are filtered out, the plant roots uptake these materials. There needs to be a large number of these small facilities distributed over the drainage in order to have an impact on pollutant levels.

RECOMMENDED ACTIONS

MAJOR EROSION SITES

- The watershed assessment identified a number of storm drain outlets with erosion problems. Many of these erosion sites are in public parks. Each one of the erosion sites requires a site-specific repair and the involvement of the City of Oakland Public Works Department. The storm drain system is owned and maintained by the City and repair is their responsibility.
- Homeowners could benefit from workshops on storm water management to reduce erosion and increase slope stability. This workshop could be combined with workshops on rain barrel installation and maintenance.
- The erosion sites documented for Joaquin Miller Park point to a need for re-design and maintenance of many of the park trails. In addition, several of these erosion sites were caused by urban stormwater runoff released into public lands from residential areas (Castle Drive) and new developments (Chabot Space & Science Center). The City's approval of a large development like the Chabot Space & Science Center with no provision to reduce the effects of storm water runoff from large parking lots built on top of a slope indicates the need for the City of Oakland to specifically evaluate this impact when permitting new development in the Oakland hills.

WATERSHED STORMWATER IMPROVEMENTS

- Urban development causes a permanent change in the watershed processes of infiltration of rainfall and runoff of stormwater. These system-wide changes in the drainage basin produce larger volumes of stormwater delivered into creek channels over a short time frame. In response, ephemeral creeks in the steep hills of the watershed erode and can initiate a slide on the hillslope.
- All of the aquatic insect studies in Sausal Creek show poor aquatic habitat conditions. While urban creeks can be daylighted and enhanced with vegetation, studies of urban creek restoration projects in numerous locations show only small improvements in aquatic habitat conditions. This lack of habitat improvement occurs because the urban watershed still produces high velocity flows which scour creeks and greatly reduce aquatic habitat values. Mitigating the effects of urbanization through watershed stormwater improvements can improve aquatic conditions, reduce bank erosion and sustain riparian habitat to a much greater extent than creek restoration projects alone will ever accomplish.

- Stormwater source control practices such as the rain barrels, parking lot detention, and small detention basins simulated in Scenario 1 have a significant effect on reducing flow rates and volumes for the 1-year runoff event. Larger storm events produce larger quantities of runoff,

which quickly overflow these facilities producing only minor reductions in flow rates and volumes for the 2- to 100-year events.

- Cisterns and detention basins significantly reduce flow rates in the reaches below the facilities for the 1-year event, and less so for the larger events. However, as additional tributaries join the channel downstream of the detention facility, the flow dampening effect becomes less pronounced. Flow volumes are less affected by the detention facilities.

- The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

- In relation to the other sub-basins, Palo Seco Creek is relatively undeveloped. The proposed improvements included in Scenario 1 within the sub-basin reduce flow rates by 14% to 17%, and flow volumes by 15% to 24% compared to existing conditions for the range of storm events. Because the majority of the improvements occur on publicly-owned lands, implementation of these measures may be simpler and less expensive. For these reasons, it is recommended that implementation of watershed stormwater improvements in the Palo Seco Creek sub-basin be considered as a demonstration project.

- The larger program of watershed stormwater improvements in the other sub-basins can be phased over a 10-year period as grant funds become available.

- Installation of biofiltration facilities along roads and in parking lots should be implemented in as many locations as possible as part of the pilot green street projects required by the Regional Board NPDES permit.

INVASIVE NON-NATIVE PLANTS

The abundance and broad distribution of invasive non-native plants in the Sausal Creek watershed is a major threat to native habitat in public parkland and creeks. This problem is further exacerbated by the purchase and planting of many of these invasive species by uninformed homeowners, creating an infinite source of infestation in the watershed.

The main actions recommended to address the invasive plant problem are:

- Eradication of invasives in the Palo Seco Creek sub-basin would implement the best opportunity for improvements of both upland and creek habitats.

