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Geomorphology, sediment analysis and restoration plan for an incised urban creek : Don Dahvee Creek, Monterey, California

Kimberly Anne DeRenzo
California State University, Monterey Bay

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Geomorphology, Sediment Analysis and Restoration Plan for an Incised Urban Creek: Don Dahvee Creek, Monterey, California

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A Capstone Project

Presented to the Faculty of Earth Systems Science and Policy
in the
Center for Science, Technology, and Information Resources
at
California State University, Monterey Bay
In Partial Fulfillment of the Requirement for the Degree of
Bachelors of Science
By
Kimberly Anne DeRenzo
May 6, 2004

ABSTRACT

The progression of urbanization throughout the state of California has had overwhelming and long-term effects on the state's waterways. Don Dahvee Creek appears to be physically declining because of active channel erosion due to urbanization. This erosion has affected the amount of sediment being conveyed into Lake El Estero and the Monterey Bay.

For this assessment the geometry of Don Dahvee Creek, adjacent to Whole Foods Market in Monterey, CA, was examined to determine rates of erosion. Suspended sediment concentration samples (SSC) were taken in an attempt to determine if the creek is a source of water pollution due to bank erosion, creating excess sediment downstream. Using a regression model of SSC it was found that there is no significant difference between the amount of sediment in the water entering and leaving the stream reach, during low-flow conditions. The P-values from the regression of SSC against distance downstream are much greater than .01; therefore, we fail to reject the null hypothesis at 99% confidence, leading to our conclusion that the stream banks are not generating sediment during low-flow conditions. A budget analysis used for discharge determined that there is a loss of 1/3 the water between the upper and lower culvert during low-flow conditions, possibly due to infiltration.

Using cross sectional data it has been determined that the best restoration plan for Don Dahvee Creek involves dressing back and stabilizing both the bed and banks with a combination of vegetation and rock, increasing the width/depth and entrenchment ratio.

INTRODUCTION

The Clean Water Act

In 1972 the Clean Water Act (CWA) was enacted and became the principle law governing pollution control and water quality of the nation's waterways. The CWA established guidelines for restoring and maintaining the chemical, physical, and biological integrity of all rivers, lakes, streams, tributaries, wetlands, and groundwater. Additional objectives were to make all waters of the United States fishable and swimmable by eliminating all pollutant discharges into waters of the U.S. by 1985 and securing healthy waters for fish, shellfish, wildlife, and people by 1983 (Northern California River Watch Annual Report 2002 – 2003). The CWA created a process to quantify the maximum amount of a pollutant from all possible point and nonpoint sources that a typical water body can hold, and still meet water quality standards. This process is called Total Maximum Daily Load (TMDL). The most prevalent and damaging pollutant requiring TMDLs is sediment (Pons, 2003). Physical, chemical, and biological damage associated with sediment flow costs about $16 billion annually in North American (Pons, 2003). Excessive erosion and the transport and deposition of sediment in surface waters are major water-quality problems (Pons, 2003).

Hydrologic and geomorphic impacts of watershed urbanization

By creating innumerable impermeable surfaces, we have altered the sediment load and discharge regime of our nations rivers (Mount, 1995). Urbanization involves widespread application of impermeable materials to the surface of a watershed (Mount, 1995). These impermeable surfaces impact sediment load and discharge of rivers by reducing infiltration of precipitation in watersheds.

Infiltration is the process by which precipitation moves downward through the surface of the earth and replenishes soil moisture, recharges aquifers, and ultimately supports streamflow during dry periods (Viessman and Lewis, 1995). The rate at which infiltration occurs is influenced by such factors as the type and extent of vegetal cover, the condition of the surface crust, temperature, rainfall intensities, physical properties of the soil and water quality (Viessman and Lewis, 1995). Roofs, sidewalks, streets, and parking lots have negligible infiltration capacities (Mount, 1995).

Rain that falls on urbanized areas is rapidly converted to overland flow, which discharges into local rivers and streams through complex runoff subsystems (Mount, 1995). The impact of rainfall and overland flow on bare soils or in watersheds undergoing urbanization will often have sediment yields that are one hundred times higher than natural rates (Mount, 1995). The influx of sediment eroded from uplands to local tributaries during urbanization overwhelms local tributaries, thus leading to aggradation downstream.

