University of California, Berkeley
Strawberry Creek
Biological Resources- Flora and Fauna
2008 Status Report

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Office of Environment, Health & Safety
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Strawberry Creek Biological Resources- Flora and Fauna - 2006 Status Report, October 2006
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University of California, Berkeley Strawberry Creek Biological Resources: Flora and Fauna

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Biological Resources

University of California, Berkeley Strawberry Creek Biological Resources: Flora and Fauna

1.0 University of California, Berkeley Strawberry Creek Management

Strawberry Creek is a small urban creek draining the western slope of the East Bay Hills in the San Francisco Bay estuary watershed (see maps below). It is a major landscape feature of the University of California, Berkeley, and it was one of the main reasons the site was chosen in 1860 as the location for the campus. The 1163 acre (1.8 sq. mile) watershed draining through draining the campus and upstream headwaters, is approximately 40% urbanized (residential, commercial and institutional), with the remainder consisting of undeveloped, largely natural wildlands.

Urban creeks are increasingly valued for the aesthetic, recreational and wildlife benefits they bring to a city. Strawberry Creek has been the focal point of educational activities for years. More than 3,000 university students, and many elementary and high school students from surrounding communities, use Strawberry Creek each year as an outdoor laboratory for subjects as diverse as environmental studies, biodiversity restoration, landscape design, engineering, and art.

The greater Strawberry Creek ecosystem, consisting of neighboring watersheds, Tilden Regional Park to the east and tidal mudflats and salt marsh at the Berkeley Marina outfall, provides important habitat for plants and wildlife in the largely urban San Francisco metropolitan area. As a source of nutrients and fresh water, Strawberry Creek supports the fisheries of the San Francisco Bay, and continued pollution prevention and restoration in the watershed contribute to the health of the fisheries.

Urban creeks also provide storm water drainage and serve as a flood control system to prevent damage to the urban environment through which they flow. Historically the creek provided sanitary sewer drainage. These uses led to historic erosion, habitat loss and water pollution. By 1987, water quality and ecosystems were highly degraded and the creek was considered a public health risk due to chronic sewage pollution.

In response to campus and community concerns over the deteriorated environmental quality of Strawberry Creek, the campus Office of Environment, Health and Safety (EH&S) sponsored a comprehensive study of the creek. The results of the study completed by Robert Charbonneau were published in December 1987 as the "Strawberry Creek Management Plan" (1987 Strawberry Creek Management Plan). Implementation of the 1987 Strawberry Creek Management Plan significantly improved water quality in Strawberry Creek, as evidenced by the successful reintroduction of locally native fish species to the creek in 1989 – the first resident fish population in the creek in approximately 100 years.

This status report provides a summary current conditions of the biological resources of the Strawberry Creek ecosystem on the University campus. This is one of a series of technical reports being issued by the EH&S to commemorate the twentieth anniversary of the restoration program.

Strawberry Creek Watershed

Strawberry Creek Watershed Facts
Strawberry Creek Watershed total area = 1,977 acres (CH2M Hill, 1994)
Length of Strawberry Creek = ~4.5 – 5 miles
Watershed area under jurisdiction of UC Berkeley = ~ 800 acres
Watershed under jurisdiction of Lawrence Berkeley National Laboratory = 202 acres
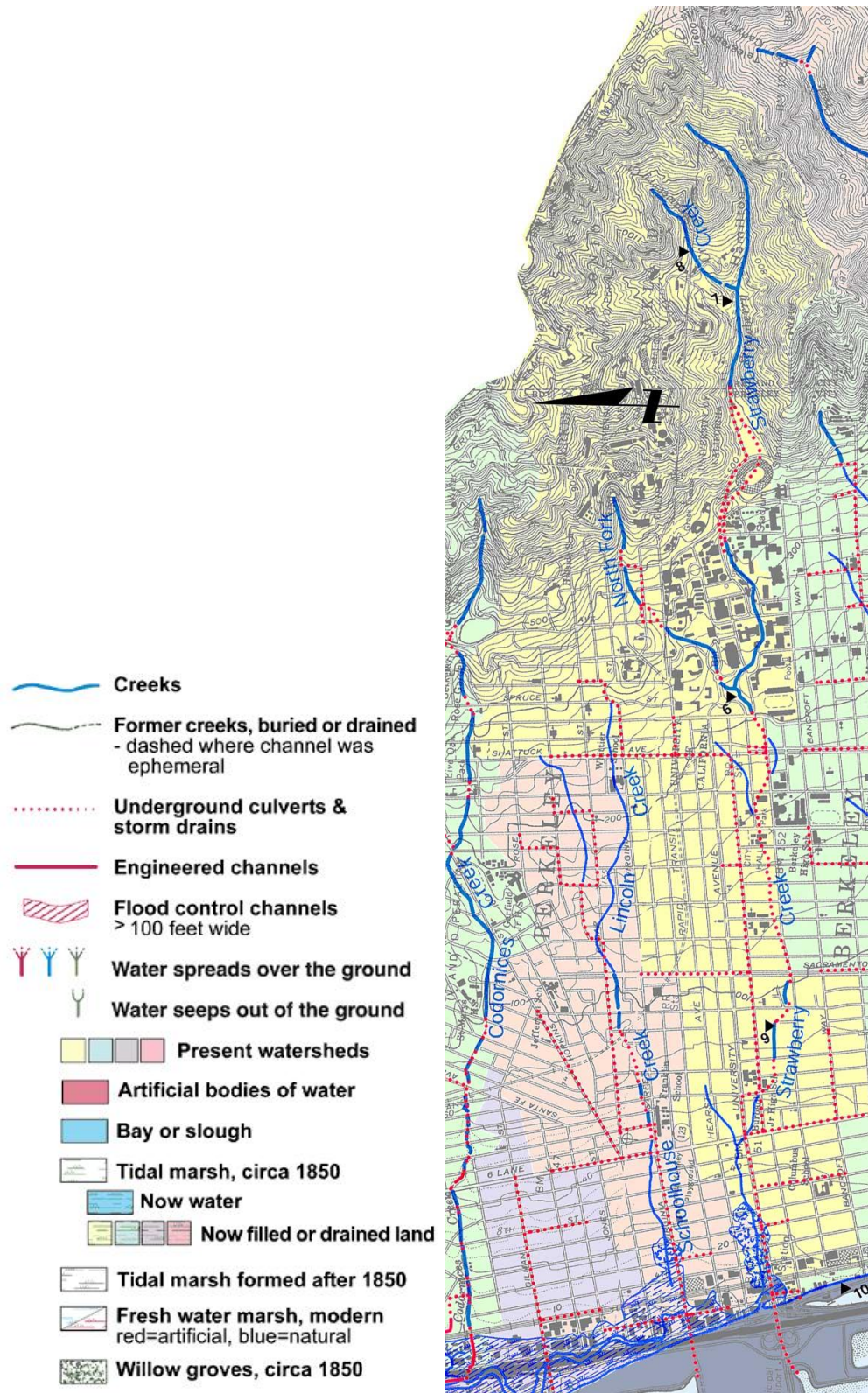Central Campus, Oxford to Gayley (base of Hill Campus) = ~ 165 acres
Change in elevation between headwaters and mouth (SF Bay) = 1,760 feet
Change in elevation from Grizzly Peak (1, 1760 ft) to Oxford St. (200 ft) = 1,560 ft

