1994 Strawberry Creek Surface Bed Material Size Study

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Office of Environment, Health and Safety
Strawberry Creek Restoration Program

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Purpose

This study was undertaken to establish a method by which to document the effects of sedimentation on Strawberry Creek. It presents baseline data for the distribution of surface bed material size at points above and below suspected points of sediment discharge along the creek. This information can be used in future sedimentation monitoring efforts to quantify changes in bed material size.

Study Site

Strawberry Creek (37°52'30" N, 122°15',30" W) is a small 4th order stream which flows from Strawberry and Blackberry Canyons, through the University of California campus and the city of Berkeley to enter San Francisco Bay at the Berkeley Marina.

I sampled at 8 gravel bars along this creek: one site in Strawberry Canyon, four sites along the south fork of the creek, two on the north, and one site below the confluence of the two forks (map 1).

The Strawberry Canyon site is located approximately four meters above where the creek crosses the fire trail. This site is also above the Botanical Gardens slump. The next downstream site on the South Fork is located immediately below the "little inch" culvert, east of the Women's Faculty Club. Below this, I sampled also at a gravel bar below the bridge located northwest of the Faculty Glade and east of Stephens Hall. The next transect is located upstream of Sather Gate and below the stairs leading to Sproul Hall. The last site on the South Fork is located in the Eucalyptus Grove, below the footbridge west of the Life Sciences Building Addition. On the North Fork, my first study site is located below the footbridge between Giannini and Haviland Hall, near the Sproul Centennial Redwood. I sampled also north of the Life Science Building, at a gravel bar located just west of the eastern most staircase on the northern facing side of the building. The one site on the main channel is located approximately 27 meters downstream of the confluence. Sketches of the eight sites are presented in Appendix B.

Methods

Field Procedures: To determined the gravel bar material size distributions for these eight populations, I followed the pebble count technique as described in Kondolf and Li, 1992.

From each distinct population I chose at random 100 pebbles. Pebbles were chosen by walking along the gravel bar surface, and with eyes averted touching the surface in front of my boot. For the pebble on which the right edge of my fingernail had landed, I measured the intermediate axis. From this value I recorded the pebble as falling into one of 12 size classes: ≤ 4 mm, 4 - 8, 8 - 11.3, 11.3 - 16, 16 - 22.6, 22.6 - 32, 32 - 45, 45 - 64, 64 - 90, 90 - 128, 128 - 180, and 180 - 255 mm. These size classes vary by a factor of $\sqrt{2}$, and are extensions of the Wentworth Scale. Where pebbles were embedded to greater than half of their width, I denoted this in the field notebook as "E" rather than simply a slash mark.

Data Analysis: For each population I plotted a cumulative size distribution curve of grain size (on a log scale) versus cumulative percent finer. On this scatter plot I drew in the best-fit curve and from this read D16, and D18 (the grain size below which 16 and 84 percent, respectively, of the sample are finer), and D50, median diameter. Using D16 and D84 values I computed the geometric mean diameter: $dg = (D84 * D\ 16)^{0.5}$; and the geometric sorting coefficient: $sg = (D84/D16)^{0.5}$. Where the cumulative percent finer than 4mm was greater than 16%, I reported only the percent finer than 4mm.

Results

Gravel Bars at the Canyon, Stephens Hall, Sather Gate, LSA, Confluence, and LSB sites all had greater than 16% cumulative percent finer than 4mm (Table 1). Mean diameter size was greatest at the Giannini gravel bar, followed then by Sather Gate, the Little Inch, and Confluence sites. The populations at Strawberry Canyon, Stephens Hall, and LSB all followed with a D50 of 8 mm. LSA site population was smallest with 6 mm.

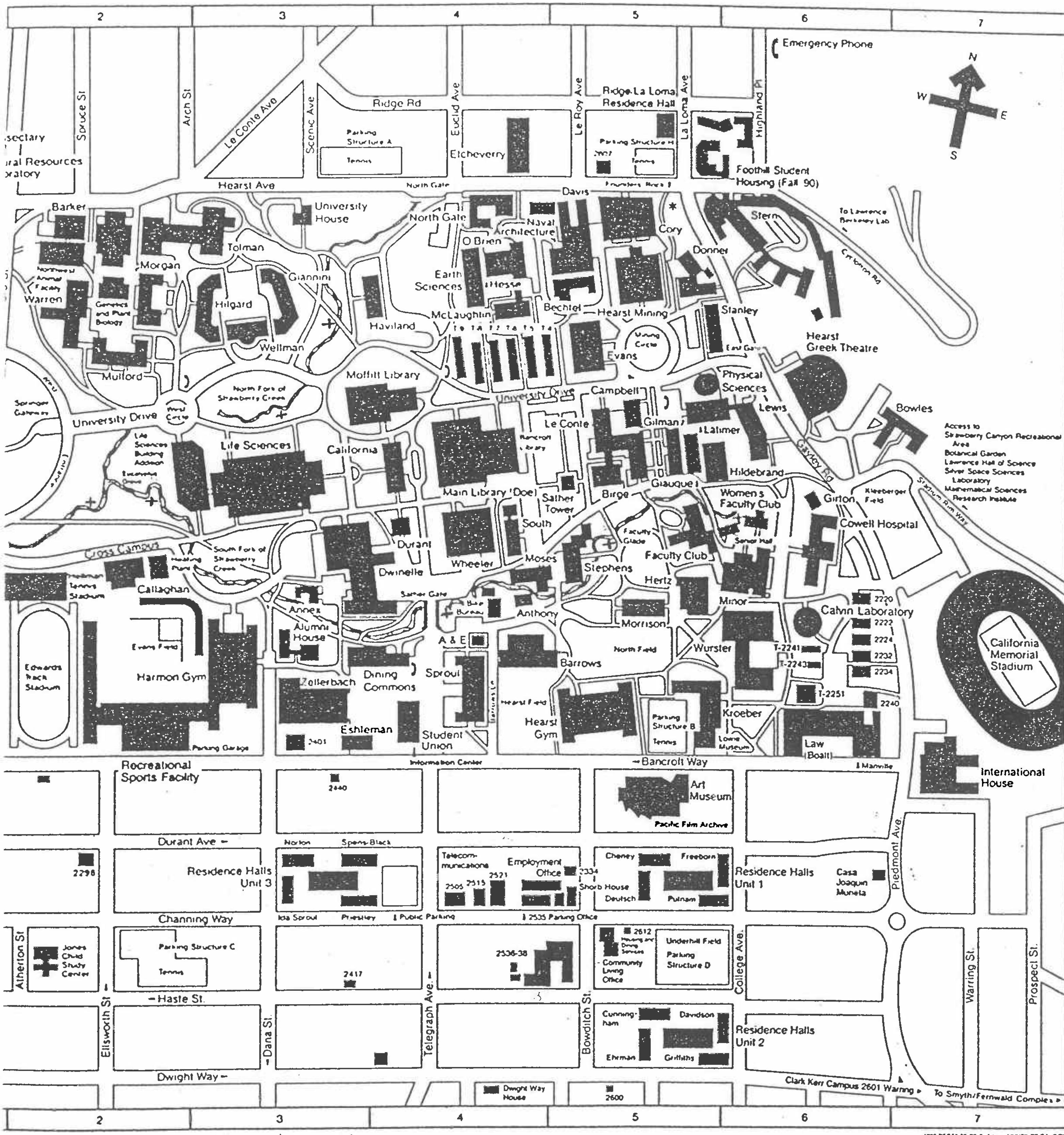
Transect	% ≤ 4mm	D_{16}	D_{50}	D_{84}	dg	sg
Straw. Canyon	22	-	8	-	-	-
Little Inch	12	5	16	53	16.8	3.2
Stephens Hall	30	-	8	-	-	-
Sather Gate	18	-	23	-	-	-
LSA	41	-	6	-	-	-
Confluence	17	4	11	55	14.8	3.7
Giannini	9	9	43	75	26.0	2.9
LSB	29	-	8	-	-	-

Table 1: bed material size data from pebble count , Strawberry Creek, California
note: all data in mm, except sg, which is dimensionless

Reference:

Kondolf, G.M. and Stacy Li, 1992, The pebble count technique for quantifying surface bed material size in instream flow studies, in *Rivers*, v3, n2, pp. 80-87.

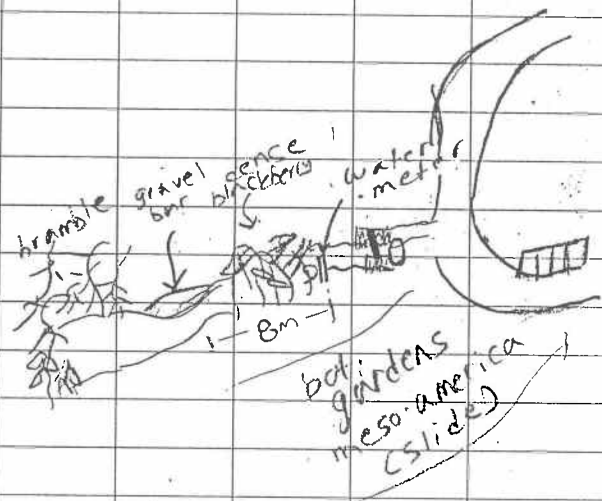
Appendix A: Study Site Locations



+ study site location

5/24/94

Strawberry Canyon Site



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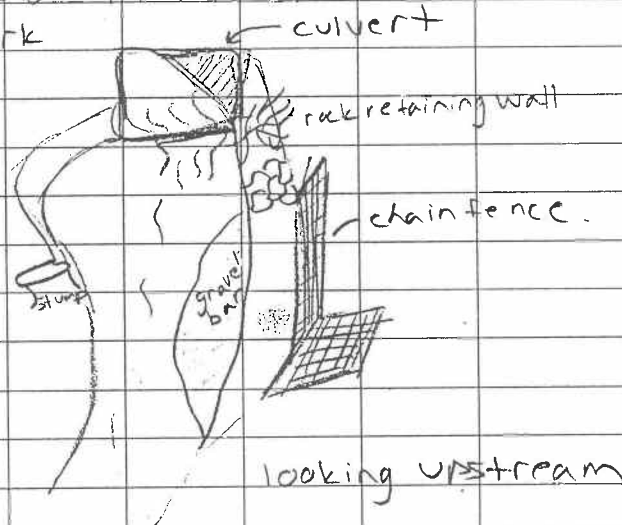
16-22.6	卌 |
22.6-32	|
32-45	|||
45-64	
64-90	|

Sediment Size Distribution Study

1/31/94

Below little inch

South Fork



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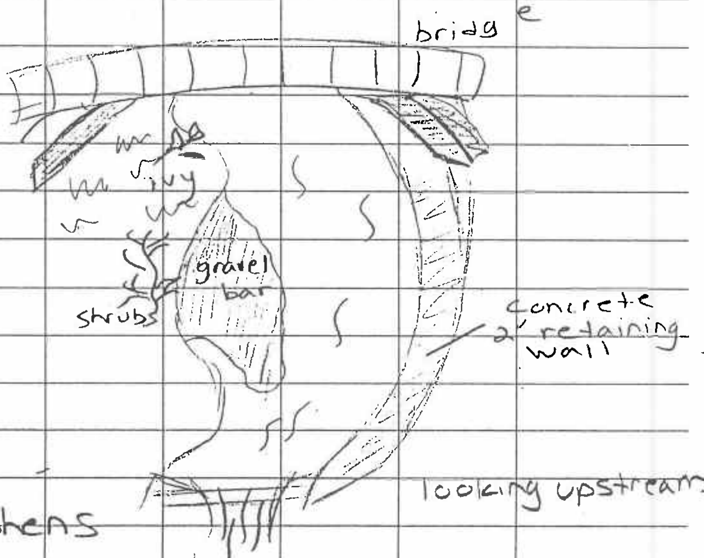
23 - 32	卌 ||
32 - 45	卌 |||
45 - 64	卌 卌
64 - 90	卌
90 - 128	||
128 - 180	||||