Incised urban creeks

Incised rivers can be caused by several factors such as channelization, straightening, encroachment, confinement, urban development, major flood, change in sediment regime and riparian vegetation conversion.

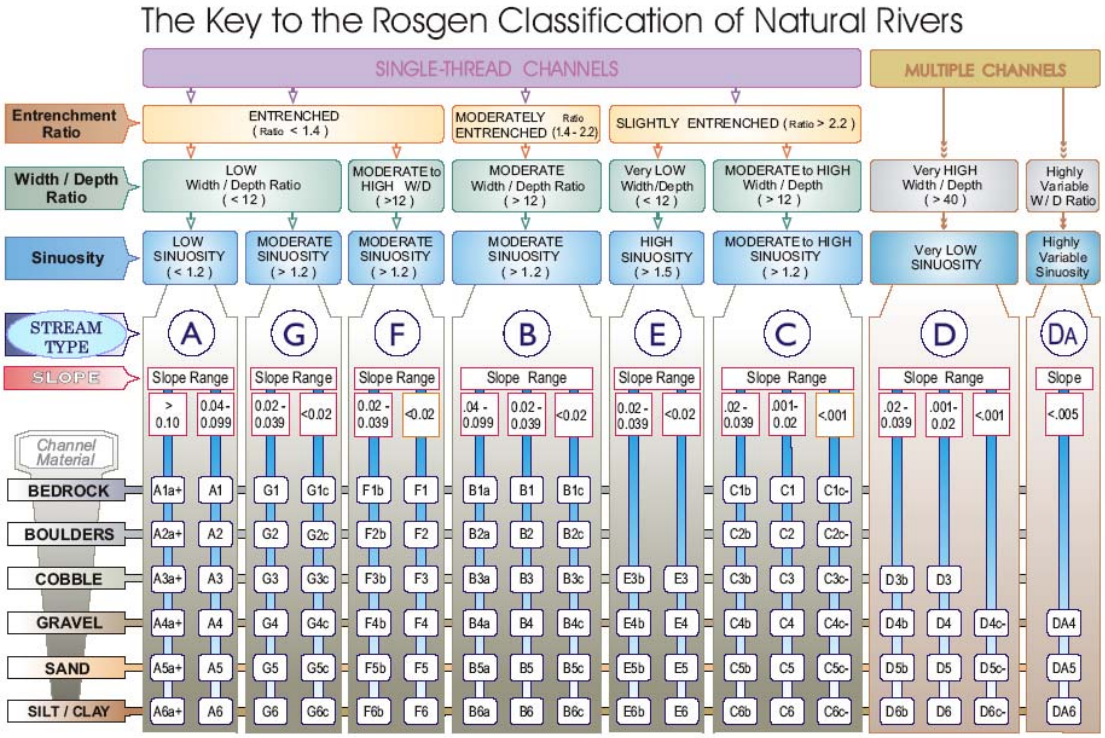
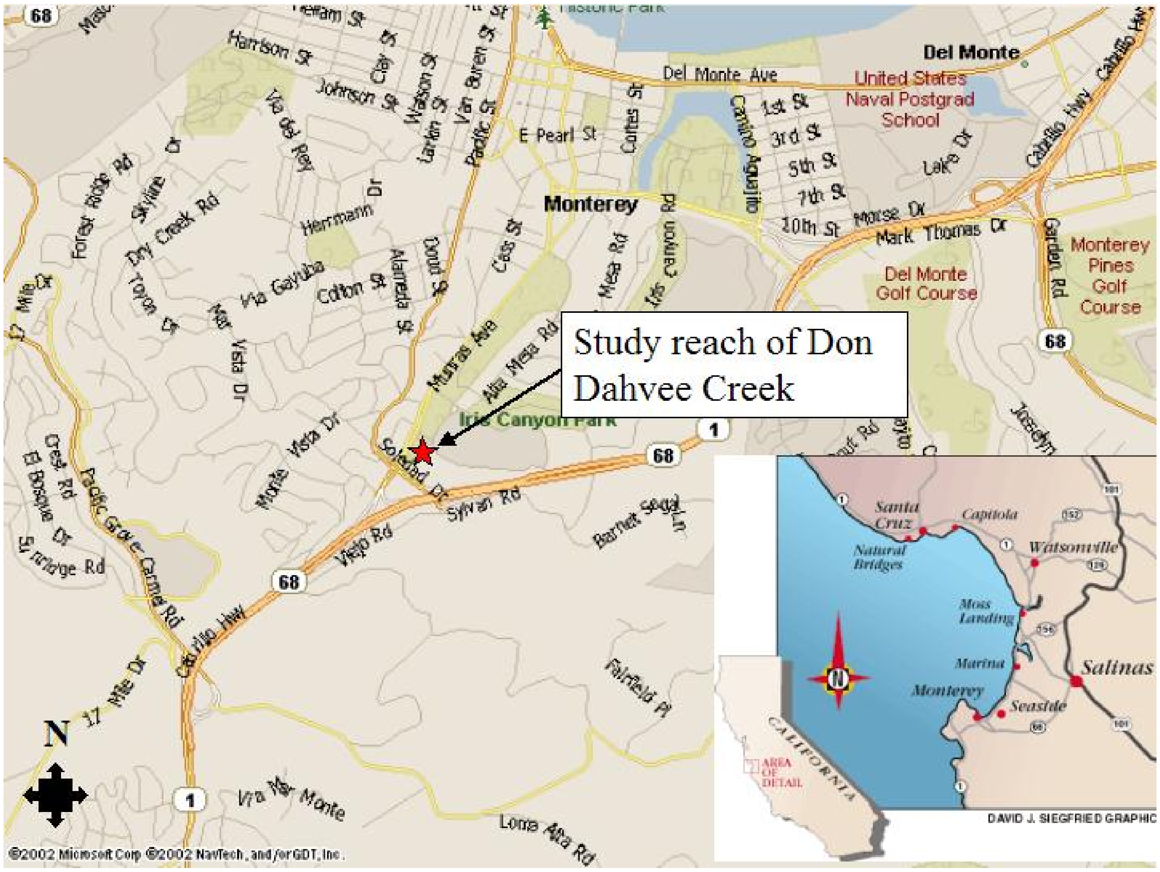