Strawberry Creek on University of California Campus Park
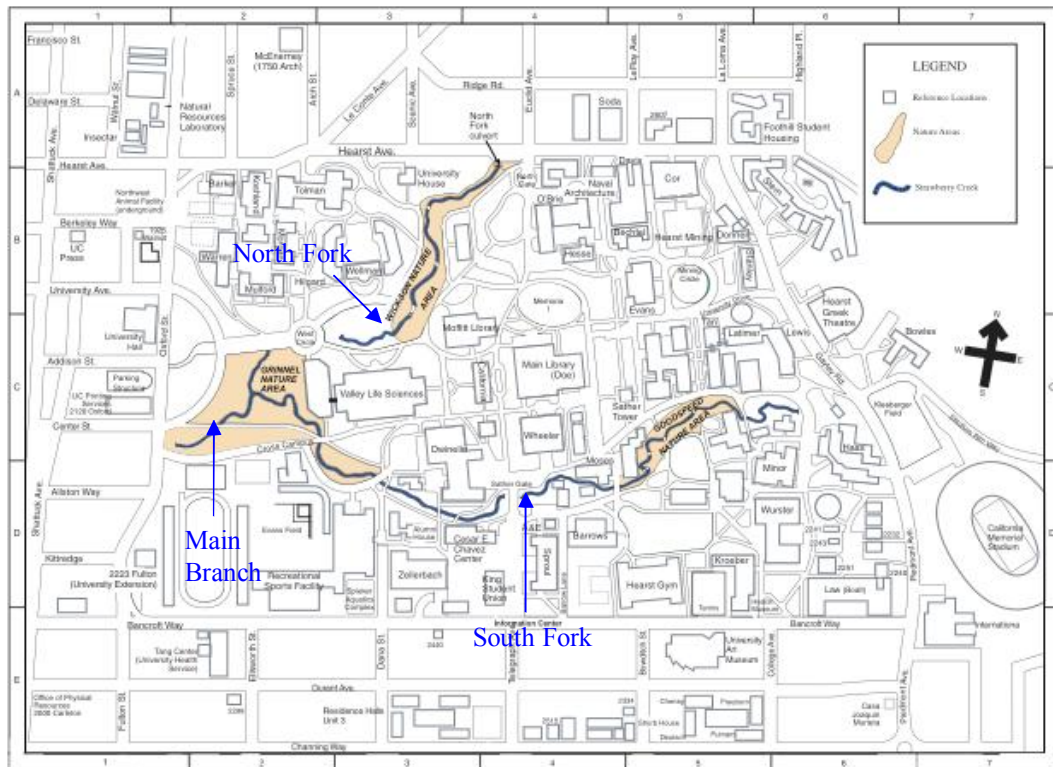
Strawberry Creek and Natural Areas on UC Berkeley Central Campus Park

Legend

Creeks

Former creeks, buried or drained
- dashed where channel was ephemeral

Underground culverts & storm drains

Engineered channels

Flood control channels
> 100 feet wide

Water spreads over the ground

Water seeps out of the ground

Present watersheds

Artificial bodies of water

Bay or slough

Tidal marsh, circa 1850

Now water

Now filled or drained land

Tidal marsh formed after 1850

Fresh water marsh, modern
red=artificial, blue=natural

Willow groves, circa 1850

Strawberry Creek Watershed. *Courtesy of the Oakland Museum, www.museumca.org.*

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1.1 Strawberry Creek Ecosystem Overview

The greater Strawberry Creek ecosystem provides important habitat for plants and wildlife in the largely urban San Francisco metropolitan area. The ecosystem includes the Strawberry Creek watershed, contiguous East Bay regional park property and neighboring watersheds, and tidal mudflats and salt marsh at the outfall. As a source of nutrients and fresh water, Strawberry Creek supports the fisheries of the San Francisco Bay, and continued pollution prevention and restoration in the watershed contribute to the health of the fisheries.

Wildlife corridors between watersheds allow animals to range through a large system of undeveloped parkland in the East Bay. While many large mammals, such as grizzly bears and elk, were exterminated from the area long ago, the Strawberry Canyon wildlands still provide habitat for other large mammals such as deer, fox and mountain lions. Several endangered or threatened plant and animal species, such as the Alameda whipsnake are known to inhabit the greater Strawberry Creek ecosystem. The corridor from the UC Berkeley campus to the Bay is largely culverted and restricts access to most organisms, which to date has prevented invasion by some exotic species, such as the Asian mitten crab.

Historically, Strawberry Creek provided habitat for a seasonal salmon run and many other aquatic organisms. Urban development in the watershed, particularly the diversion of creek water for domestic use, is believed to have exterminated the fisheries by the end of the 19th century. Implementation of the Strawberry Creek Management Plan (SCMP) beginning in 1987 has led to a steady recover of many of the historic biological residents of the ecosystem.

This report describes the findings of restoration activities and ecosystem monitoring completed as part of the implementation of the SCMP and presents current conditions. It does not provide a comparison to numerous historic floristic and faunal studies performed over the many years of the history of the institution or information on the status of the resources in the campus hill area above Gayley Road.

1.2   Biological Indicators of Water Quality

Biota such as fish and macroinvertebrates can be affected by infrequent contamination that may not be captured during discrete water sampling. Therefore the species distribution can be used as an indicator of longer-term water quality or habitat conditions (Haslam, 1990). EPA (US EPA Consolidated Assessment and Listing Methodology 2002, section 5.2.4.) recommends the use of one or more of four principal indicator assemblages, benthic macroinvertebrates, fish, algae, and aquatic macrophytes as biological indicators of water quality (research is underway on birds and amphibians as candidate assemblages).

Water-reliant organisms, especially benthic macroinvertebrates, are often used to determine water quality in a creek due to their predictable patterns of reaction to certain pollutants and water quality conditions. When certain families of organisms known for pollutant sensitivity begin to disappear from a creek, it is virtually certain that some type of pollution in occurring. Water quality tests based upon these organisms, including "EPT percentage" and "Family Biotic Index", have been used to routinely test water quality in Strawberry Creek. Additionally, organisms' responses to spills have been used to determine how harmful certain types of water pollution are and have helped to shape disaster and spill avoidance in the future. Large quantity spills of such seemingly benign substances as drinking water can decimate fish and invertebrate populations in a matter of hours.

Prior to implementation of the SCMP, Strawberry Creek on central campus had been degraded to the point that macroinvertebrate studies showed a low family richness consisting of pollutant tolerant organisms compared to relatively undisturbed canyon portions of the creek. No fish were present, except the occasional mosquito fish or gold fish dumped into the creek (Charbonneau and Resh, 1992).

The SCMP included baseline surveys of macroinvertebrates, periphyton as well as two bioassays to assess toxicological effects of uptake and assimilation of pollutants. Results of bioassays after the initial phases of SCMP implementation indicated that water quality had improved enough to attempt fish restocking, which subsequently was completed (Charbonneau and Resh, 1992).