2/22/94

Below Stephen's Hall Autobridge

South Fork



Stephens

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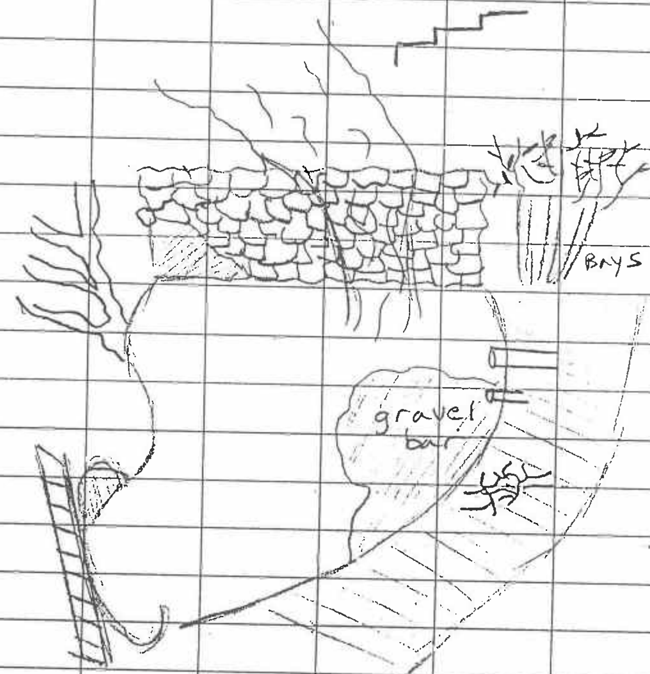
8 - 11.3	~~||||~~ |
11.3 - 16	~~||||~~ ~~||||~~ ||
16 - 22.6	|E|| ||EE
22.6 - 32	~~||||~~ E
32 - 45	|||E ||
45 - 64	||||
64 - 90	EEE
90 - 128	

2/20/94

Above Sather Gate

South Fork



< 4	~~||||~~ ~~||||~~ ~~||||~~ |||
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32 - 45	IEE |||
45 - 64	IEE IIE IIE I
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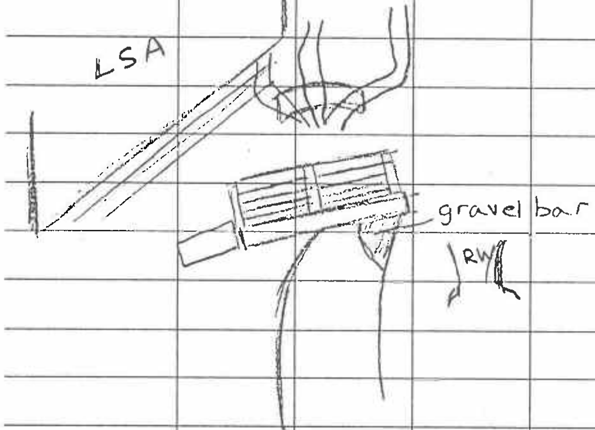
90 - 128	IEE
128 - 180	|||
180 -	|

3/2/94

West of LSA , South Fork



looking upstream

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22.6-32	卌 E
32 - 45	||
45-64	E|

4/1/94

12^{30} PM

Location: below confluence ≈27m

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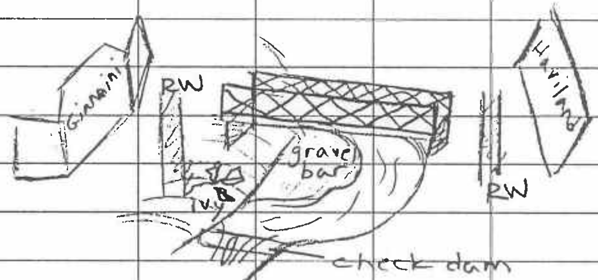
16 - 22.6	卌 |
22.6 - 32	||||
32 - 45	卌 卌 E卌
45 - 64	||E卌 |||
64 - 90	EE
90 - 128	EE|
128 - 180	EEEE
180 - 254.6	EEE

2/22

Beneath Haviland-Giannini Footbridge

N. Fork



looking upstream

≤4	𝍸 ||||
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64 - 90	𝍸 E𝍸 𝍸 |||
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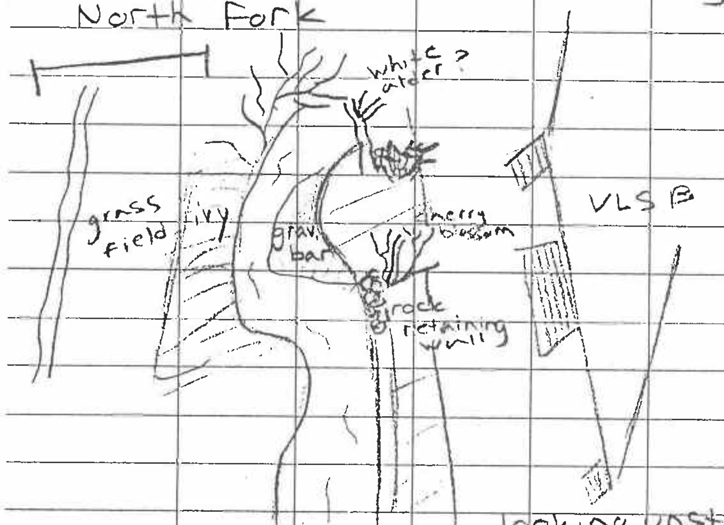
128 - 180	|||

2/21/94

N of Life Sciences Building

North Fork



looking upstream

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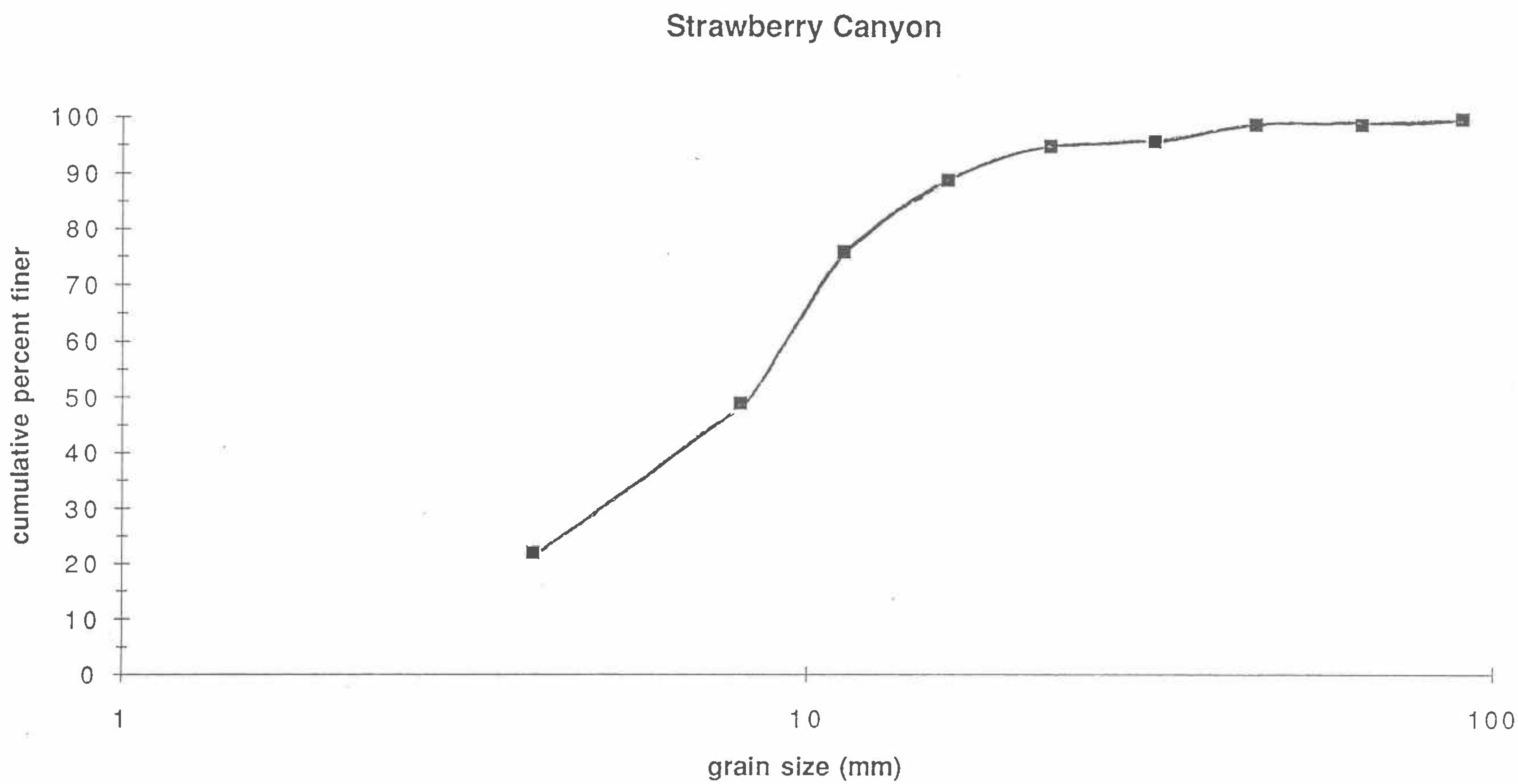
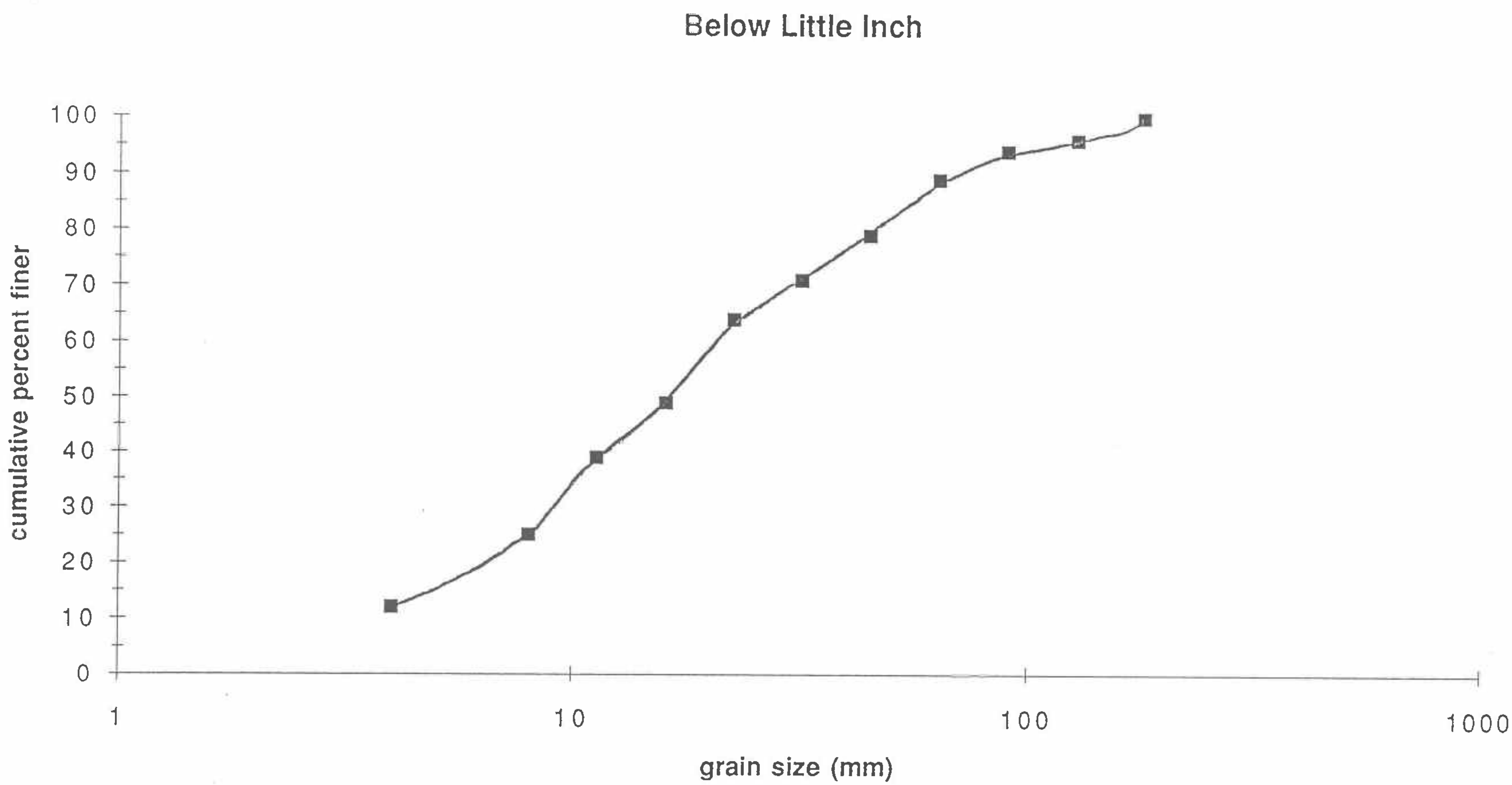
22.6-32	IEIE IE
32-45	IEIE EI
45-64	EIE)
64-90	IE
90-128	II
128-180	
180-254.6	