This effort, while involving FOSC and the Friends of Joaquin Miller Park, will require grant funding and contracts with companies who specialize in invasive plant mapping and eradication projects. This is a major ecological restoration project and requires a larger-scale, more difficult work effort than community volunteers can provide. The watershed lands outside the park need to be included to evaluate all infested locations on ridge tops and upstream locations. The ridge tops and headwaters are sources of infestation to downhill and downstream areas and should be treated first. Using GPS/GIS, map invasive plants listed in Table 77 and devise an eradication strategy, taking into account the rate of spread, population size, and proximity to at-risk stands of rare plants or intact stands of native vegetation. Using GPS/GIS, also map and identify any rare, unusual or significant plants at risk from invasive plant populations and identify native plant "hotspots" at risk from invasive plant populations. Determine creek and hillside locations most susceptible to bank failure or erosion due to invasive plant infestations.

Areas along trails and roads are priority control areas due to the spread of seed and stem materials by hikers, dogs, and bicyclists.

The use of herbicide as a cut-and-paint method will be needed to make eradication efforts effective. The use of controlled burns may also be evaluated, especially for Algerian ivy infestations. Work should be done by paid contractors.

The eradication effort needs to be well-publicized to neighboring homeowners and park users. Both fire hazards and ecological issues need to be explained thoroughly. Neighboring homeowners with these species on their property should be encouraged to participate in the eradication effort. For the other invasive species—Cape ivy, Algerian ivy, yellow star thistle, Himalayan blackberry, holly, and various grasses—a broad-based community outreach effort is needed.

By focusing on invasive plant eradication in Joaquin Miller Park, public funding may be available, particularly if the program can describe this effort in terms of acres of each habitat type improved and number of private landowners involved. The eradication of non-natives in the Palo Seco Creek watershed will need to extend over at least a 5- to 10-year period.

- Homeowner education throughout the watershed on invasive garden plants could reduce the re-infestation problem. Homeowners provide the primary infestation mechanism of invasive non-native plants in the Sausal Creek watershed through their planting, cultivation, and disposal of garden waste in creeks and empty lots. It is likely that most homeowners do not realize the long-term negative effects of their actions.

- The sale of known invasive non-native plants in the state needs to be restricted.

- Maintenance of revegetation sites free of invasive non-native plants is needed.

- Focused eradication of fire hazard invasive plants is needed in the entire watershed.

WATER QUALITY

- The most serious water quality problem identified from the monitoring data is high *E. coli* levels in Sausal Creek and raw sewage spills and overflows from the sanitary sewer system. In the short-term when sewage spills occur in open creek areas where children have access to the water, the City of Oakland must post closure signs. *E. coli* measured at high levels by the water quality monitoring indicates a potential health hazard for water contact recreation. A watershed-wide program of bacterial monitoring and monitoring of the location of sewage spills and overflows need to be implemented by the City in conjunction with the San Francisco Bay Regional Water Quality Control Board and the Environmental Protection Agency. Identifying the locations of sewage spills will assist in implementing a control program. In the long-term, the sewer system needs to be upgraded so that stormwater infiltration into the sewer pipes, a major cause of overflows, is eliminated. Dry season leaks indicated by the monitoring results also need to be identified and repaired.

- In addition to bacteria monitoring, monitoring of aquatic insects in creeks in the watershed can provide a long-term basis for comparison of conditions and improvements. As discussed on page 105, aquatic insects are an excellent indicator of the condition of aquatic habitats. Sausal and Palo Seco Creeks have had aquatic insect monitoring from 1999-2004/2005 to set a baseline for current watershed conditions. As watershed stormwater improvements are implemented, continued aquatic insect monitoring can document the change in aquatic habitat conditions resulting from reduced scour and lower flow velocities. Aquatic insect monitoring should be done using the SWAMP protocols and a professional lab. A spring and fall sampling at all the SWAMP stations with an additional station in the upstream area of Palo Seco Creek would provide adequate review of changes and improvements.