1.3   Benthic Macroinvertebrates

Biological assessments use aquatic insects, and other macroinvertebrates that serve as biological indicators, in order to monitor both habitat and water quality. These aquatic insects are attractive as indicators because they represent a diverse group of long-lived, sedentary species that react strongly and often predictably to human influences on aquatic systems (Cairns and Pratt, 1993). Because these relationships have been thoroughly catalogued, and the sampling protocol is relatively simple, the incorporation of macroinvertebrate analysis in stream monitoring has proven to be particularly useful.

Regular benthic macroinvertebrate surveys began in 1986 prior to the implementation of the SCMP. Surveys based on EPA standard methods have continued to be performed approximately every other year in the Environmental Sciences Policy and Management class 115B, Aquatic Entomology.

Three sets of metrics are used as a means of numerically discussing creek quality. These metrics are Family Richness; percentage of Ephemeroptera, Plecoptera, and Trichoptera organisms; and Family Biotic Index.

This section provides data from the biological assessments completed on these macroinvertebrates on Strawberry Creek since 1987.

Family Biotic Index

Strawberry Creek water quality has been assessed from campus macroinvertebrate surveys using Hilsenhoff's (1988) family-level biotic index (FBI). FBI values are calculated with the following equation:

$$FBI = \Sigma \, n_f \, t_f \, / \, N$$

> where:
> n_f = the individuals of a family in the sample
> t_f = the tolerance value of organic pollution of a family
> N = the total number of individuals in the sample

FBI is one of the most comprehensive and reliable metrics used for determining water quality (Rosenberg & Resh, 1992). Because of this, it is also widely used, and helpful for comparative purposes. Hilsenhoff (1988) placed FBI values into a graded scale in order to numerically rate water quality (as shown in the table below- Hillsenhoff's Family Biotic Index Explanation). On this scale, higher FBI values indicate more degraded water quality.

Hillsenhoff's Family Biotic Index Explanation

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial organic pollution likely
5.76-6.50	Fairly poor	Substantial organic pollution likely
6.51-7.25	Poor	Very substantial organic pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Family Richness

Family richness is calculated by simply counting the number of families that are present in a given sample. Lower richness indicates that a stream may be under stress. Higher richness indicates that the habitat can sustain a more diversified array of invertebrates. However, this metric is not as reliable as the Family Biotic Index (FBI). Difficulty in identification can result in under-estimation. Richness measure counts at the level of the order or family may ignore the range of pollution tolerance across the family, genus, or even species level (Bartenhagen, et al, NCSU, 1995).

EPT Percentage

Aquatic insects from the orders Ephemeroptera, Plecoptera and Trichoptera (EPT)- commonly referred to as mayflies, stoneflies, and caddis flies- are among the most pollution sensitive and disturbance intolerant organisms that can be found in biological stream communities. Because of their vulnerable nature, EPT organisms predominantly occur in non-stressed environments. This metric provides a comparison of environmental stressors between sampling and reference sites. However, much like the family richness metric, identifications done at the level of the order or family may ignore the range of pollution tolerance across the family, genus, or even species level. Another problem with the %EPT metric is that species level keys are only available for 1/2 of the known taxa. Because of these possible shortcomings, %EPT is often used as a supplementary measure, not a primary metric (the way that FBI is).

%EPT is calculated with the following equation:

%EPT= (Total number of EPT organisms)/(Total number of organisms in sample)

Summary of Data Since 1987

The following tables are compilations of FBI metrics that provide an at-a-glance summary of the water quality in Strawberry Creek since 1987. FBI is the primary metric used in this data analysis and explanation. Supplementary metrics (%EPT and Number of families) that might be helpful for data analysis are included at the end of this section.

The following Family Biotic Index tables are organized by test site (either Canyon site, South Fork, or North Fork), and provide a broad view of habitat and water quality change over time. Table 1 summarizes data from Strawberry Canyon, located in the upper reaches of the South Fork; Table 2 summarizes data from the South Fork, on central campus; and Table 3 summarizes data from the North Fork, on central campus. Charts with corresponding numbers provide graphic representations of these tables.
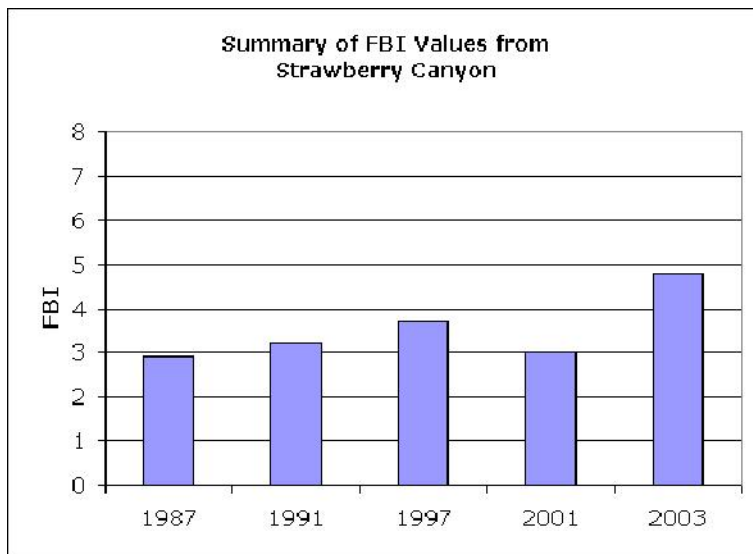

Figure 1. Graphic Summary of Family Biotic Index values from Strawberry Canyon between 1987 and 2003

Table 1: FBI values from Strawberry Canyon, 1987-2003

FBI **Canyon Site** on the South Fork		
Year	*FBI*	*Water Quality*
1987	2.9	Excellent
1991	3.2	Excellent
1997	3.7	Excellent
2001	3	Excellent
2003	4.8	Good

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Figure 2: Graphic Summary of Family Biotic Index values from the South Fork of Strawberry Creek on Central Campus between 1987 and 2003.