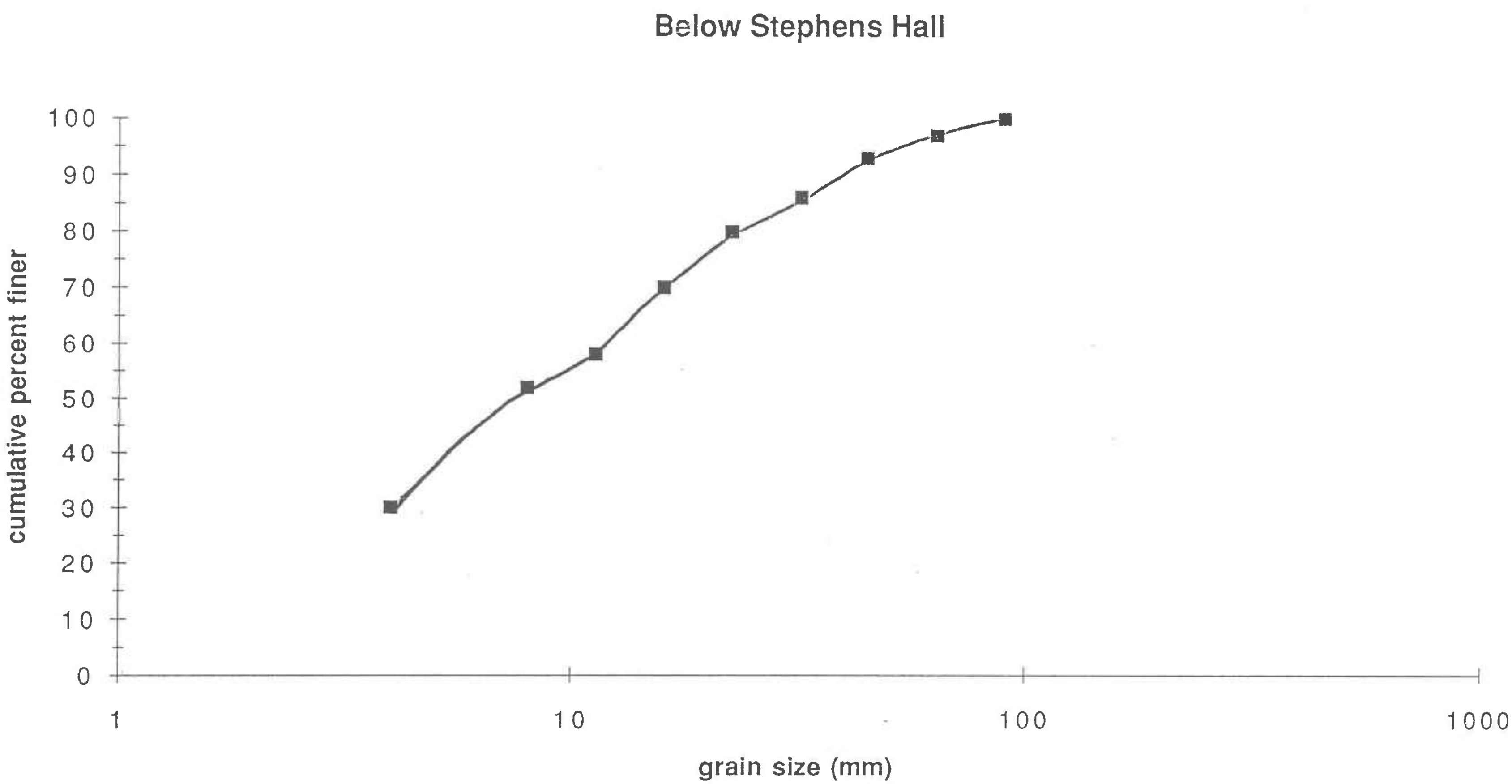
Appendix B:
Cumulative Size Distribution Curves