- The implementation of biofiltration improvements, if completed in enough locations, can effectively remove nutrients and persistent pollutants typical of urban runoff. These facilities also collect floatable trash. Biofiltration facilities, however, require maintenance annually or they are not effective.

- Trash as a pollutant also can be reduced through the work of volunteers, neighborhood groups, and businesses. It can also be controlled through enforcement of littering and dumping laws. The City of Oakland has tried using citations to reduce littering.

AQUATIC AND RIPARIAN HABITATS

- Except for Palo Seco Creek, the aquatic and riparian habitats of the Sausal Creek watershed have been significantly degraded by urbanization of the watershed and the increase in storm flow volumes and velocities, and the resulting scour of the channel. The first and most important step in restoring aquatic habitats in the Sausal Creek watershed is implementation of watershed stormwater improvements to reduce the scouring high velocity flows caused by urbanization of the watershed.

- By focusing on creek restoration, invasive plant removal, and watershed stormwater improvements in Palo Seco Creek, the greatest degree of habitat enhancement can be achieved.

This approach could create high quality aquatic habitat in Palo Seco Creek and provide a genuine refuge for a resident population of rainbow trout. This same goal cannot be met on Sausal Creek. With implementation of all of the watershed stormwater improvements in Scenario 3, flow velocities and channel scour in Sausal Creek still exceed thresholds needed to support high quality aquatic habitat conditions under most flood levels. Implementation of Scenario 3, however, does represent a major improvement in creek conditions under the most frequent 1-year flow event.

- Table I outlines recommended actions in the creek reaches available for revegetation and improvement. Most of the restoration recommendations will require designs by qualified professionals: civil engineers, geomorphologists, hydrologists, and riparian ecologists. They will also require implementation by contractors with experience in stream restoration. Community groups like FOSC and Friends of Joaquin Miller Park can supply assistance to grant efforts, grow native plants in the Joaquin Miller nursery, coordinate volunteer assistance with planting native plants, and maintain creek areas after restoration.

Table I: Restoration Recommendations for Stream Reaches*

Reach	Priority	Recommendations
PSC1	High	• Repair Erosion Site 1 by installing culvert where the trail crosses an ephemeral creek. Culvert must be set in the channel at the slope of the stream to minimize erosion at the culvert outlet and have a minimum of 18 inches of trail fill on top to avoid damage to culvert. Fine sediment from this erosion site is filling the creek. • Relocate trail out of meadow and direct traffic onto Sunset Trail. Restrict bikers and hikers to allow stream restoration. • Install berm at downstream end of Upper Meadow with standpipe connected to culvert under trail. Eradicate Himalayan blackberry and revegetate the floodplain with native trees. • This reach offers one of the only locations for a floodplain riparian restoration with a detention and sediment basin. This site is part of the overall watershed improvements to reduce velocity and volume of stormwater and improve Palo Seco Creek aquatic habitat.
PSC2	High	• The creek is culverted through a meadow likely created during the WPA era when recreational areas were created at the expense of environmental protection. • This reach is a major candidate for daylighting and restoration, especially as the culverts are old and will require replacement in the near future. • Install berm at downstream end to detain stormwater during peak runoff events. • The downstream portion of Fern Ravine Creek now runs overland during nearly every rainfall event as the culvert outlet clogs. The creek should be daylighted and directed into the proposed stormwater detention area and eventually integrated with a daylighted and restored Palo Seco Creek.
PSC3	High	• Improved grade control structures need to be installed at the two knickpoints (Erosion Sites 3 and 4) to avoid the migration of the knickpoints upstream and the undercutting of large trees. Downstream of the bridge a number of trees along the banks have been eroded. The banks should be set back and revegetated once the Himalayan blackberry is removed.
PSC4	High	• Invasive non-native plants are degrading the redwood/California bay laurel forest riparian habitat and weakening the trees. Holly trees are the only species regenerating in the corridor. The holly and ivy need to be eradicated to restore the health of the forest. Ivy should be cut around the base of each tree, and the stumps immediately painted with herbicide to kill the ivy quickly and effectively. If the trees along the steep-sided gorge become weakened by the parasitic ivy and fall, the slopes may fail due to the ground disturbance. The holly needs to be cut and the stumps painted with herbicide to quickly remove this invader before it becomes established and dominates the corridor.
PSC5	Moderate	• FOSC has completed an erosion control project and an invasive plant removal/native plant revegetation project here. Continued maintenance will be needed. • Replace bridge at stream level or re-route trail.