Table 2: FBI Values from South Fork, Central Campus, 1987-2003

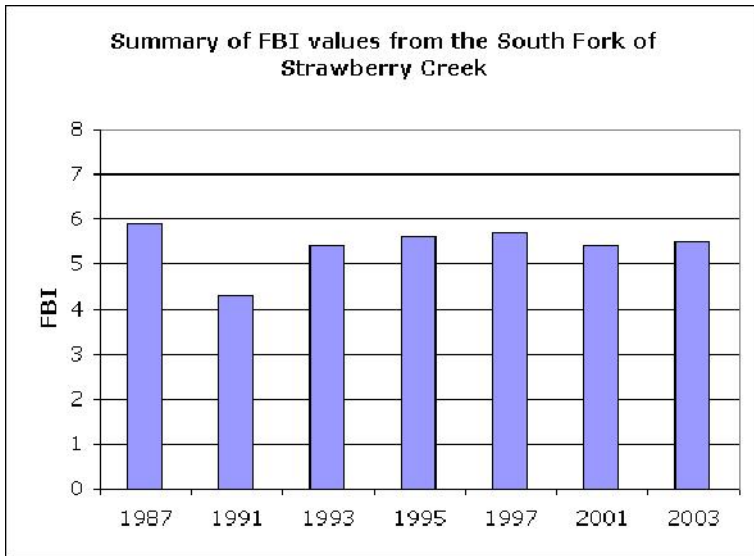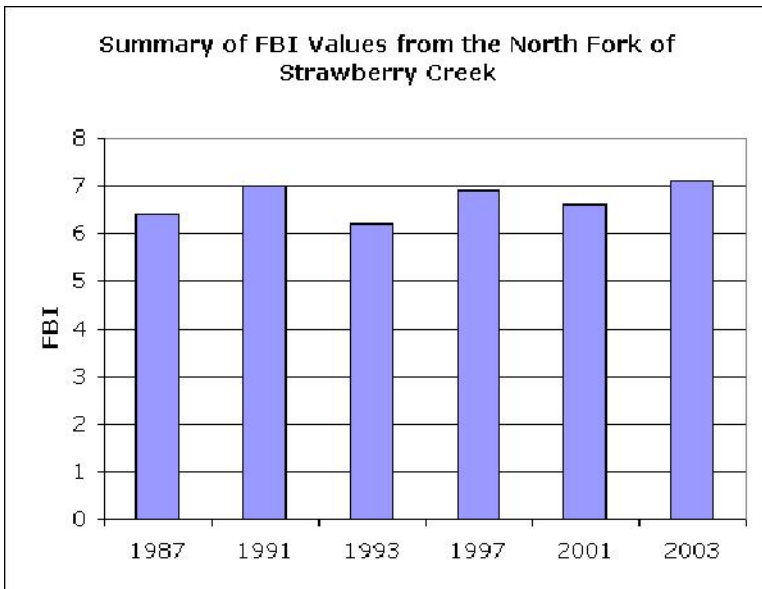| FBI **South Fork** Strawberry Creek, Central Campus		
Year	*FBI*	*Water Quality*
1987	5.9	Fairly Poor
1991	4.3	Good
1993	5.4	Fair
1995	5.6	Fair
1997	5.7	Fair
2001	5.4	Fair
2003	5.5	Fair

Figure 3: Graphic Summary of Family Biotic Index values from the North Fork of Strawberry Creek on Central Campus between 1987 and 2003.

Table 3. FBI values from North Fork, Strawberry Creek, 1987-2003

FBI **North Fork** Strawberry Creek, Central Campus		
Year	*FBI*	*Water Quality*
1987	6.5	Fairly Poor
1991	7	Poor
1993	6.2	Fairly Poor
1997	6.9	Poor
2001	6.6	Poor
2003	7.1	Poor

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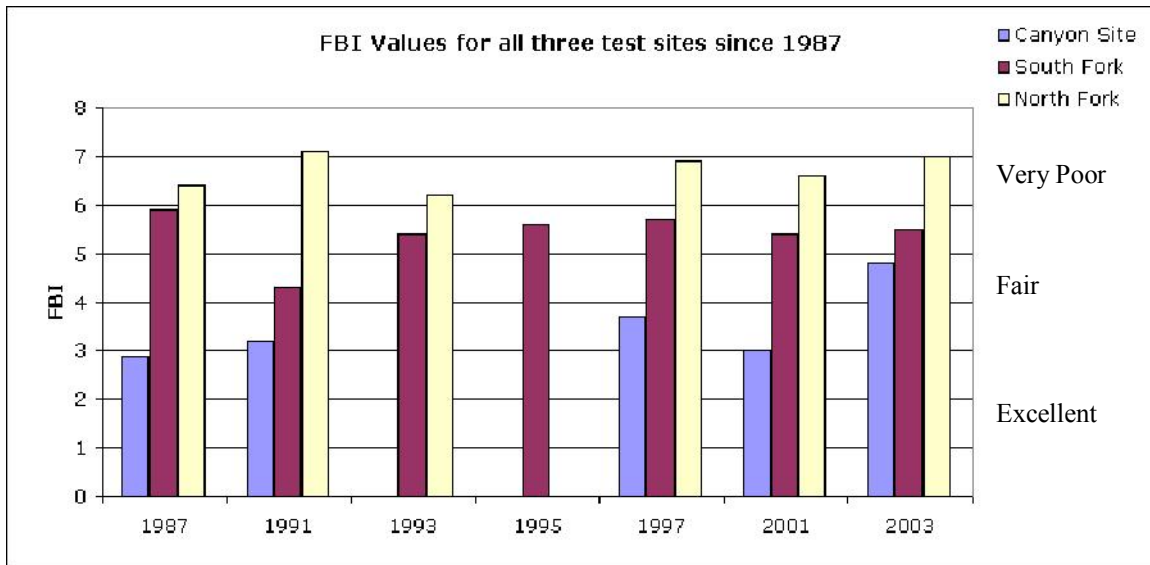
Figure 4: Graphic Summary of Family Biotic Index values from the Canyon Site, the South Fork, and the North Fork of Strawberry Creek.

The results of the periodic Family Biotic Index surveys indicate that Strawberry Canyon has consistently exhibited the best water quality. Between 1987 and 2001, the Canyon site consistently exhibited the most favorable Hillsenhoff rating ("excellent"). This relatively protected site is not subject to the same urban stresses that many of the downstream reaches continually experience. However, in 2003 the water quality at the Canyon site was found to have deteriorated from "excellent" to merely "good." This is not a devastating shift; however, it is notable change from historically better findings. This change may have been caused by siltation due to construction runoff in the upper canyon area or from increased runoff into the Winter Creek tributary. Siltation and mineral loading can negatively affect biological communities and water quality (Charbonneau, 2000).

The South Fork, although consistently of lower habitat and water quality than the Canyon site, has been less degraded than the North Fork through out its recorded history. Results from the South Fork demonstrate the effectiveness of improvements from relatively easy operational changes made during the beginning of the restoration program. In 1987, prior to restoration the South Fork was rated as "fairly poor." At this time the South Fork received a significant amount of pollution from various sources: latrines at Memorial Stadium, campus buildings (cooling water, laboratory and machine room drainage) and construction sites. However, records from monitoring indicate that after the implementation of the SCMP in 1987, the South Fork had improved water quality and significantly better habitat conditions than the North Fork. The year 1991 marks the first visible results of the restoration efforts made possible by the implementation of the SCMP. The improvement in water quality on the South Fork (from "fairly poor" to "good") can most likely be attributed to the SCMP's simple yet immensely effective strategy to eliminate point sources of pollution.

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Unfortunately, the North Fork of the creek did not experience the same boost in water quality. Because of its steep downhill slope and its proximity to Hearst Avenue, the North side of the UC Berkeley campus is highly prone to non-point source urban runoff. Urban development has created a higher percentage of impermeable area in the North Fork watershed than the South Fork. During the wet season, flash torrents of water drain from the street and surrounding area. This urban pollutant laden runoff can cause "shock loading" upon entering Strawberry Creek (Charbonneau & Resh, 1992). Because of this combination of unfavorable conditions, it has proven to be more difficult to restore the habitat in the North Fork of the creek than the South Fork. The North Fork is also prone to more spill events, such as sewer overflows and water main and fire hydrant breaks, due to the greater urban development along this branch, and because a large portion of the north east quadrant of campus drains to the creek via the cross-campus culvert. These spills can have a devastating affect on aquatic life and full recovery can take years.