Figure 1. Rosgen classification

Incised streams are channels that are vertically contained and in a general sense have abandoned their floodplains, typical of stream types A, G and F (Fig. 1; Rosgen, 1997). Incised urban creek channels lead to accelerated stream bank erosion, land loss, aquatic habitat loss, lowering of water tables, land productivity reduction, and downstream sedimentation. Rivers, being very dynamic, are subject to change when the variables that shape and maintain their geometry are altered. These variables include velocity, roughness of the boundary, slope, width, depth, discharge, size of sediment debris, and concentration of sediment (Leopold, 1997).

Don Dahvee Creek, located in the city of Monterey, CA is an incised urban creek (Fig. 2). The creek at the location of the study reach has an estimated drainage area of .224

square miles. The water flowing into the creek is discharged from a culvert at a high velocity during storm events, creating a steep gully with a poorly defined step-pool system in the upper reach. Sediment from this erosion site is either transported to El Estero lagoon, or is stored in a lower gradient section of the channel just below the gully.



Study reach of Don Dahvee Creek

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DAVID J. SIEGFRIED GRAPHIC

Figure 2. Location map for Don Dahvee Creek

Restoration of urban creeks

Restoration in the purest sense is often associated with returning a stream to a pristine or pre-disturbance condition (Rosgen, 1997). Returning a stream to a pristine condition is often not possible because the sediment and flow regime, as well as many other variables, have been significantly altered in the watershed (Rosgen, 1997). In cases where pre-disturbance conditions cannot be achieved, we strive to create a stable stream within a disturbed watershed. Restoration of a functioning stable system takes into consideration the morphological potential of each individual stream.