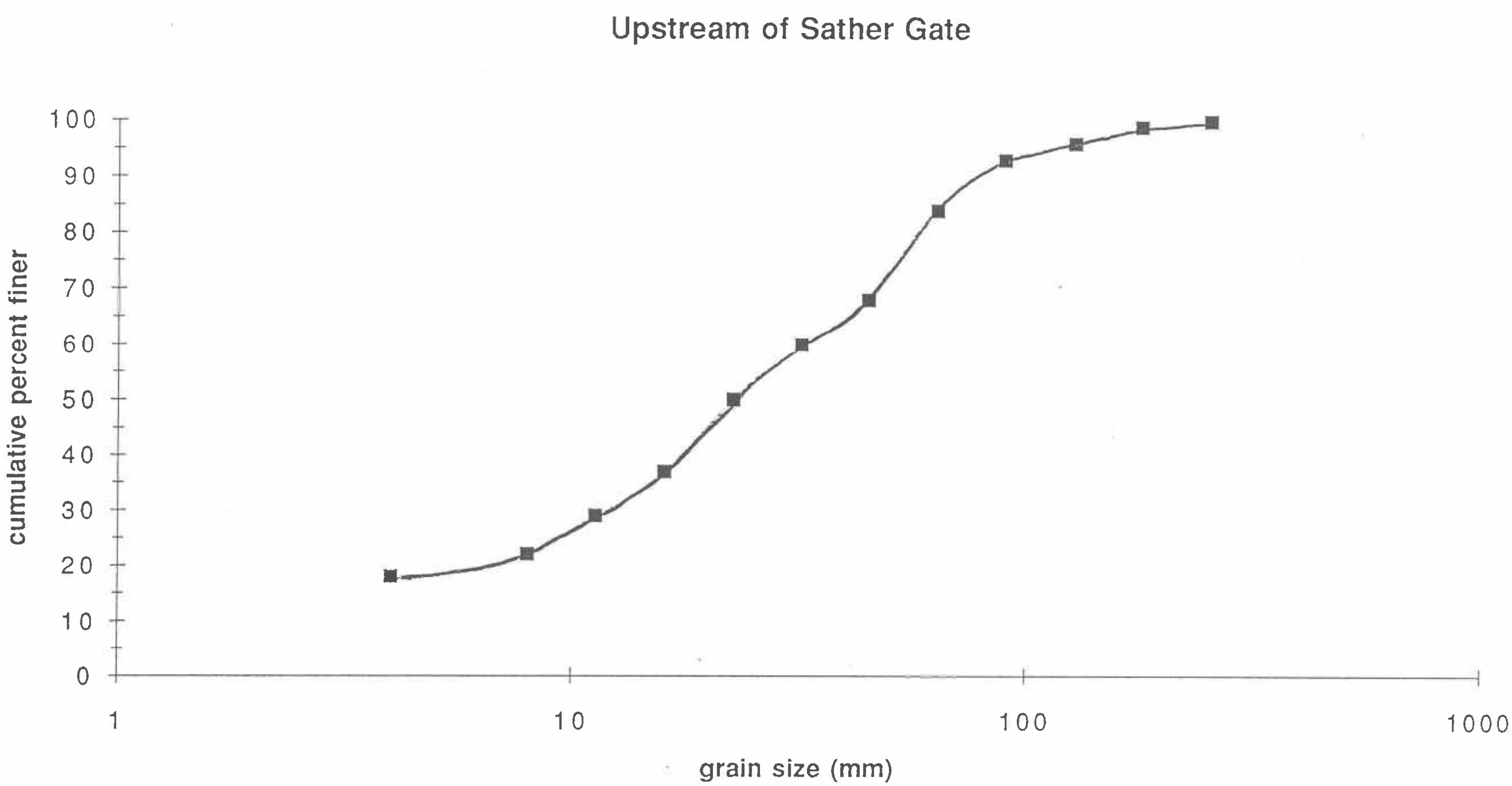
Cumulative Size Distribution Curves



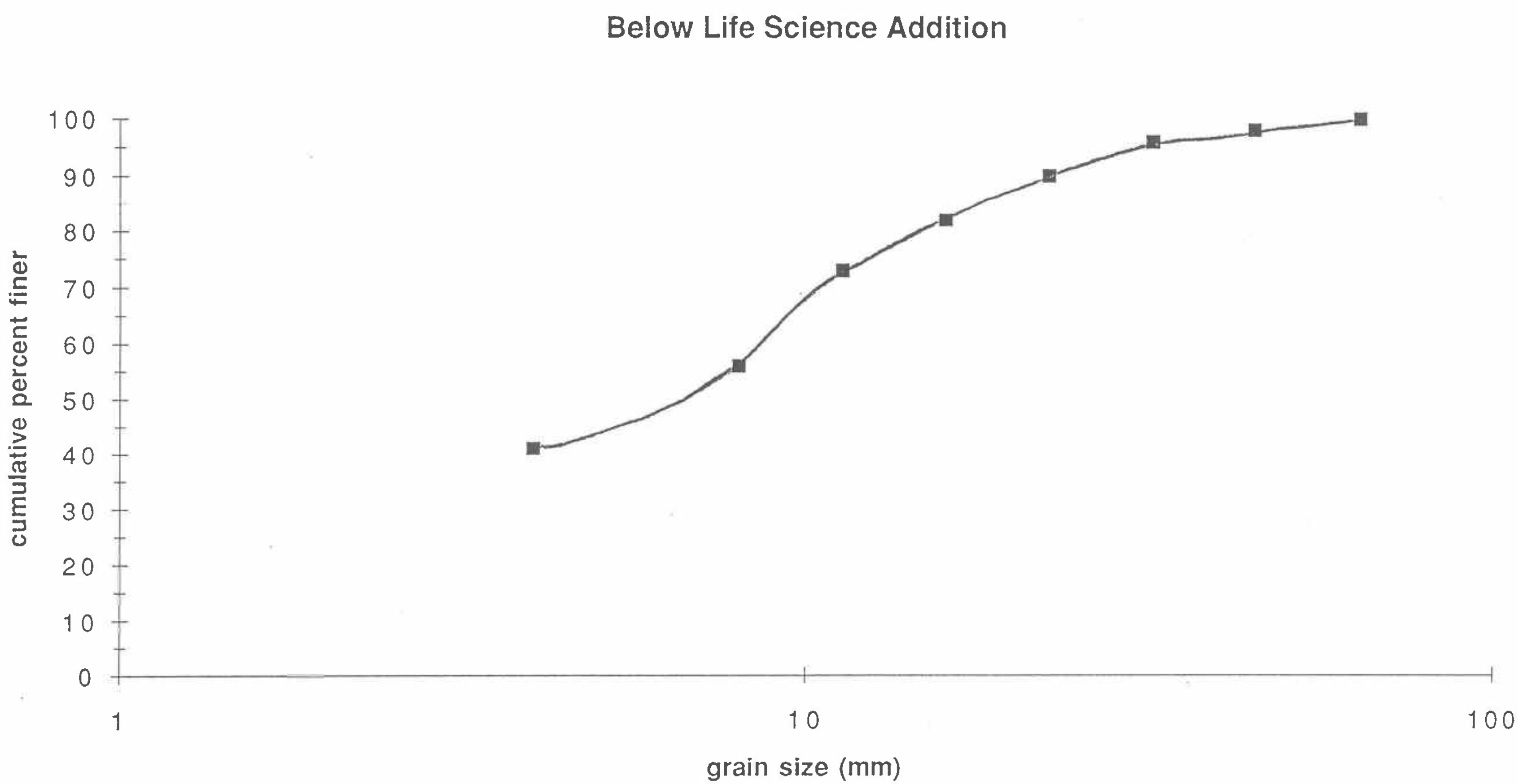
Cumulative Size Distribution Curves



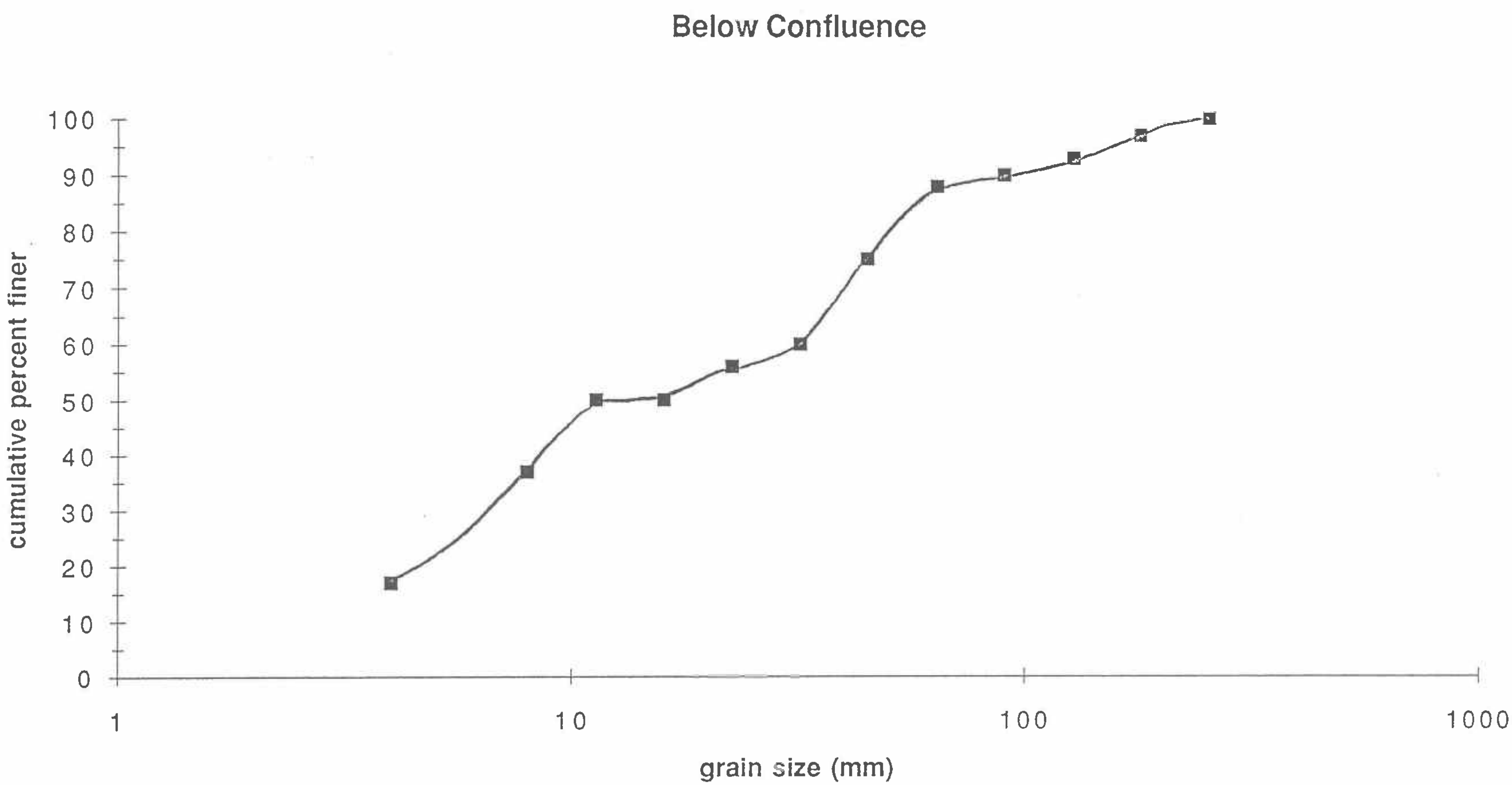
Cumulative Size Distribution Curves



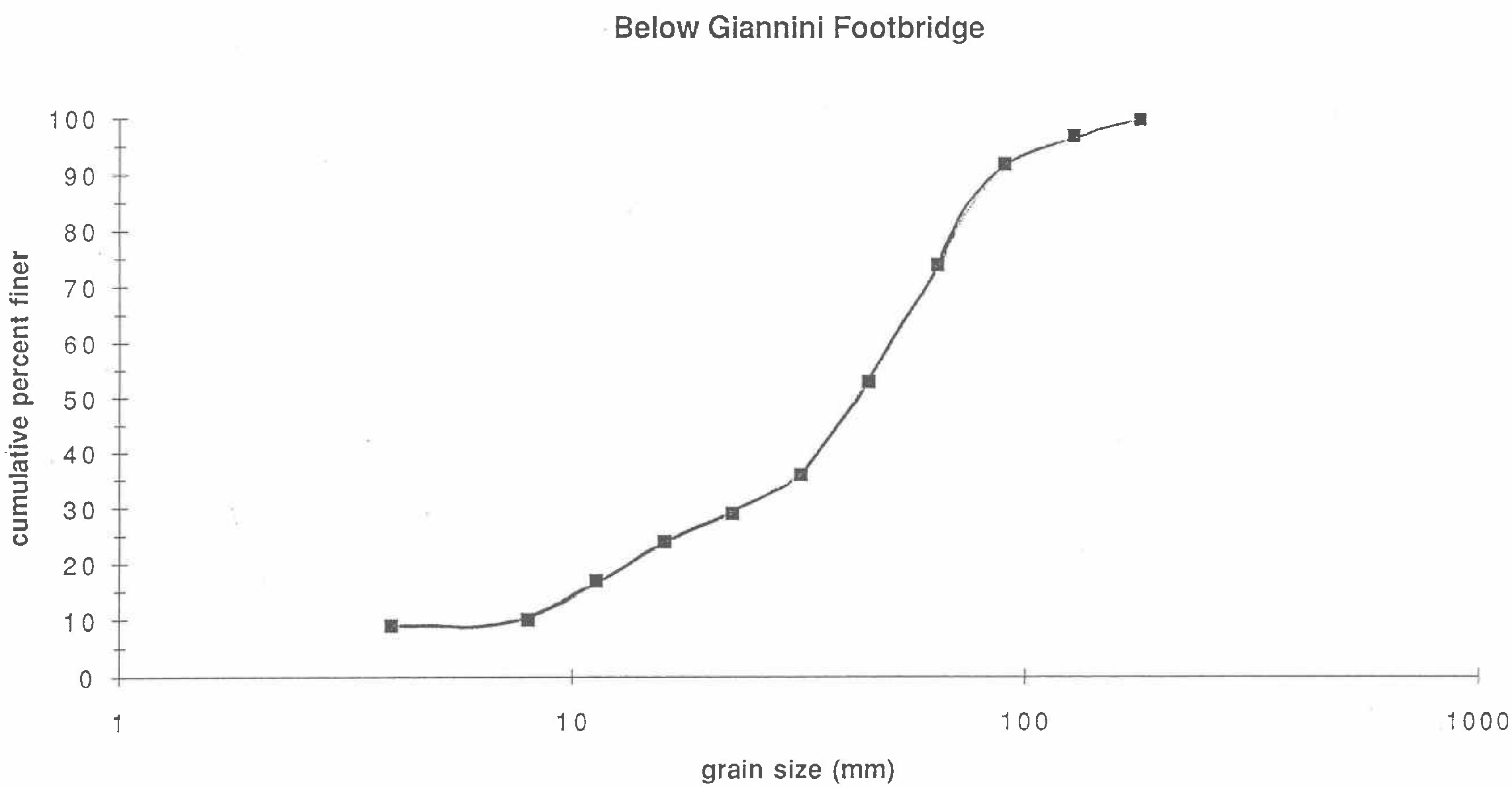
Cumulative Size Distribution Curves



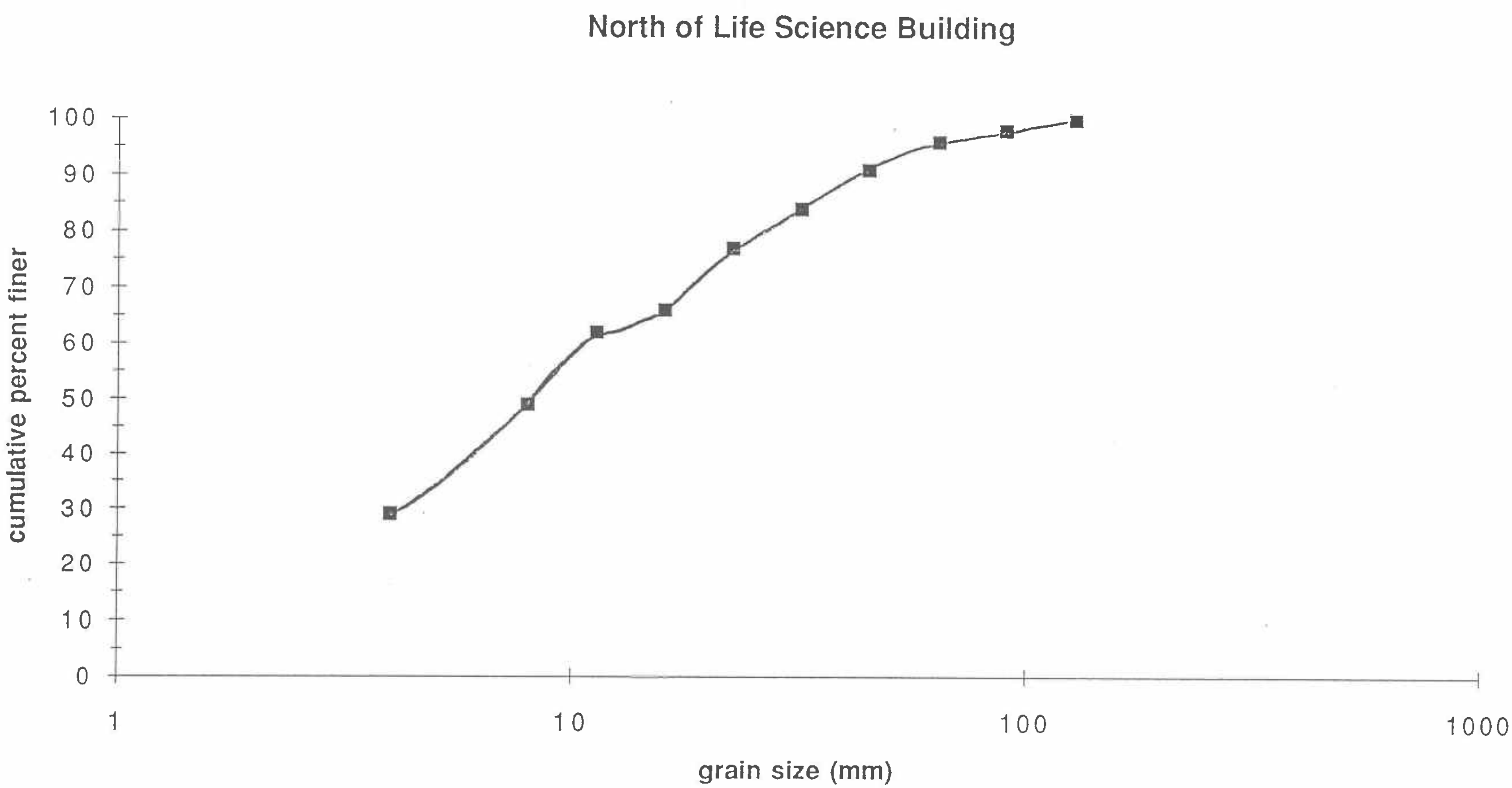
Cumulative Size Distribution Curves



Cumulative Size Distribution Curves



Cumulative Size Distribution Curves



FALL 1994

Sediment Transport in Strawberry Creek

Sandra Huang

Introduction

Strawberry Creek, located in Berkeley, California, has been the subject of many studies focused on water quality and biology of the Creek. The substrate, upon which life forms depend, and which makes up a part of the stream's ecosystem, has largely gone unstudied.

As the product of erosion, whether natural or anthropogenic, sediment plays a significant role in the ecosystem of a stream. Sediment, from the naturally evolving channel and stream bed, is subject to the flow of water which is continually running through the stream. The placement of sediment, as well as the distance it travels, is influenced by seasonal changes and by human activities in or near the stream. Many studies have been completed about the biological aspects of Strawberry Creek. This project focuses on the natural dynamics of sediment in the Creek and tracks the changes shaped by seasonal variations and winter runoff. The goal of this project is to obtain an overall view of sediment transport in the regimen of the Creek. I focus on transport, deposition, and size distribution of the sediment in the stream.

Past Studies

Past Environmental Sciences Senior Seminar students have extensively studied the water quality of Strawberry Creek and the presence of macroinvertebrates and fish living in the Creek. Owen (1992) studied benthic invertebrates and briefly discussed erosion mitigation techniques. Ouyang (1992) qualitatively assessed the substrate at three study sites and found that the water chemistry was adequate to support fish. Morley (1994) gathered data to quantify bed surface material in Strawberry Creek. However, the study did not include explanation, discussion or analysis of the data.

In the Strawberry Creek Management Plan, Charbonneau (1988) described highflow stream characteristics, the erodability of streambank sediments, and trace metal content in sediment. He did not quantify sediment in grain size categories. Charbonneau concluded that much of the stream bank erosion results from the confinement of the stream's channel. Haltiner and Sklar (1991) concluded that check dams have had limited success in halting the erosion of the stream bed and the downcutting of the channel.

Ochsner (1976) observed life forms burrowed into the sediment, stating that these organisms are indicators of a healthy creek. Wischemann (1979) observed bank failure of the streambanks and briefly described the substrate at various undesignated sites along the Creek.

Hoyer (1981) studied transportable sediment in the North Fork of the Creek and concluded that there was less sediment present after storms had occurred.

Several Biology 1B classes and Landscape Architecture classes have quantified surface bed material size in the Creek, but there is no evidence of previously recorded pebble counts to determine the grain size distributions that are related to this project (Kondolf, 1994, pers. comm.). My project will serve as a baseline study and can be compared to future sediment monitoring over time.

Background