The North Fork is currently recovering from two recent, large spill events. In March 2002, a subcontractor involved in Hearst Memorial Mining Building construction backed a truck into a fire hydrant. Water from the high-pressure water main spilled into the underground steam-heating system, was heated to 125°F, then flowed into the creek's north fork (UC Berkeley News, Berkeleyan, 22 October 2003). The discharge of hot, silted and chlorinated water killed nearly all of the aquatic life on the North Fork downstream of the Mining Circle Creek culvert (also known as the Cross Campus Culvert or CCC). By 2003 the creek had begun its recovery, but was further impacted from a water main break from off campus that flowed into the creek overnight for fourteen hours, decimating fish populations and probably further impacting invertebrates due to chloramine exposure. The results from monitoring performed in fall 2003 indicate that its habitat and water quality were more degraded than they had ever been since 1987.

The less-than-pristine conditions found through invertebrate sampling on the South Fork and North Fork on the central campus are indicative of some type of chronic pollution. Further monitoring is needed to determine causation and to better understand the impacts of these stressors.

The following figures are graphic representations of fluctuations in metrics other than the Family Biotic Index. They contain information regarding changes in all three reaches of the creek (Canyon Site, South Fork, and North Fork) over time. Figure 5 describes the fluctuation of %EPT organisms at each reach over time. Figure 6 describes changes in the number of taxonomic families present on each reach over time. Information is not available for either metric for the year 1995.
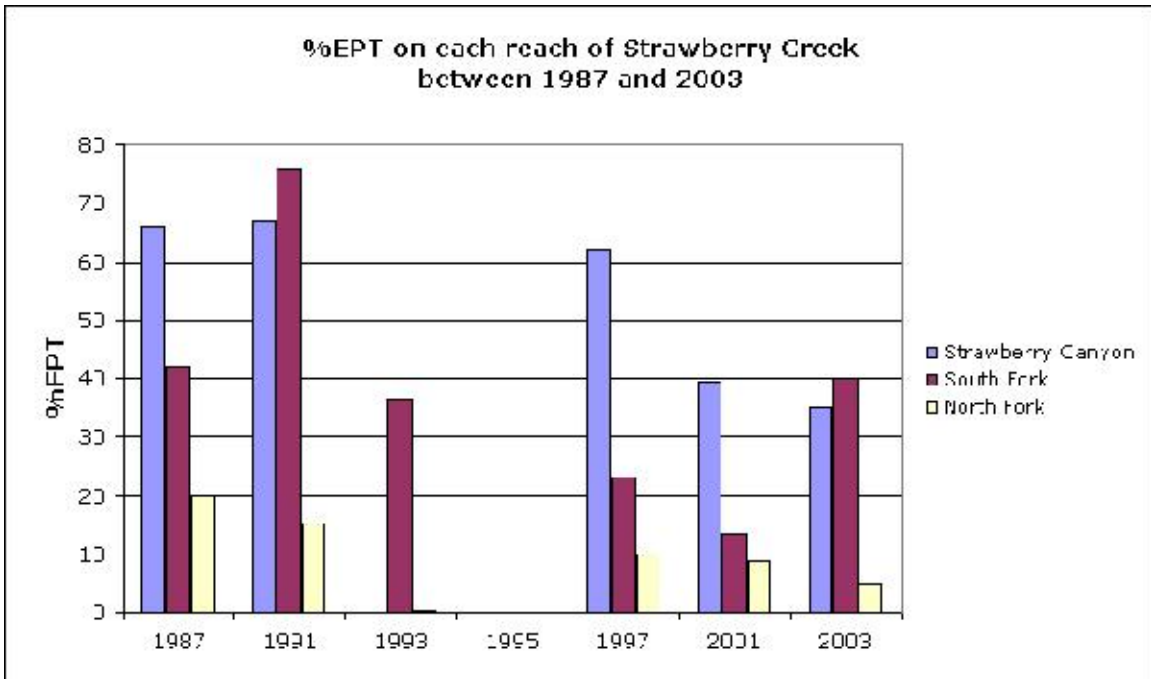
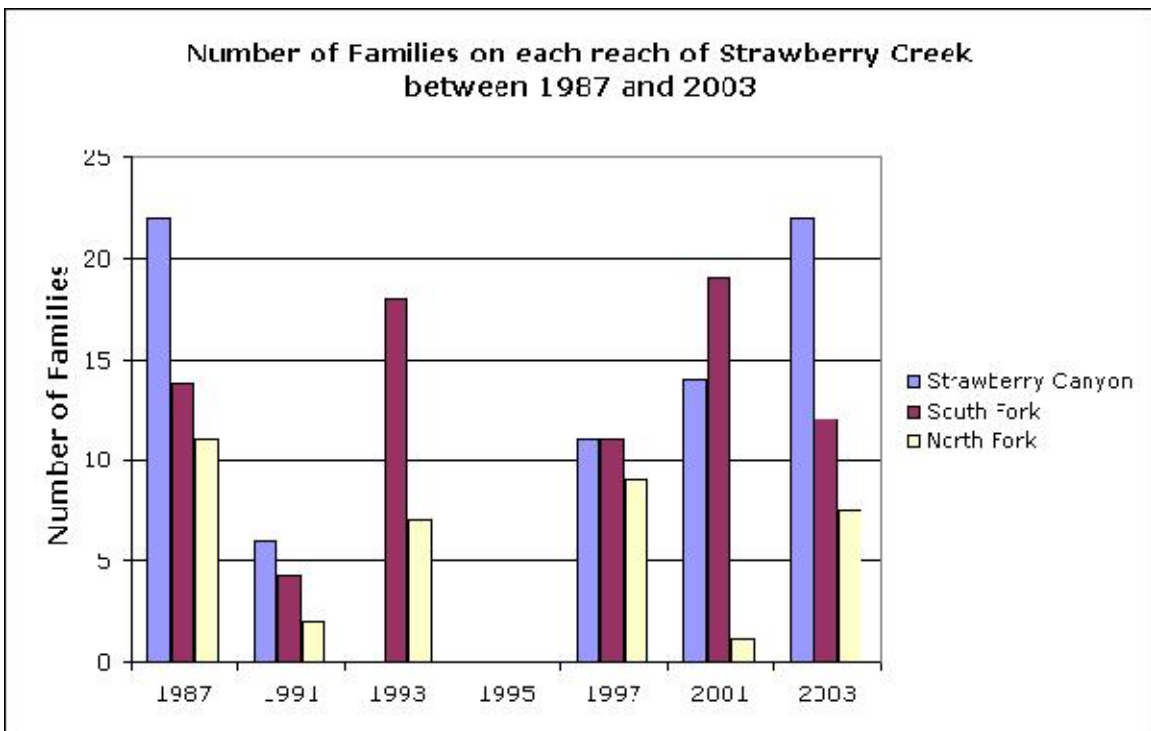*Figure 5: %EPT on each reach of Strawberry Creek between 1987 and 2003.*

Figure 6: Number of Families on each reach of Strawberry Creek over time.