Table I: Restoration Recommendations for Stream Reaches*

Reach	Priority	Recommendations
CC1	Low	• Houses line the upstream portion of this reach, leaving few opportunities for restoration. The sediment/stormwater detention basin on this reach needs to be cleaned out and retrofitted in order to function better. A large gully in this sub-basin requires repair.
CC2	Moderate	• The Beaconsfield Canyon reach needs to have the rusted culvert removed and a geomorphic /revegetation restoration plan that includes a riparian floodplain area completed. • Downstream drop inlet to storm drain needs to be repaired/replaced.
SC1	Low	• This reach presents a real challenge for restoration. There are two major culverts and numerous concrete structures including a cement wall protecting the sanitary sewer pipe. • California bay laurel trees have eroded off the canyon wall and into the creek. Replanting these trees will maintain shade cover for the creek. • Eradicate ivy and other invasives to retain health of native trees. • Work with the City of Oakland to repair erosion from storm drains, especially the major erosion sites along Park Blvd. • Sanitary sewer overflows into Sausal Creek occur during major storms and need to be alleviated to avoid both contamination of the creek and a public health problem.
SC2	Low	• This reach is a restoration project completed in 2001. Control of invasive plants and revegetation are necessary both along the channel and alongside channels. The channel does not provide adequate room for regeneration of riparian species, and replanting will be required. Installing white alder along the channel could diversify the vegetation and provide some stability to the undercut bank areas, which provide refuge to wildlife in floods.
SC3	Moderate	• Replanting of white alder and removal of waste cement and asphalt is needed along this reach. Riparian shade cover over the El Centro pool is also needed to maintain cool water temperatures. • Recreation uses preclude the option of daylighting the creek through Dimond Canyon Park. • Future City of Oakland project to stabilize private property and revegetate stream banks.
SC4	Low	• Creek is entrenched with steep banks and fill from the McKillop slide. With this slide affecting the creek it is difficult to implement revegetation. Houses are very close to the channel, further restricting restoration options. Community-based invasive plant removal and native plant installations would provide local educational opportunities.
SC5	Low	• Creek is entrenched with steep banks and numerous houses. Channel is hardpan clay and revegetation will be difficult in most locations. Community-based invasive plant removal and native plant installations would provide local educational opportunities.

* Stream restoration should be implemented once watershed stormwater improvements are also implemented.

IMPLEMENTATION OF THE WATERSHED PLAN

There are recommended actions in this plan that are suitable for community groups such as Friends of Sausal Creek (FOSC), Friends of Joaquin Miller Park, Shepherd Canyon Homeowners' Association, and others. Many of the actions needed to restore productive aquatic habitat to Sausal Creek and its tributaries, however, require a significant change to storm drain and sanitary sewer infrastructure, including construction of both stormwater detention facilities and creek restoration. This change requires the involvement of the owner of the infrastructure: the City of Oakland. Many areas of Oakland have old and deteriorating infrastructure such as storm drain and sewer systems. The construction of stormwater detention and biofiltration facilities may be able to attract grant funds and allow for the upgrade of storm pipes as part of water quality and creek improvements. The recent municipal stormwater permit from the San Francisco Bay Regional Water Quality Control Board to Alameda County requires implementation of LID (low impact development) practices. This permit also requires the construction of two pilot green street projects. The recommended focus on Palo Seco Creek sub-basin as a demonstration project includes a number of stormwater detention facilities on City property. Table J outlines lead and supporting agencies and organizations for each of the recommended actions in the watershed plan.