The health of life forms in a stream is greatly affected by sediment transported by the stream and deposited in the channel. Sediment is a natural part of any stream ecosystem. Sediment in Strawberry Creek must be understood as an aspect of the creek system as a whole.

The characteristics of water flow and the physical properties of sediment affect the transportation and deposition of sediment in the Creek. Silt can clog spaces in the streambed gravel and reduce oxygen delivery to the living organisms that live in the Creek. Suspended sediment creates turbid waters that decrease light penetration in the stream and can pose problems for living organisms. When peak storm flows scour the channels of the stream, erosion contributes to the degradation of aquatic ecosystems.

Sediment in aquatic systems exists in different forms. Sediment is defined as soil particles, sand and other mineral matter that has eroded from the land and carried in surface waters (Chiras, 1991). Stream loads are carried in the flow of water and classified into three categories: suspended loads, which consist of the sediment that is supported by the turbulence of the water; bed loads consisting of sediment that is made up of material that is rolled along the bottom of the stream bed; and dissolved loads, which consist of material that is in solution (Gilluly *et al.*, 1968).

The South Fork of Strawberry Creek originates in Strawberry Canyon and enters the Berkeley campus by way of an underground culvert running under Memorial Stadium (Fig. 1). The on-campus portion flows through an open channel. The North Fork of the Creek has open channels in parts of North Berkeley and is then culverted underground until it enters the north side of the Berkeley campus, where it flows in an open channel. The cross-campus culvert empties into the North Fork about 15 feet downstream from the footbridge connecting Giannini and Haviland Halls. The confluence of the South and North Forks is located on the west side of the campus. The Creek is then culverted under the city of Berkeley and finally empties out into San Francisco Bay. To allow for development on the campus, about one-fourth of the Creek has been culverted so that it flows under surficial structures and pavement.

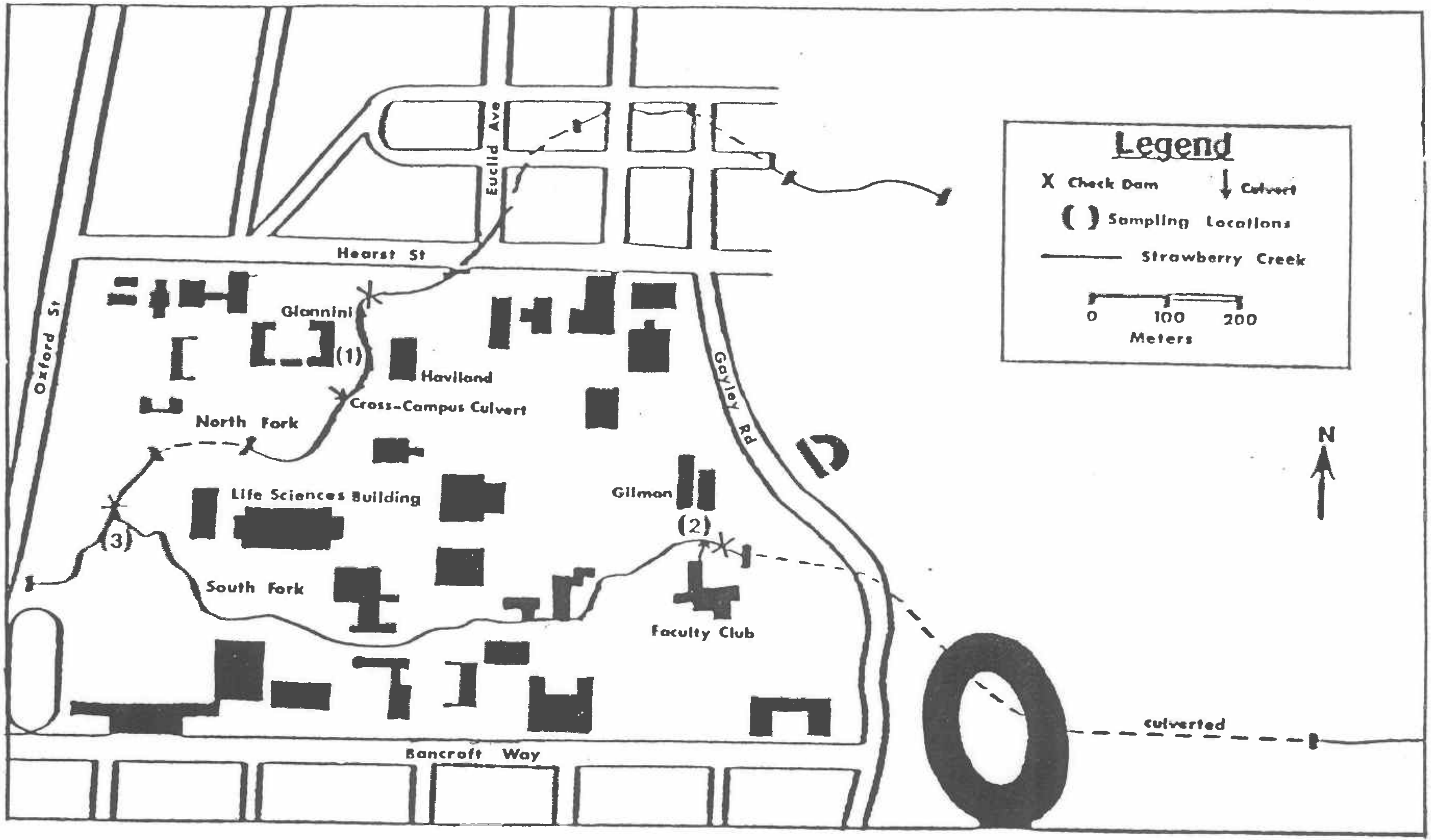


Figure 1. Map of Strawberry Creek, showing sampling sites.
Source: Adapted from Stephens, 1987

Erosional processes affect hill slopes, stream banks, and the stream channel. These three sources of eroded materials are the sources for transported sediment in the Creek. The stream banks on campus are composed of older alluvium, some of which contains large (20-100cm) angular blocks. Those blocks accumulate in the Creek bed because they are too large to be transported by the present Creek. The sediment that is being transported under present conditions is finer gravel, four to 10cm, and rounded.

The Creek has been severely modified by the urbanization of Berkeley (Wischemann, 1979). In the 19th century, runoff from the Strawberry Creek drainage increased as the area was developed and the surfaces were paved or built upon (Charbonneau, 1995, pers. comm.). As a result, downstream erosion on campus increased. Check dams were first built in the late 1800s to reduce erosion in the channel. These dams impounded sediment that is transported by the stream. In addition, the channel was artificially confined in places with rock works or concrete walls to reduce erosion on the banks (Charbonneau, 1988). That lateral confinement of peak flows of water accentuated scouring of the channel.