The metrics %EPT and Number of Families are both relative measures. They are useful in determining which reach is healthiest, relative to the other reaches. However, at this time, there is no scale which dictates a stream's degrees of health based on established standards.

The purpose of providing this data is to acknowledge that no single metric can effectively describe all of the chemical/physical conditions at a given sampling location. The reader is encouraged to consider the data in combination with the above Family Biotic Index historical explanation.

1.4 Fish

Historically, Strawberry Creek supported around 13 species of fish, including coldwater salmonids, anadromous steelhead and coho salmon (Gold 1998, Moyle 1992). The current altered hydrologic regime and physical disturbances, such as culverts and check dams, restrict restoration of a diversity of assemblages by preventing creation of habitat present, such as deeply scoured pools in meanders, and by restricting movement of fishes up and down stream. These conditions may be optimal for fishes with a wide range of temperature tolerances, such as Sacramento suckers, which can be found in streams with water temperatures ranging from 15- 30C (Moyle 2002), but may ultimately prevent establishment of a permanent cold freshwater habitat. The SCMP reported that no fisheries existed in Strawberry Creek in 1987. With the successful improvements in water quality, fish reintroductions were begun in 1989.

Strawberry Creek has supported breeding populations of fishes since the initial transfer in May 1989. Maintenance of the fisheries has required some hands-on management, including additional transfers. Populations in the portions of the creek have diminished at times for uncertain reasons that include pollutant impacts, wash down during storms, and competition. The South Fork of the creek, the healthier fork, has always supported fishes. The North Fork, the fork with poorer habitat quality (as measured by benthic macroinvertebrate studies) and more urban runoff impacts, has not been able to support populations as readily, due to spill impacts and for other yet to be determined reasons. The Main Branch (below the confluence in the Eucalyptus Grove) has supported fish throughout the 1990s, despite numerous pollutant releases. Following is a summary of fish transfers and observations.

At the initiation of the fish reintroduction process, four preferred collecting sites were identified by the campus Ichthyology Lab- Wildcat Creek, Los Trampas Creek, San Ramon Creek near Alamo and Walnut Creek near Willow Way. In July 2000, prickly sculpin were collected from San Pablo Creek in Orinda. There have been six documented transfers of fish from these off-site locations (see Table 7 below).

Table 4: Fish Transfers

Transfer Date	Collection Location	Fish Collected (number)	Deposit site
May 5, 1989	Wildcat Creek	Sticklebacks (96)	SF- Big Inch outfall, Stephens, Dining Commons & Alumni House. NF- University House
June 29, 1989	Walnut Creek	Suckers, Roach and Hitch Minnows (100)	SF- Little Inch (WFC) NF- three pools above Wickson Bridge
July 15, 1989	Walnut Creek	Roach and Hitch Minnows (25)	SF Big Inch outfall
September 8, 1990	San Ramon Creek	Roach (196), Hitch (3) and	NF upstream of Wickson Bridge (47 Roach), Botanical Garden (30 Roach), SF downstream of Big Inch culvert
July 1, 1991	Los Trampas Creek San Ramon Creek	Sticklebacks (56) Minnows (112), sticklebacks (19) and suckers (21)	SF Big Inch to Stephens
July 6, 2000	San Pablo Creek Los Trampas	Prickly sculpin (172) Minnows (159), suckers (84), sticklebacks (120)	SF- 8 pools Stephens to LSA (56 suckers, 116 sticklebacks, 172 sculpin, 127 minnows) NF- above Wickson Bridge 28 suckers, 32 minnows
Summer 2001	Main Fork and South Fork	Suckers, minnows, sticklebacks	NF- pools between Wickson Bridge and University House SF- Botanical Garden

Observations of fish populations are dispersed through EH&S records and student reports. In general, records of observations suffer from a high degree of uncertainty due to high variability in observation methods and observer skills. Observing fishes on the creek can be difficult due to lighting, water quality conditions and fish behavior, which changes during the day and during life stages and often in response to the observer. It is easy for even skilled observers to miss a reclusive, small population if observing conditions are poor and not enough time is spent on observations. In addition, populations have changed from year to year due to pollutant impact, human intervention (such as redistribution of fry from the lower to upper stretches of the creek), unknown population dynamics, and other factors.

Due to these factors, and because a standard, reproducible protocol has not been used to assess the relative abundance of species in the assemblage, historical trend data is not available. Therefore only the most recent observations are presented here.

The five species of fish that have been transferred to Strawberry Creek are: three-spined stickleback (*Gasterosteus aculeatus*), California roach (*Lavinias symmetricus*), California Hitch (*Lavinia exilicauda*), Sacramento sucker (*Catostomus occidentalis*), and the prickly sculpin (*Cottus asper*).

On February 27, 2002, EH&S staff and Tom Dudley (Research Associate in the Integrative Biology department) performed a fish census in the Main Branch and North Fork of Strawberry Creek using an electrofishing apparatus. Many suckers, sticklebacks and minnows were found in the Main Branch (from below the confluence in the Eucalyptus Grove to the debris barrier). On the North Fork, 7 suckers were found from the stretch above the West Circle to Haviland Hall (see Table 5).

Table 5: North Fork Fish Census February 27, 2002

Reach	Minnow	Sucker	Crayfish
West Circle Culvert to Mid-VLSB	0	1 (18cm)	500
Mid-VLSB to Wickson Bridge	3 (4 cm)	3 (8-10 cm)	50
Wickson Bridge to Cross-Campus Culvert	1 (3-4 cm)	2 (3-4 cm)	0
Cross-Campus Culvert to University House	1 (3-4 cm)	2 (3-4cm)	5

The North Fork fish populations below the Cross Campus Culvert were practically exterminated in March 2002 as a result of the fire hydrant accident at the Hearst Memorial Mining Building construction site. In spring 2003, sticklebacks and suckers were observed in the North Fork pool by Haviland Hall, indicating survival since the July 2000 introductions. These populations were decimated by the off-campus water main break in September 2003 that ran for 14 hours and discharged an estimated 50,000 gallons of domestic water. Mortality was likely due to chloramines exposure. Some sticklebacks survived and stickleback populations recovered up to Haviland Hall with successful breeding in 2004.

As of September 2005, mixed populations of minnows, suckers and sticklebacks were observed on the Main Branch. Minnows and stickleback were observed in the North Fork below the West Circle, and sticklebacks above the West Circle to Haviland Hall. Fish were observed in the South Fork to the Octagon Bridge, but no further upstream. Two suckers were seen in a pool near the Dining Commons in Spring 2005, but no other fish have been observed in the upper stretches of the South Fork for unknown reasons.