Although Don Dahvee Creek is located in an urban setting, it is protected from development due to its location in the Don Dahvee greenbelt (Fig.3). Don Dahvee greenbelt is one of the few greenbelts in the city of Monterey that represent the link between the grass and oak-covered hillsides of the upper watershed (Haltiner, 1996). While the greenbelt status protects this area from development, the quality of the creek is declining due to severe erosion, which contributes sediment annually to lake El Estero (Haltiner, 1996). In 1983 it was recognized that watershed erosion was the cause of excess sediment in lake El Estero and the construction of a series of sediment basins was recommended (Haltiner, 1996). These measures would be of some benefit to the system, they are based on the assumption that the sediment is being diffused throughout the watershed (Haltiner, 1996). Instead, the source of the sediment is the actual creek banks and channels, which are being eroded and down-cut by each winter's flows (Haltiner, 1996).

Figure 3. Don Dahvee Creek

Urban channel design has traditionally focused solely on erosion control and flood conveyance, ignoring geomorphology and habitat sustainability (Byars, 2002). Like Don Dahvee Creek, the Fort Branch of Boggy Creek in Austin, Texas, has experienced significant downcutting and bank erosion due to urbanization (Byars, 2002). The stream restoration and rehabilitation design of Fort Branch has attempted to arrest further downcutting and bank instability (Byars, 2002). Therefore, a natural design approach, allowing some mobility in the channel bed and utilizing sediment transport as a basis for channel stability was preferred for this project (Byars, 2002). This natural design approach is now being evaluated to provide a better understanding of sediment loads and better design for channel restoration.

In the case of Don Dahvee Creek, without the implementation of an active erosion control system, the processes of erosion and deposition will continue until the creek channel is down-cut completely to the underlying bedrock (Haltiner, 1996). There is evidence of this in the upper section of the study site where granite is exposed in the channel bottom forming a grade control. If the banks of Don Dahvee Creek continue to erode to the point of bedrock exposure, the ecosystem will consist of large, unvegetated deep gorges in place of prior meandering stream and bankside vegetation that occurred naturally (Haltiner, 1996). The traditional approach to prevent further erosion has been the construction of a series of check dams. These check dams are generally constructed out of loose rock, which is placed in a trench excavated across the banks and bottom of the channel and placed to a height of 4 to 6 feet (Haltiner, 1996).

In most check dams the unnatural straightening of the channel and the flattening of the channel gradient causes the river to react by undercutting and often produces a scour hole at the toe. There are local examples of this undercutting at recently constructed check dams located in the Skyline Forest area of Monterey, CA and the Bryant Canyon area of Soledad, CA. The stream in Skyline forest was previously a small gully possible caused by a culvert at highway 68. Culverts are often used inappropriately, forcing too much water into a concentrated, erosive, high velocity flow. In the Skyline Forest case, a series of check dams were installed for grade control, the gully was most likely down cutting and the check dams were installed to arrest the downcutting.