Further restoration efforts began in 1987. In 1988, a survey of the stream banks noted that additional erosion control was needed (Haltiner and Sklar, 1991). This study led to the design and construction of more check dams along the Creek. Because check dams were constructed by different people at different times, the quality, materials, and workmanship of the check dams built on the Creek vary. The last restoration project focused on repairing and taking out broken check dams, and creating new check dams where they were needed (Charbonneau, 1995, pers. comm.). Some reaches of the stream banks were also enclosed in cement to prevent further bank erosion (Charbonneau and Resh, 1992). Efforts were also made to reduce Creek pollution from the leakages in the sanitary sewer system.

Charbonneau and Resh (1992) reviewed the results of restoration efforts and reported that they had been successful. Water quality characteristics improved from 1985 to 1991, and then worsened in the later months of 1991, possibly due to an increase in construction activities on campus (Kondolf, 1994, pers. comm.).

Methodology

This section describes the rationale for choosing the particular sites studied and the technique that was used in quantifying surface bed size material. Measurements obtained consist of grain size distributions, dimensions of gravel bars, and width, depth and velocity of the Creek.

Data were collected from both forks of the Creek. In choosing specific study sites, I walked along the Creek and paced off reaches of the channel that were composed of either angular debris or rounded sediment. I then selected the sites from the longest stretches of sediment in and adjacent to the channel bed. I selected gravel bars exposed at the water's edge to measure characteristics of the sediment.

Three sites were chosen for detailed observation. Site One is on the North Fork between Giannini and Haviland Halls (Fig. 1). Site Two is on the South Fork between the Faculty Club and Gilman Hall. Site Three is at the confluence of the two forks at the west of the Eucalyptus Grove.

At each site, two measures were taken: approximate dimensions of the site area and gravel bar studied and grain size diameters. In addition, the velocity of the water travelling through the site at low water was measured. The maximum depth of the Creek during peak flows was inferred from physical evidence.

The grain size of the surface bed material is quantified by using the pebble count method described by Kondolf and Li (1992). By looking in the opposite direction of the hand that is selecting the pebble, I randomly chose 100 pebbles by choosing the first pebble that touched the tip of my outstretched index finger. I tallied each pebble into standard ranges of different grain size in millimeters.

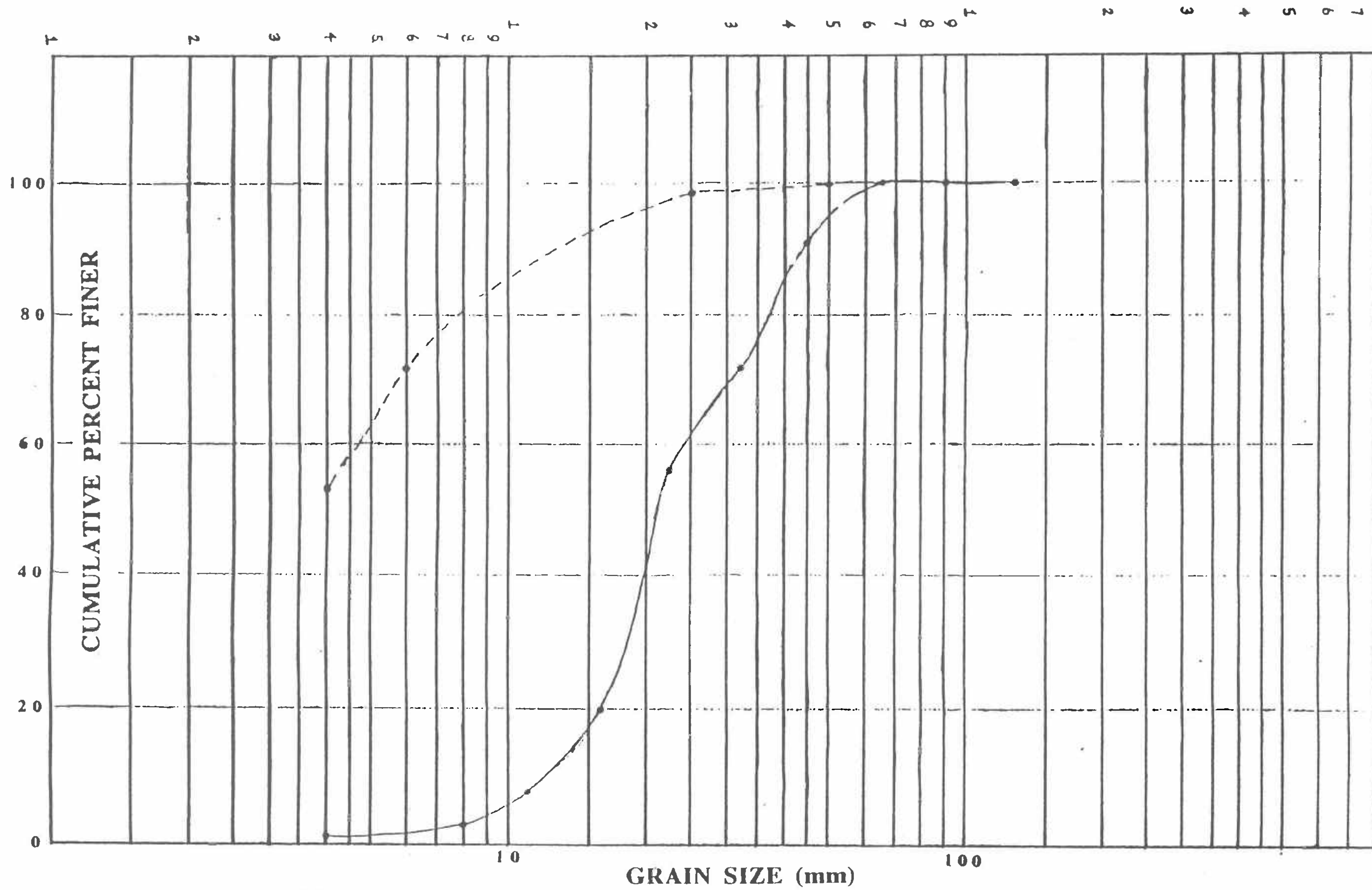
When my finger touched sand, clay, silt, organic matter such as tree debris and underbrush litter, or any grains that were smaller than 4mm, I tallied them into separate categories according to their different names. I totalled all of the above types of items that I chose into the < 4mm category.

Pebble counts were performed twice at each of the three sites in the dry season, before a storm occurred and after two major periods of storms. At each site, the width of the Creek was measured in meters, as well as the dimensions for the gravel bar where the pebble count was performed. I did not measure the gradient.

For the purpose of summarizing the results of the pebble counts, data are plotted on logarithmic paper (Fig. 2). Categories of standard diameters have been established. The standard diameter categories are: < 4mm, 4 to 8mm, 8 to 11.3mm, 11.3 to 16mm, 16 to 22.6mm, 22.6 to 32mm, 32 to 45mm, 45 to 64mm, 64 to 90mm, 90 to 128mm, and 128 to 180mm (Kondolf, 1994, pers. comm.). The size corresponding to that at which 16 percent of the sediment is finer is designated D16. Two different measures of central tendency are the median grain size, D50, and the geometric mean diameter (dg):

$$dg=[(D84)(D16)]0.5.$$

To calculate the percentage of each grain size category, an appropriate denominator must be selected. For that purpose, the number of pebbles larger than 4mm, was added to the number of times that my finger encountered material smaller than 4mm. The cumulative size distribution curve of grain size (Fig. 2) was plotted against a cumulative percent finer axis on a logarithmic scale.



- - - - - before storm on 10/17/94
------------ after storm on 11/06/94

Figure 2. Cumulative percent finer vs. grain size.

Data

Measurements were made on the three largest gravel bars that were exposed above water and available for pebble counts in October, 1994. Counts were repeated on all three bars after storms of October and November. Heavy rains in subsequent months redistributed the gravel; large bars in different places existed at other sites in March, 1995. One further pebble count was made at one of the initial sites in late March.

Site One is located on the North Fork about 9m upstream from the cross-campus culvert. A check dam is 30m upstream of the site. Site Two is on the South Fork. Just upstream of Site Two, a large culvert empties into the Creek from which water flows from Strawberry Canyon. About 12m downstream of the site is a concrete utility pipe that is 3m above the water, and about 18m downstream of the site is a concrete pedestrian bridge. A check dam is 2m upstream of the site. Site Three is located at the confluence of the North and South Forks of the Creek. It is located at the west edge of the Eucalyptus Grove, about 1m below a check dam on the North Fork. The general condition of the check dams is deteriorating.

At Site One, the channel is incised about 3m. The west bank is gently sloping and is covered with English Ivy. The east bank is a steeply cut slope covered with litter from a pine tree. The channel is about two to three feet wide, varying at different reaches of the Creek. About 90 percent of the flat channel bed is covered with gravel. The gravel bar where I performed pebble counts was located on the west bank. Most of the bed is covered with gravel; the part I studied is exposed and extends into the water.

At Site Two, the channel is incised about 3m. The north bank is an artificially constructed wall of cement blocks standing about seven feet high. It continues for about 20m downstream of this site. The south bank is steeply cut and covered with ivy and vegetative matter. The general channel is about 3.5m wide. At low water levels the stream occupies only part of the channel floor. Along this reach, gravel deposits cover over 50 to 60 percent of the bed channel. There are also about seven large, angular boulders scattered in this reach of the stream. The boulders are interspersed with the concrete and vegetative matter. The measured gravel bar is on the north bank. The bar consists of mostly medium and finer sediments lining the stream bed.

At Site Three, the channel is incised about 1m. The west bank is cut steeply with grass on the top of the bank. During low flows, water occupies an area about 4m in width and 3m in length. At low flows, the water is about 1m deep and resembles a shallow pool of water during low flows. The east bank is the end of the Eucalyptus Grove and ends where the South Fork of the Creek enters the confluence. The gravel bar is located on the west bank.

The gravel bars exposed at the edge of the stream and susceptible to measurement are all parts of larger deposits that extend under the stream water. The lengths of these exposed bars before storms, in October, ranged from 1.2 to 1.9m; the largest exposed bar was at Site Three (Tables 1, 2, and 3). The dimensions of these bars changed marginally after storms. The dimensions recorded here depend on water level; they do not reflect total dimensions of the gravel deposits. Continuous bodies of gravel are much larger (more that 10m long) than these reported measurements.

Heavy rainfall (Table 4) and high water flows during the winter months substantially modified all of these gravel bars (Monaghan, 1995, pers. comm.). Maximum depth of runoff during the storms is inferred from physical evidence such as stream-dragged rootlets, erosion of banks, and scouring of artificial embankments. The maximum inferred depths were on the order of 1m: 0.7m at Site One; 1.2m at Site Two; 0.9m at Site Three.

Stream velocities were not measured during high flows. On January 29, 1995, when water depths were low (on the order of 25cm) the velocities recorded were less than 0.5m/sec: 0.16m/sec at Site One; 0.39m/sec at Site Two; 0.21m/sec at Site Three.

The sites and parameters of gravel at all three sites are rather similar. At the time of initial measurement in October, the largest pebbles at Site Three were slightly, but consistently smaller than upstream. D16, D50 and D84 do not vary systematically from upstream to downstream. D16 averaged 1-2mm, D50 averaged about 5mm, and D84 averaged 11-25cm. At all three sites, the size and sorting of the gravel changed after high runoffs in the fall (Tables 1, 2, and 3). The largest pebbles after storms were smaller than before -- 15cm before, 13cm after. At the same time, D50 increased, from less than 1cm before to about 2cm after.