Larval fish usually first appear in the creek between late April and early June, and continue to appear into August. Spawning frequency and period in the creek are unknown. Rigorous observations have not been performed and reports of first sightings of larvae have varied by weeks. Some first reports of larvae observations are:

- May 14, 1990
- May 15, 1992
- June 7, 1994
- May 8, 1996
- April 26, 1998
- May 20, 1999
- Early May 2001
- May 30 2000
- May 17 2002
- May 27 2003
- April 12, 2004 (a very warm spring)
- May 6, 2005

As an indicator of water quality, fish populations that have continued to reproduce successfully since 1989 demonstrate an improvement in water quality, primarily from reduction in chemical pollution. However, while chemical pollution has been reduced, biological pollution (exotic species) and pollution in the form of hydrologic modification and physical alterations leading to habitat destruction prevent further restoration of the creek towards pre-disturbance conditions.

Many of the historically native fish would not likely survive under existing conditions. However, water quality has improved dramatically since 1987 and some of the hardier species more tolerant of a wide range of physical conditions have become established in the creek. Student studies of Strawberry Creek (Gold, 1998; Neilsen, 1988) have concluded that the creek is capable of supporting a more diverse fishery (more species) with a larger number of individuals, provided that corrections to the deteriorated habitat are made. While limiting factors for growth and maintenance of fisheries are not currently understood, a number of poor conditions have been identified and recommended improvements have been proposed that would lead to better habitat quality for fishes, thereby enhancing the aesthetic and educational value of the creek. These include: lack of woody vegetation and other refuge in the creek bed, presence of exotic species, urban runoff, hardscape in the creek bed, fine silt and migration barriers, including downstream culverts in the City of Berkeley.

1.5   Periphyton

Benthic algae (periphyton) is commonly defined as a community of microorganisms that are attached to or live upon submerged surfaces. The Environmental Protection Agency (US EPA, 2002) notes that alga are primary producers and responsive indicators of environmental change. The assemblage serves as a good biological indicator in streams and shallow areas because of it naturally high number of species and rapid response to exposure and recovery. The EPA *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition* (Barbour, 1999) states the following regarding Perhiphyton

> "Benthic algae (periphyton or phytobenthos) are primary producers and an important foundation of many stream food webs. These organisms also stabilize substrata and serve as habitat for many other organisms. Because benthic algal assemblages are attached to substrate, their characteristics are affected by physical, chemical, and biological disturbances that occur in the stream reach during the time in which the assemblage developed.
>
> Diatoms in particular are useful ecological indicators because they are found in abundance in most lotic ecosystems. Diatoms and many other algae can be identified to species by experienced algologists. The great numbers of species provide multiple, sensitive indicators of environmental change and the specific conditions of their habitat. Diatom species are differentially adapted to a wide range of ecological conditions.
>
> Periphyton indices of biotic integrity have been developed and tested in several regions. Since the ecological tolerances for many species are known, changes in community composition can be used to diagnose the environmental stressors affecting ecological health, as well as to assess biotic integrity.
>
> Periphyton protocols may be used by themselves, but they are most effective when used with one or more of the other assemblages and protocols. They should be used with habitat and benthic macroinvertebrate assessments particularly because of the close relation between periphyton and these elements of stream ecosystems."

In general, there is little available data on the Strawberry Creek periphyton assemblage. The SCMP considered algal growth only in the periphyton assessment and little or no follow-up assessment has occurred.

In June 1987, Charbonneau completed a survey of watershed channels for algal growth (Charbonneau, 1987, Page 69) with samples identified by the University Herbarium. The survey found no algal growth in the ephemeral upper canyon reaches. All algae identified in the dozen locations sampled were green algae (*Chorella* sp.). The most abundant found in the watershed was Cladophora glomerata, observed at nine of twelve locations. Following is a summary of the 1987 findings and conclusions:

- *Cladophora glomerata*: Found at nine of twelve locations. Indicative of "clean water" but also symptomatic of eutrophication (nutrient enrichment).

- *Vaucheria sp.*: A "clean" water alga was found in the South Fork Botanical Garden stream channel.

- *Chlorella sp.*: An alga commonly found in organically rich areas and widespread in sewage ponds, was found at North Gate on the North Fork.

- *Spirogyra sp.*: A slime-producing alga, also observed in sewage ponds, was found in a branch of the South Fork just north of the Botanical Garden.

7.5   Aquatic Macrophytes

The US EPA (EPA, 2002) identifies aquatic macrophytes as one of the four principal assemblages used for assessing water quality standards attainment and impairment decisions and state the following regarding aquatic macrophytes:

"Aquatic macrophytes include vascular plants (grasses and forbs) and may be emergent or submergent. Vascular aquatic macrophytes are a vital resource because of their value as extensive primary producers and habitat for fish and waterfowl. As an ecological indicator, this assemblage is most important in estuaries and wetlands. Excessive nutrient loadings lead to prolific phytoplankton and epiphytic macroalgal growth on grasses that outcompete the macrophytes.

Macrophytes are identified to species level or categorized as emergent, submergent, or floating leaf for purposes of this assessment. This taxonomy serves as a basis for areal coverage or standing crop biomass analyses."

A baseline survey of the aquatic macrophytes on Strawberry Creek has not been completed.

7.6   Riparian Vegetation

Riparian vegetation on Strawberry Creek on UC Berkeley campus, including the upper watershed Hill Campus, has dramatically changed from pre-development conditions when the east bay hills and plains were largely open oak savanna with riparian corridors. On the central Campus Park vegetation was cleared to make way for roads or buildings and exotic vegetation not native to the site, such as eucalyptus and redwood trees, were planted along the creek. In the Hill Campus, suppression of natural fires and introduction of non-native eucalyptus and Monterey pine have created a dense canopy that did not exist in the mid 1800s. Numerous invasive forbs and shrubs, such as scotch broom and cape ivy, dominate large sections of tributary riparian corridors. The Campus Park sections of the creek are dominated by invasive species such as English ivy, crowding out native species and creating favorable conditions for non-native animals such as Norway rats. The University recognizes the need for native revegetation on Strawberry Creek and has taken measures to return native species to the creekside environment where possible.

The 1987 Strawberry Creek Management Plan presented numerous recommendations for riparian habitat restoration (Charbonneau, 1987, Section 5.1.5, page 95) along with a list of Bay Area Native Riparian Vegetation (Charbonneau, 1987, Appendix C, page 155). Riparian restoration has not occurred except in a few limited locations:

- Stephens Hall Crib Wall- in 1988 the left bank retaining wall up stream of the automotive bridge at Stephens Hall was replaced by a redwood crib wall. The crib wall was interplanted with numerous native plants.

- In 1989, the Strawberry Creek section of the UC Botanical Gardens was planted with native creek vegetation as part of an interpretive section of the Gardens.

- Stephens Hall stretch- Now retired Groundskeeper John Sutake planted numerous native plants in the emergent and bank zones. A list of these appears in Table 7.6.