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
Major Erosion Sites			
Repair extreme and eroded sites at outlets of City storm drain system	City of Oakland	San Francisco Bay Regional Water Quality Control Board FOSC and neighborhood groups	Adopt-a-Stormdrain program could be used to maintain repaired outlets and repaired erosion sites.
Homeowner workshops on stormwater management	Alameda Countywide Clean Water Program	FOSC and neighborhood groups	
Repair erosion sites in City parks, including relocation and re-grading of trail	City of Oakland	FOSC, Friends of Joaquin Miller Park, Friends of Beaconsfield Canyon, Piedmont Pines Neighborhood Association, and other neighborhood groups	Volunteer groups can play a major role in implementing improvements in parks but designs need to be done by professionals.
Watershed Stormwater Improvements			
High Priority			
Implement Scenario 1 improvements in Palo Seco Creek sub-basin including: • Retrofit Chabot Space & Science Center parking lots 1 and 2 to detain stormwater and install biofiltration units • Retrofit Joaquin Miller Park parking lots to detain stormwater and install biofiltration units	Chabot Space and Science Center Joint Powers Agency City of Oakland	FOSC San Francisco Bay Regional Water Quality Control Board Alameda Countywide Clean Water Program Friends of Joaquin Miller Park	Due to the low level of development in this sub-basin, the greatest level of creek habitat improvement can be achieved by installing stormwater facilities. Detention facilities can also reduce the need for replacement of undersized storm drains. The ridgetop parking lots near the Joaquin Miller Community Center drain toward Joaquin Miller Park. The stormwater runoff from the Chabot Space and Science Center is actively eroding areas of the park.
Joaquin Miller Park – Upper, Middle, and Lower Meadow detention sites	City of Oakland FOSC	Friends of Joaquin Miller Park Alameda Countywide Clean Water Program	These facilities include daylighting lower Fern Ravine Creek. Daylighting Palo Seco Creek through the meadow can also be included in the detention design.

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
Metropolitan Horsemen's Association parking lot detention and biofiltration site	City of Oakland	Friends of Joaquin Miller Park Alameda Countywide Clean Water Program FOSC	
Implementation of biofiltration facilities along streets and in parking lots	City of Oakland San Francisco Bay Regional Water Quality Control Board	Alameda Countywide Clean Water Program FOSC and other community organizations	
Long-Term Priority			
Implementation of watershed stormwater improvements for Sausal Creek	City of Oakland San Francisco Bay Regional Water Quality Control Board	Alameda Countywide Clean Water Program FOSC and other community organizations	The only long-term option for sustainable improvement in Sausal Creek requires the implementation of Scenario 3 of watershed stormwater improvements.
Invasive Non-Native Plants			
Implement a comprehensive mapping, invasive plant eradication/native planting program in the Palo Seco Creek sub-basin	FOSC City of Oakland	Wildfire Prevention District	This program should be implemented with grants and contractors skilled in invasive plant eradication (i.e., Shelterbelt Builders, California Conservation Corps). Relying on community volunteers limits the extent and location of invasives removed and cannot accomplish a comprehensive program. Palo Seco Creek sub-basin offers the best opportunity for large-scale restoration of upland and wetland/riparian habitats.