At Site Two, on the South Fork, pebble counts were repeated after the heavy rains and high runoffs in early 1995. On March 22, the largest pebbles were much smaller than at previous measurements in October and November -- about 9cm compared to 13cm in November and 15cm in October. D16, D50, and D84 were likewise smaller after the storms in November, but increased slightly after the March storms.

After the intense storms occurring from January through March, the gravel bars at Site One and Site Three were smaller. The configuration of the channel bed at Site Two changed significantly after the last storm in January of 1995. Due to time constraints, I was not able to perform follow-up pebble counts after the March storms at Sites One and Three.

Additionally, a large, new gravel bar located downstream of Site Two was observed after the storms occurring from January to March, 1995. This new gravel bar is a continuous layer of sediment stretching across the width and length of the Creek bed and consists of medium and finer materials. In comparison to the coarse, angular rubble at Site Three, the gravel at this new site is rounded.

	Before storms (10/17/94)	After storms (11/06/94)	After storms (3/20/95)
Width of gravel bar	0.1-0.2 m	0.6-1.1 m	0.7-1.3 m
Length of gravel bar	1.2 m	1.2 m	1.54 m
Smallest gravel	< 4.0 mm	8.0 mm	N/A
Largest gravel	152.0 mm	128.0 mm	N/A
D16	1.4 mm	12.0 mm	N/A
D50	7.0 mm	21.5 mm	N/A
D84	25.0 mm	32.0 mm	N/A

Table 1. Site 1, dimensions and grain size distributions.

	Before storms (10/19/94)	After storms (11/08/94)	After storms (3/22/95)
Width of gravel bar	0.4-0.6 m	0.6-0.9 m	0.6-0.9 m
Length of gravel bar	1.3 m	1.3 m	1.4 m
Smallest gravel	< 4.0 mm	5.0 mm	6.0 mm
Largest gravel	152.0 mm	128.0 mm	87.0 mm
D16	2.2 mm	15.0 mm	10.7 mm
D50	3.8 mm	21.0 mm	17.3 mm
D84	11.0 mm	40.0 mm	24.0 mm

Table 2. Site 2, dimensions and grain size distributions.

	Before storms (10/17/94)	After storms (11/06/94)	After storms (3/20/95)
Width of gravel bar	0.9-1.3 m	0.4-0.8 m	0.7-1.1 m
Length of gravel bar	1.9 m	1.5 m	1.7 m
Smallest gravel	< 4.0 mm	8.0 mm	N/A
Largest gravel	146.0 mm	90.0 mm	N/A
D16	1.9 mm	12.5 mm	N/A
D50	5.2 mm	19.0 mm	N/A
D84	16.0 mm	27.5 mm	N/A

Table 3. Site 3, dimensions and grain size distributions.

October	100 mm
November	200 mm
December	100 mm
January	300 mm
February	0.5 mm
March	240 mm

Table 4. Rainfall totals from October, 1994 to March, 1995.

Discussion

In general, the pattern of change in grain sizes on gravel bars shows a decrease in the diameters of the largest pieces of gravel, disappearance of fine gravel material, and consequent increases in the size of D16 and D50 in November. In March, D16 and D50 decreased slightly. The largest pebbles have disappeared; therefore, all finer materials must have been removed as well. It seems that all of the gravel in the bars at the end of the storm season is new sediment, deposited as peak flows subsided.

It is possible that the seven-year drought had accumulated debris and built up sediment in the channels upstream of the new gravel bar at Site Two. The heavy and constant rains from January to March flushed all the accumulated debris to form this new gravel bar. The presence of this new gravel bar is evidence that storms can significantly alter the physical factors present in the Creek.

The presence of check dams upstream from the study sites may have some impact on the pebbles in the gravel. The check dams have a transitory effect. Sediment builds up behind the dam; after the accumulated sediment rises to the level of the dam itself, further sediment is washed over the dam. The dam is no longer trapping the sediment and loses its effectiveness. The initial erosion of the streambed below the check dam occurs from the force of falling water over the waterfall-like check dam. Therefore, a better place to perform pebble counts would have been just upstream of the check dams of the sites studied in this report. Additional research will have to be completed to further quantify grain sizes in the Creek.

High runoff must affect small fish and macroinvertebrates. Presumably, since all of the sediment was washed away during the storms, the habitats of these macroinvertebrates would have also been washed away during the storms. Further research must be completed to correlate changes in aquatic life with changes in gravel substrate.

Conclusion

A comparison of the sediment before and after a storm season suggests that entire gravel bars, coarse and fine material, are scoured out during high flows and replaced by new sediment as flows subsided. These seasonal variations have been shown to have significant effects on the sediment as it exists in Strawberry Creek. Effects on aquatic life must be dramatic too. Further research is needed to document the interaction between scouring and transport of substrate and aquatic life in the Creek.

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SPRING 1995

Data and Analysis on the Deposition of Sediment in Strawberry Creek

Written by
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(EH&S Intern)

Purpose:

This study was done to follow up a base-line creek surface-bed material study done by Sarah Morley in 1994. This report will present the all stream bed data that I collected, as well as compare the condition of study sites as evaluated by Sarah Morley. This report serves to offer information as to the extent of sediment distribution is Strawberry Creek, likely sources of sediment pollution, and any possible long-term effects of creek sedimentation.

Introduction:

Strawberry Creek is a small second-order stream that originates in Strawberry Canyon and flows through the UC Berkeley campus. Land uses within the Strawberry Creek watershed are highly varying and range from open space to densely developed urbanized areas. Recent stream quality indicators have declined due to unknown reasons. As part of an effort to ascertain the cause of this decline this sedimentation study was initiated in order to compare new data with baseline stream-bed sediment data collected by Sarah Morley in 1994 and to examine trends in sediment composition.

Suspected sources of sediment pollution are the Haase Business School, under final stages of construction, and possibly Memorial stadium, due to the removal of Astro-Turf and the introduction of a turf playing field. Both of these possible sources are within close proximity to the South fork of Strawberry Creek and any sediment laden runoff coming from these sights would be likely to flow into the South fork of the creek.

Background:

Sediment deposition often has a detrimental effect on the health of a stream eco-system. When sediment deposition rates exceed rates of sediment transport, fine sediment can cover gravel bottoms and may fill deep pools where organisms live and feed (NRC, 1992). Fine sediments affect invertebrates, as well as fish eggs and larva, by interfering with the dynamics of the hyporheic zone (the saturated zone beneath a river or stream consisting of substrate and water filled interstitial pores) (NRC, 1992). The spaces in between rocks and gravel in the stream bed are used as refugia and feeding areas for young invertebrates. The loss of these interstitial spaces due to silt blanketing can degrade the quality of stream habitat.

Sediment is known to adsorb metal such as copper, zinc and lead, and may have metals in higher concentrations than those found in stream water. Sediment containing organic matter can also substantially increase oxygen demand. Silt mixed with organic matter has been found to create an oxygen demand lasting 10 to 15 times longer than oxygen demand created by the same amount of organic matter mixed with sand (NRC, 1992).

Methodology:

Field Procedures-
(Taken from S. Morley, 1994)

To determine the gravel bar material size for these eight populations, I followed the pebble count technique as described in Kondolf and Li, 1992.

From each distinct population I chose at random 100 pebbles. Pebbles were chosen by walking along the gravel bar surface, and with eyes averted touching the surface in front of my boot. For the pebble on which the right edge of my fingernail had landed, I measured the intermediate axis. From this value I recorded the pebble as falling into the following 12 size classes: <4mm, 4-

8mm, 8-11.3mm, 11.3-16mm, 16-23mm, 23-32mm, 32-45mm, 45-64mm, 64-90mm, 90-128mm, 128-180mm, 180-255mm. These size classes vary by a factor of the square root of 2, and are extensions of the Wentworth scale. Where pebble were embedded to greater than half of their width, I denoted this in the field notebook as "E" rather than simply a slash mark.

Sampling Sites
(Appendix 2)

- **Site #1 Strawberry Canyon**

  Upstream approximately 8m of water meter at the third stream-crossing of the fire trail. Recognizable by U-shaped cement culvert leading into corrugated pipe where the stream hits the East side of the fire trail. This site is below the UCB Botanical Gardens and on the North side of the creek their has been a small landslide. Site is heavily vegetated.

- **Site #2 Little Inch**

  Downstream of Little Inch outfall, the first appearance of the North fork on campus, West of Haase Business school and North of the Women's Faculty Club. The gravel bed extends approximately from the white PVC drainage pipe on south side of creek to the end of the black cyclone fence on the south side of the creek.

- **Site #3 Stephens Hall Auto Bridge**

  Directly under the arched, cement bridge adjacent to Stephens Hall that leads from Faculty Glade towards Birge Hall and the Campanile. Gravel bed is on the North side of the creek.

- **Site #4 Sather Gate**

  Large gravel bar on downstream side of pool created by the approximately 1m high checkdam upstream of the Sather Gate.

- **Site #5 Life Sciences Addition**

  Along South side of creek just downstream and adjacent to the wooden footbridge behind (West of) the Life Sciences Addition, in the Eucalyptus Grove.

- **Site #6 Confluence**

  2m portion on the upstream end of gravel bar on the North side of creek after the confluence of both stream forks. This gravel bar is approximately 27m downstream of the confluence and is opposite an old rock wall and several pipes draining into the creek, which are on the South side of the stream bed.

- **Site #7 Life Sciences Building**

  North of Life Sciences Building. Following the creek down from the bridge crossing, the gravel bed where the first trees and bushes appear on the South side of the stream.

- **Site #8 Gianinni-Haviland**

  Section of gravely streambed directly upstream of the wooden footbridge connecting footpath between Giannini and Haviland Halls, on West side of stream

Data:

For clarity, the sedimentation data I collected will be presented on a site by site basis, contrasting the data I collected with Sarah Morley's baseline 1994 study. Observations relevant to each site are included. All of the raw data I collected is presented in Appendix 1.

Strawberry Canyon

Date	<4mm	4-8	8-11.3	11.3-16	16-23	23-32	32-45	45-64	64-90	90-128	128-180
2/12	18	13	6	9	10	17	11	3	5	8	
2/22	23	9	6	7	12	12	11	5	10	5	
3/5	7	17	12	13	13	7	4	3	7		
4/11	8	19	6	19	10	12	6	7	5	5	3
S.M.	***22***	***27***	***27***	***13***	***6***	***1***	***3***	***0***	***1***		

Table 1- Describing data collected at Strawberry Canyon site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters.

This site was mostly characterized by gravel, sand and large rocks, with very little silty sediment. Some signs of erosion, such as exposed roots were evident. This site was difficult to get to due to dense vegetation and fallen limbs.

Little Inch

Date	<4mm	4-8	8-11.3	11.3-16	16-23	23-32	32-45	45-64	64-90	90-128	128-180
2/11	12	11	11	11	12	10	11	11	7	3	2
2/22	55	4	1	8	4	6	5	5	5	3	2
2/26	58	9	8	2	7	1	2	5	6	2	
3/5	47	11	8	6	7	6	8	3	4		
3/18	8	21	7	19	18	8	7	6	5	1	
4/11	2	12	13	29	15	9	12	4	3	1	
S.M.	***12***	***13***	***14***	***10***	***15***	***7***	***7***	***10***	***4***	***2***	***4***

Table 2- Describing data collected at Little Inch site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters

This site had the most dramatic depositions of sediment seen in the creek. At the time of my first survey there was a layer of floury sediment forming a bar about 2m from the culvert outfall. I measured it's depth to be up to 110m, tapering down to about 20mm around the downstream edge, then eventually blending into the gravel bar. This bar had moved slightly downstream at the time of my 2/26 survey, and I measured areas where the silt was up to 250mm deep. At the time of my next survey on 3/5, high flows had filled the whole pool created by the outfall culvert. In addition, the substrate appeared to be more gravely than silty, and a gravelly bar ringed the area directly under the outfall culvert. However, the streambed was still soft to the point where my boots sank half-way into the substrate. When I next surveyed the site on 3/18 this gravelly bar had moved approximately 1m out from the culvert outfall and the floury sediment had almost completely been washed away, leaving a substrate consisting of rocks with diameters ranging from 8mm-30mm on the surface of this bar . At the time of my 4/11 survey most of the gravel had been washed out of the pool and the streambed had a sticky, muddy consistency. There was a fine covering of golden silt.