Table 6: Stephens Hall stretch vegetation- volunteer plants and John Sutake transplants

Emergent Zone
Curly dock
Alisima saggitaria- water plantain
Indian rhubarb (not native to Alameda County but does well in submerged areas- these individuals are from the McLoud River)
Potentilla ansurina- native to the County
Yellow nutgrass sedge
Coltsfoot
Osmaronia cerusiformis
Smilacina stellata False solomons seal
Bank Zone
Rosa California
Sympohicarpos- snowberry
Cornus sericoa- red oser dogwood
Aritolocchia ca.- easily transplanted by moving rooted pieces
Stinging nettle
California bee plant
Mugwort
Rhamnus ca.- Coffeeberry
Stychys sp.- mint
Poke salad weed
Poystichium
Oregon oxalis- a good substitute for ivy
Physocarpus capitatus San Bruno- ninebark, good for coastal prairie
Button willow
Dicentra Formosa- good ground cover

| Thimbleberry |
| Aralia ca.- elk clover |
| Fraxinus oreg. |

In addition to these projects, promotion of native flora is occurring as part of the active management of fire fuel in Hill Campus projects where large stands of eucalyptus trees are currently being removed.

2003 Vegetation Inventory
A survey of riparian corridor vegetation on the Campus Park sections of Strawberry Creek was completed in September 2003 by staff from the campus groundskeeping and planning departments. The inventory was limited to the open channels of the creek on the central Campus Park, on the North Fork, South Fork and Main Branch. The inventory includes most of the existing native and non-native species in the riparian corridor and is available on the Strawberry Creek website at:

http://strawberrycreek.berkeley.edu/naturalhistory/biology.html.

Grinnell Natural Area Native Biodiversity Restoration Project
The Grinnell Natural Area Native Biodiversity Restoration Project is a multiyear project of weed removal and native plant re-vegetation along the banks of Strawberry Creek in the Grinnell Natural Area at the West Entrance of the University of California, Berkeley campus in Berkeley, California. The project consists of removal of invasive species of such as Periwinkle (*Vinca minor*) and English Ivy (*Hedera helix*) which are recognized by the California Invasive Plant Council as species of significant concern to California wildlands. These areas of low biodiversity are then be re-planted with locally native plants that will provide improved habitat for other flora and fauna and which will contribute to improved aesthetic conditions, water quality and educational opportunities.
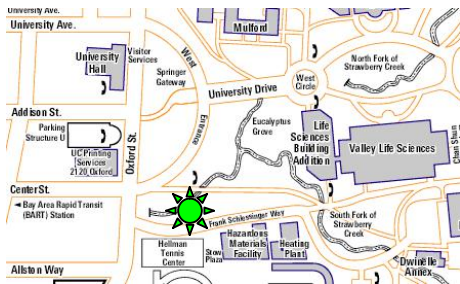
The project formulated in 2004 as a demonstration project to convert a poorly use area overgrown with weeds in the vicinity of an grove of California live oak trees that are a remnant of the historic campus ecosystem that existed prior to urbanization of Berkeley. Two phases of planting were completed in the winters of 2005-06 and 2006- 07.

A goal of the project is to include students from the university and from local elementary, middle and high schools as part of their studies. To date the project has included participation of over five hundred students from UC Berkeley, Berkeley High School and elementary schools.

The project serves as a showcase of ecological restoration in a highly visible area with a great amount of foot-traffic. Locally available natural areas are often overlooked in urban areas as areas perceived to have aesthetic or ecological value. The attractive groundcover

provided by native vegetation will serve as a "Green Gateway' through the west entrance of the campus at Oxford and Center streets.

Project Metrics

Funding: $3,500 Chancellor's Green Campus Fund grant (two cycles), $1,450 Alameda Countywide Clean Water Program Community Stewardship Grant.

Area planted = ~ 3, 600 square feet

Number of plants planted = ~1,300 Number of plant species re-introduced = ~ 60

In order to prevent genetic contamination of locally native plants, it is a goal of the project to adhere to University Natural Reserve System and California Native Plant Society guidelines to the greatest extent feasible in using only plants collected and grown from local sources.

Planting List, Grinnell Nat. Area, UCB (Updated February 15, 2008)

Grasses, sedges and rushes	Common Name	Total*
Agrostis pallens	Bent grass	7
Bromus carinatus var. carinatus	Brome, California	27
Carex densa		11
Carex obnupta	Slough sedge	3
Carex praegracilis	Deer-bed sedge	13
Carex subbractiata		5
Dathonia californica	California oat grass	74
Elymus glaucus ssp. glaucus	Blue wild rye	27
Elymus trachycaulus (RFS)	Slender wheatgrass	83
Festuca californica	California fescue,	1
Hordeum brachyantherum	California meadow barley	63
Juncus balticus	Baltic wire rush	4
Juncus patens	Spreading rush	10
Juncus UCB Upper Jordan	Unidentified rush	2
Juncus Xiphiodes	Iris leaved rush	7
Koeleria macrantha	June grass	1
Melica californica	California melic grass	60
Nassella lepida	Foothill needle grass	10
Nassella pulchra	Purple needle grass	150
	TOTAL grasses	558

Planting List, Grinnell Nat. Area, UCB (Updated February 15, 2008)

Forbs and shrubs		Total*
Achillea millefolium	Yarrow	49
Actaea rubra	Red baneberry (poisonous)	7
Aristolochia californica	California pipevine	5
Artimesia californica	Sagebrush	21
Artimesia douglansiana	Mugwort	5
Aster chilensis	California aster	29
Baccharis pilularis	Coyote bush	3
Camissonia ovata	Suncup	3

Chlorogalum pomeridianum var. pomeridianum	Soap Plant	39
Clinopodium douglasii (Micromeria chamissonis)	Yerba buena	3
Delphinium californicum	California delphinium	17
Escholtzia californica	California poppy	108
Fragaria vesca	Woodland strawberry	12
Gnaphalium palustre	Western marsh cudweed	2
Grindelia hirsutula var. hirsutula	Hairy gumplant	47
Helenium puberulum	Rosilla, Sneezeweed	34
Hemizonia congesta	Hayfield tarplant	23
Heracleum lanatum	Cow parsnip	8
Heuchera micrantha	Alumroot	18
Holodiscus discolor	Oceanspray	1
Iris douglasiana	Douglas iris	23
Lonicera hispidula	Honeysuckle	28
Lonicera involucrate	Twinberry honeysuckle	29
Lotus scoparius var. scoparius	Deerweed	2
Lupinus sp	Lupine	32
Madia sativa		3
Mimulus aurantiacus	Sticky monkey flower	34
Mimulus guttatus	Yellow monkey flower	2
Physocarpus capitatus	Ninebark	4
Potentilla glandulosa	Sticky cinquefoil	10
Prunella vulgaris	Common selfheal	4
Ranunculus californica	California buttercup	20
Rhamnus californica ssp. californica	Coffeeberry	4
Ribes menziesii	Canyon gooseberry	3
Ribes sanguineum var. glutinosum	Red-flowered currant	5
Rubus parviflorus	Thimbleberry	3
Scrophularia californica ssp. californica	California Figwort, Beeplant	47
Sisyrinchium bellum	Blue-eyed grass	11
Stachys ajugoides var. rigida	Hedge Nettle	3
Symphoricarpos albus	Snowberry, Bush	3
Tarplant unidentified- Cerrito Creek		2
Tellima grandiflora	Fringe cups	62
Veronica americana	American brooklime or speedwell	10
Wyethia angustifolia	Mules ears	24
	Total Forbs	774

* Plant totals are for three seasons of planting- 2005-06, 2006-07 and 2007-08.

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