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
Homeowner education	Wildfire Prevention District FOSC City of Oakland	Homeowner and community groups	Urban gardens are the primary infestation mechanism for invasive non-native plants. Most homeowners are not aware of the problem and could be convinced to avoid planting them.
Ban the sale of invasive plants for gardens	City of Oakland FOSC and Friends of Joaquin Miller Park Wildfire Prevention District	Homeowner and community groups California Native Plant Society California Invasive Plant Council	The continued sale of invasive plants in California is a state-wide issue.
Maintain FOSC revegetation projects	FOSC	Community volunteers	Invasives have affected FOSC revegetation projects in several locations.
Control fire hazard plants	Wildfire Prevention District	FOSC, Friends of Joaquin Miller Park, Friends of Beaconsfield Canyon, Piedmont Pines Neighborhood Association, and other neighborhood groups	Eradicating fire hazards and not planting these species are important actions in fire reduction.
Water Quality			
Monitor creeks for *E. coli*	City of Oakland San Francisco Bay Regional Water Quality Control Board	EPA, FOSC, and community groups	
Monitor location and frequency of sewage spills	City of Oakland San Francisco Bay Regional Water Quality Control Board	EPA, FOSC, and community groups	

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Recommendations	Lead Entity	Supporting Entities	Comments
Post creek areas in parks when sewage overflows occur	City of Oakland San Francisco Bay Regional Water Quality Control Board	EPA, FOSC, and community groups	
Twice annual monitoring of aquatic insects at a number of stations in the watershed	San Francisco Bay Regional Water Quality Control Board FOSC	City of Oakland	A long-term study of changes in aquatic insect communities as watershed improvements are implemented may attract academic interest.
Implement biofiltration projects to reduce nutrients, trash, and other pollutants	City of Oakland San Francisco Bay Regional Water Quality Control Board	Alameda Countywide Clean Water Program FOSC and other community groups	
Aquatic and Riparian Habitats			
High Priority			
Implement Watershed Stormwater Improvements, Scenario 1			
Creek Reach PSC1 • Repair Erosion Site 1 by installing culvert where the trail crosses an ephemeral creek. Culvert must be set in the channel at the slope of the stream to minimize erosion at the culvert outlet and have a minimum of 18 inches of trail fill on top to avoid damage to culvert. Fine sediment from this erosion site is filling the creek. • Relocate trail out of meadow and direct traffic onto Sunset Trail. Restrict bikers and hikers to allow	City of Oakland FOSC, Friends of Joaquin Miller Park	San Francisco Bay Regional Water Quality Control Board Community groups	Palo Seco Creek has the greatest potential for major improvement in aquatic habitat conditions through a combined program of watershed stormwater improvements, creek restoration, and invasive plant eradication. This focus would create a sustainable habitat area to provide refuge for resident rainbow trout.

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
stream restoration. • Install berm at downstream end of Upper Meadow with standpipe connected to culvert under trail. Eradicate Himalayan blackberry and revegetate the floodplain with native trees. • This reach offers one of the only locations for a floodplain riparian restoration with a detention and sediment basin. This site is part of the overall watershed improvements to reduce velocity and volume of stormwater and improve Palo Seco Creek aquatic habitat.			
Creek Reach PSC2 • The creek is culverted through a meadow likely created during the WPA era when recreational areas were created at the expense of environmental protection. • This reach is a major candidate for daylighting and restoration, especially as the culverts are old and will require replacement in the near future. • Install berm at downstream end to detain stormwater during peak runoff events. • The downstream portion of Fern Ravine Creek now runs overland during nearly every rainfall event as	City of Oakland FOSC, Friends of Joaquin Miller Park	San Francisco Bay Regional Water Quality Control Board Urban Creeks Council and other community groups	Daylighting Palo Seco and Fern Ravine Creeks would be one of the largest habitat improvements in the watershed; however, it would require a major re-design of recreational uses of a part of Joaquin Miller Park