This site underwent the most drastic changes in visual appearance and stream bed composition observed at any site. *(Appendix 3)*

Stephens Hall

Date	<4mm	4-8	8-11.3	11.3-16	16-23	23-32	32-45	45-64	64-90
2/11	18	15	14	17	20	7	6	3	
2/26	22	14	16	9	10	6	14	4	2
3/5	22	15	21	13	17	7	5		
3/18	5	8	9	12	18	19	11	3	
4/11	8	8	8	13	19	16	17	9	2
S.M.	*30*	*22*	*6*	*12*	*10*	*6*	*7*	*4*	*3*

Table 3- Describing data collected at Stepehens site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters

This site experienced minimal sedimentation. Golden, silty deposits of sediment were observed at the leading and lagging ends of the gravel bar on 2/11, and 2/26, but were washed away by storm events. The gravel bar had a finer, more sandy consistency at the time of the 3/5 survey. At the 3/18 survey the substrate had no silt, little sand and appeared to consist of larger gravel. Some silty deposits were noticed at the 4/11 survey.

Sather Gate

Date	<4mm	4-8	8-11.3	11.3-16	16-23	23-32	32-45	45-64	64-90	90-128	128-180
2/11	**13**	**19**	**16**	**17**	**7**	**7**	**6**	**4**	**6**	**6**	**1**
2/26	**12**	**19**	**17**	**15**	**11**	**1**	**4**	**3**	**6**	**1**	**2**
3/5	**30**	**24**	**14**	**5**	**5**	**4**	**1**	**6**	**8**	**5**	
3/18	**1**	**13**	**13**	**15**	**11**	**13**	**8**	**8**	**11**	**7**	
4/11	**7**	**6**	**6**	**17**	**17**	**15**	**12**	**7**	**1**	**1**	**11**
S.M.	***13***	***4***	***7***	***8***	***13***	***10***	***8***	***16***	***9***	***3***	***1***

Table 4- Describing data collected at Sather Gate site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters

This site showed some sediment depositions on 2/26, but without large accumulations. On 3/5 the storm seemed to have brought large amounts of fine pebble substrate. The data collected on 3/18 may be inaccurate, high water levels made sampling difficult.

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Behind LSA

Date	<4mm	4-8	8-11.3	11.3-16	16-23	23-32	32-45	45-64	64-90	90-128
2/11	40	4	4	10	8	14	5	6	9	
2/26	41	5	1	5	10	11	11	7	7	2
3/5	47	5	3	12	9	5	4	9	6	2
3/18	31	9	7	10	11	6	9	5	8	5
4/11	27	5	11	10	12	8	9	13	3	2
S.M.	*41*	*15*	*17*	*9*	*8*	*6*	*2*	*2*		

Table 5- Describing data collected at LSA site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters

This site showed some signs of slight silt accumulation at the time of the 2/11 and 2/26 surveys. There was a much more gravelly appearance to the substrate at the time of the 4/11 survey then previously noticed.

Confluence

Date	**<4mm**	**4-8**	**8-11.3**	**11.3-16**	**16-23**	**23-32**	**32-45**	**45-64**	**64-90**	**90-128**	**128-180**	**180-255**
2/12	**11**	**12**	**7**	**9**	**8**	**16**	**13**	**12**	**9**	**9**	**4**	
2/26	**9**	**10**	**6**	**5**	**7**	**10**	**16**	**12**	**12**	**8**	**4**	**1**
3/5	**5**	**6**	**3**	**7**	**6**	**9**	**19**	**14**	**16**	**15**		
3/18	**7**	**12**	**7**	**12**	**11**	**9**	**13**	**9**	**10**	**10**		
4/11	**6**	**15**	**10**	**18**	**12**	**7**	**15**	**8**	**3**	**6**		
S.M.	***17***	***20***	***13***	***0***	***6***	***4***	***15***	***13***	***2***	***3***	***4***	***3***

Table 6- Describing data collected at Confluence site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters

On 2/12 the gravel bed was characterized by finer substrate as one moved downstream along the bed, with a greater frequency of large rocks in the area of study than downstream portions of the gravel bar. On 2/26 there were some signs of light sediment deposition, however, most substrate <4mm was more sandy than it was silty. On 3/5 the study site was scattered by high flows and was directly in the stream flow. At the time of the 4/12 sampling the stream bed appearance had changed as a result of the storm.

Life Sciences Building

Date	**<4mm**	**4-8**	**8-11.3**	**11.3-16**	**16-23**	**23-32**	**32-45**	**45-64**	**64-90**	**90-128**	**128-180**
2/12	12	3	5	17	12	17	15	8	6	5	
2/26	14	6	10	4	8	14	12	18	8	5	1
3/19	12	5	5	7	11	17	21	12	8	1	
4/12	17	18	15	13	12	14	7	2	2		
S.M.	***29***	***20***	***13***	***4***	***10***	***7***	***7***	***5***	***2***	***2***	

Table 7- Describing data collected at VLSB site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters

There were some signs of erosion due to the storm at the time of the 3/18 survey, such as exposed roots. The gravel bed seemed to have been pulled downstream by high flows.

Gianinni

Date	**<4mm**	**4-8**	**8-11.3**	**11.3-16**	**16-23**	**23-32**	**32-45**	**45-64**	**64-90**	**90-128**	**128-180**
2/12	6	13	5	9	7	15	15	13	11	1	3
2/26	8	10	14	9	12	13	9	13	2	1	
3/19	4	7	5	10	15	20	11	10	16	2	
4/12	35	3	8	14	13	10	8	6	2	1	
S.M.	***9***	***1***	***7***	***7***	***5***	***7***	***17***	***21***	***18***	***5***	***3***

Table 8- Describing data collected at Gianinni site. Numbers are all percentages of substrate in each size class. Size classes are in millimeters.

The stream bed at the time of the 4/11 sampling was dramatically different form previously samplings in that it for the first time looked like a real "gravel bed". Substrate <4mm had a more sandy than silty quality.

Discussion-

It is apparent that the composition of the streambed substrate in any one location is fluid and subject to fluctuation. Changes in size class frequency are particularly pronounced during periods of high rainfall, when stream flow reaches peak levels. It is most likely that these changes in stream bed composition are often the result of natural processes, rather than anthropogenic perturbations. The possibility of natural fluctuation makes it difficult to isolate any particular site as a source of sediment pollution, or evaluate the long term effects of sediment deposition in Strawberry Creek.

The large amounts of gold-colored, silty sediment that accumulated in the pool created by the Little Inch outfall culvert is most likely to be a result of sediment pollution from the Haase Business School construction site. The stark golden color of the sediment deposited there differs greatly from any color observed elsewhere in the stream. It is the same color of sediment laden surface runoff coming form the construction site and observed to be flowing into the creek, entering through storm drains.

The nature of the sediment contamination seems to preclude natural deposition. The sediment was observed in this area of the creek during periods of low flow. The large amounts sediment found in the outfall pool likely resulted from activities such as the cleaning of equipment. landscaping activities or the rinsing of pavement, where a large amount of sediment laden water entered the creek through the Little Inch culvert.

The most important question to answer is whether or not this sediment contamination will have long-term, negative effects on the health of Strawberry Creek. None of the sites downstream of Little Inch showed any signs of lasting effects due to sediment pollution. Any spots of golden silt deposition were relatively small and were washed away in the storms.

However, Little Inch still appears to be impacted by sediment deposition. Although the percentage of substrate less-than-or-equal-to 4 mm has dropped (*Figure 1*), there is still a sticky, muddy layer filling much of the interstitial spaces in the stream bed. This sediment did not wash away in the storms and due to it's clay-like nature will likely remain present at the site.

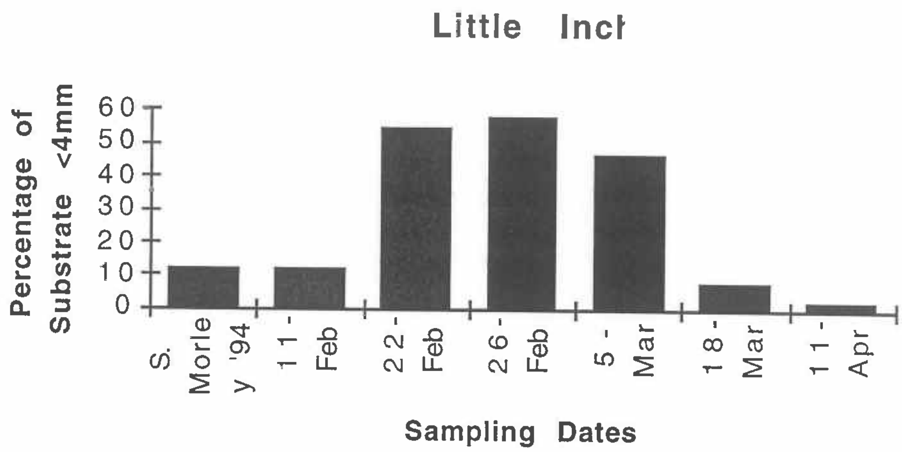

Figure 1- The frequency of substrate less than or equal to 4mm at the Little Inch site throughout the sampling period. Notice that fine sediment appears to have been washed away by storms starting between the 3/5 sampling, lasting through the 3/18 sampling and ending before the 4/11 sampling. The peak in fine substrate observed at 2/26 in a result of sediment washing from the pool into the sampling area, rather than substantial new deposits of sediment into the outfall pool.

It is in evaulation of long term trends that Morleys data is most useful. The 1994 stream bed data can be used to help ascertain the nature of annual fluctuations in stream bed composition. The Stephens Hall, Strawberry Canyon and VLSB sites showed a decrease in the frequency of small size classes (<4mm, 4-8mm), possibly due to the scouring effect of high flows. Other sites showed only minor changes in stream bed compisition.

Conclusions

It is clear that sediment originating from the Haase Business School construction site had a negative impact on Strawberry Creek. Silt blanketing served to destroy the gravel bed habitat at the Little Inch site, and some sediment deposition seen downstream can be safely sourced from the Little Inch outfall as well. Much of the sediment deposited at Little Inch, and other sites, was washed away by the high flows experience in March. However, the gravel bed at the Little Inch site is still affected by sediment that was not washed away in the storms.

Further study should be focused on continued monitoring of Little Inch and other sites to determine the extent of long term effects of sediment deposition. It might also be valuable to start monitoring suspended sediment at several points in the creek, in order to determine base-line levels, and frequency of sediment pollution. Monitoring of the Little Inch culvert and suspended sediment may be particularly important when the turfing of Memorial Stadium is complete and water draining off of the field starts entering Strawberry Creek. Drainage effluent may contain sediment, fertilizers, pesticides and other substances capable of harming organisms in Strawberry Creek.

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