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
the culvert outlet clogs. The creek should be daylighted and directed into the proposed stormwater detention area and eventually integrated with a daylighted and restored Palo Seco Creek.			
Creek Reach PSC3 • Improved grade control structures need to be installed at the two knickpoints (Erosion Sites 3 and 4) to avoid the migration of the knickpoints upstream and the undercutting of large trees. Downstream of the bridge a number of trees along the banks have been eroded. The banks should be set back and revegetated once the Himalayan blackberry is removed.	City of Oakland FOSC, Friends of Joaquin Miller Park	San Francisco Bay Regional Water Quality Control Board Community groups	
Creek Reach PSC4 • Invasive non-native plants are degrading the redwood/California bay laurel forest riparian habitat and weakening the trees. Holly trees are the only species regenerating in the corridor. The holly and ivy need to be eradicated to restore the health of the forest. Ivy should be cut around the base of each tree, and the stumps immediately painted with herbicide to kill the ivy quickly and effectively. If the trees along the steep-sided gorge become weakened by the	City of Oakland FOSC, Friends of Joaquin Miller Park	San Francisco Bay Regional Water Quality Control Board Community groups	

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
parasitic ivy and fall, the slopes may fail due to the ground disturbance. The holly needs to be cut and the stumps painted with herbicide to quickly remove this invader before it becomes established and dominates the corridor.			
Moderate Priority			
Creek ReachPSC5 • FOSC has completed an erosion control project and an invasive plant removal/native plant revegetation project here. Continued maintenance will be needed. • Replace bridge at stream level or re-route trail.	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board Other community groups	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented.
Creek Reach CC2 • The Beaconsfield Canyon reach needs to have the rusted culvert removed and a geomorphic /revegetation restoration plan that includes a riparian floodplain area completed. • Downstream drop inlet to storm drain needs to be repaired/ replaced.	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board Other community groups	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented.
Creek Reach SC3 • Replanting of white alder and removal of waste cement and asphalt is needed along this reach. Riparian shade cover over the El Centro pool is also needed to maintain cool water temperatures. • Recreation uses preclude the option	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board Other community groups	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented.

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
of daylighting the creek through Dimond Canyon Park. • Future City of Oakland project to stabilize private property and revegetate stream banks.			
Low Priority			
Creek Reach CC1 • Houses line the upstream portion of this reach, leaving few opportunities for restoration. The sediment/ stormwater detention basin on this reach needs to be cleaned out and retrofitted in order to function better. A large gully in this sub-basin requires repair.	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board Other community groups	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented.
Creek Reach SC1 • This reach presents a real challenge for restoration. There are two major culverts and numerous concrete structures including a cement wall protecting the sanitary sewer pipe. • California bay laurel trees have eroded off the canyon wall and into the creek. Replanting these trees will maintain shade cover for the creek. • Eradicate ivy and other invasives to retain health of native trees. • Work with the City of Oakland to repair erosion from storm drains, especially the major erosion sites along Park Blvd. • Sanitary sewer overflows into Sausal	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board Other community groups	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented.

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
Creek occur during major storms and need to be alleviated to avoid both contamination of the creek and a public health problem.			
Creek Reach SC2 • This reach is a restoration project completed in 2001. Control of invasive plants and revegetation are necessary both along the channel and alongside channels. The channel does not provide adequate room for regeneration of riparian species, and replanting will be required. Installing white alder along the channel could diversify the vegetation and provide some stability to the undercut bank areas, which provide refuge to wildlife in floods.	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board Other community groups	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented.
Creek Reach SC4 • Creek is entrenched with steep banks and fill from the McKillop slide. With this slide affecting the creek it is difficult to implement revegetation. Houses are very close to the channel, further restricting restoration options. Community-based invasive plant removal and native plant installations would provide local educational opportunities.	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board Other community groups	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented.
Creek Reach SC5 Creek is entrenched with steep banks and numerous houses. Channel is hardpan	City of Oakland FOSC	San Francisco Bay Regional Water Quality Control Board	These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats

Table J: Implementation of Recommended Actions in the Sausal Creek Watershed

Recommendations	Lead Entity	Supporting Entities	Comments
clay and revegetation will be difficult in most locations. Community-based invasive plant removal and native plant installations would provide local educational opportunities.		Other community groups	unless Scenario 3 watershed stormwater improvements are implemented.