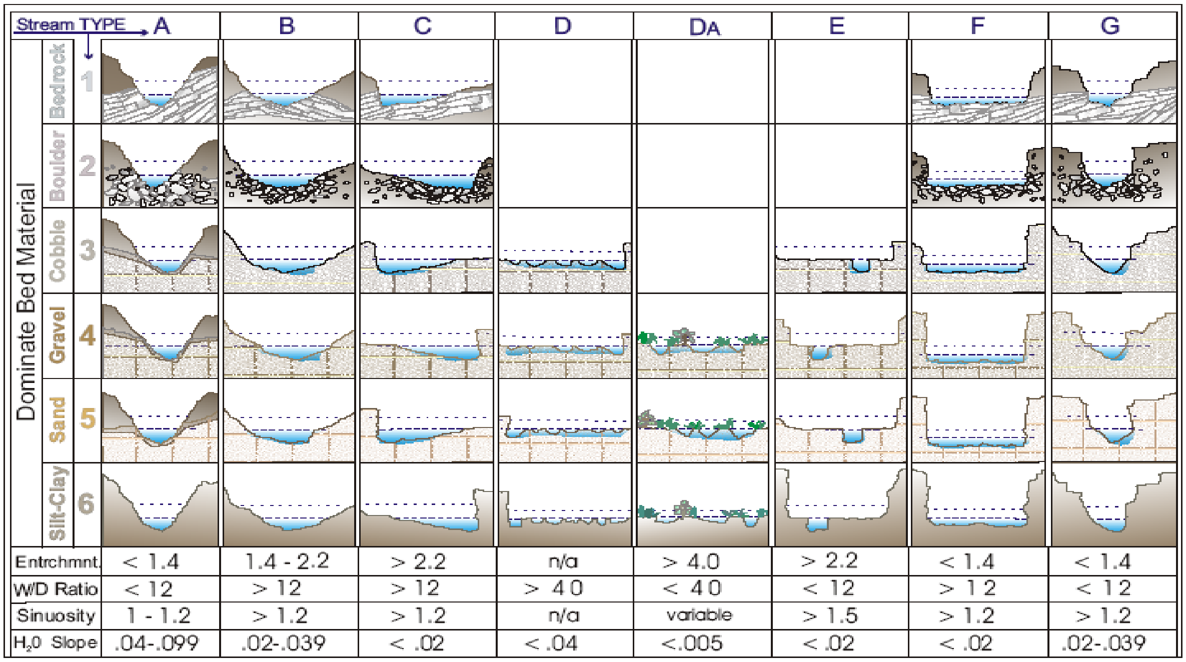
When erosion begins, the stream cuts downward, loses energy and widens. In the check dam system the widening of the channel is often not accounted for. At this site, rocks were inset and grouted to prevent failure from widening. There were obvious problems produced by reducing gradient locally to a low gradient then high then low and so on. Coir rolls were also put in place to stabilize the banks however, the channel is undercutting at these areas possible because they were not embedded in the sides of the banks deep enough. Another problem at this site is that there is not enough energy dissipation at the falls; larger rocks should be placed at the toe of the falls to prevent scouring. The elevation should also be the same to prevent degradation; another visible issue was water leaking through the dam causing standing water where mosquito larvae have been observed.

At Bryant Canyon a drop structure was installed to prevent sheet flow as well as grade control. This stream in a natural setting would be a C-type with a high amount of meander (Fig 1.). In the current setting the channel is fairly straight and the structure is already starting to fail after only one season. There is visible downcutting and knick point migration up the valley. There is a large pile of sediment in front of the first drop structure strictly from the knick point. At the third drop structure there is major undercutting and loss of gradient. At the culvert the grass is being buried by sediment, on the backside of the culvert the river is developing its own channel through deposition of the floodplain and in large flow events the grass is being overpowered and buried by sediment.

The deviation from the natural slope of the river is the clearest reason that drop structures cannot be permanent and should be avoided in erosion control programs (Leopold, 1997). For most river systems the most successful approach to understanding a river is quantitative field observations. A stream classification system is used to quantitatively describe a combination of river features that integrate mutually adjusting variables of channel form (Rosgen, 1997).

STREAM TYPES

Stream types are used in restoration primarily to describe and extrapolate data associated with the reference reach of a stable channel (Rosgen, 1997). Stream types are grouped by morphological similarities and are products of erosional and depositional events over time in specific valley types (Rosgen, 1997). They reflect similarities in entrenchment, channel form, width/depth ratio, sinuosity, slope, and channel materials (Rosgen, 1997). The entrenched incised rivers in this classification system are A, F and G stream types (Fig. 4).



Stream TYPE	A	B	C	D	DA	E	F	G
Entrchmnt.	< 1.4	1.4 - 2.2	> 2.2	n/a	> 4.0	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 40	< 12	> 12	< 12
Sinuosity	1 - 1.2	> 1.2	> 1.2	n/a	variable	> 1.5	> 1.2	> 1.2
H_2O Slope	.04-.099	.02-.039	< .02	< .04	<.005	< .02	< .02	.02-.039

Figure 4. Representation of stream-type classification

Stream type G is an incised, moderately steep channel where the previous floodplain becomes a terrace following incision of the channel. Don Dahvee Creek has the characteristics of a G stream-type. Don Dahvee Creek may have previously been a B-type until it was destabilized by the construction of the culvert in the upper section. Adjustments in channel morphology leads to stream-type changes through evolutionary cycles, through these cycles a B stream type will incise to a G and begin to erode its banks until it reaches a B type again (Fig. 5; Rosgen, 1997). The G stream type tends to have a floodplain, sinuous channel, and lower gradient. To achieve this geometry it will continue to erode its banks to increase its floodprone width (Rosgen, 1997).

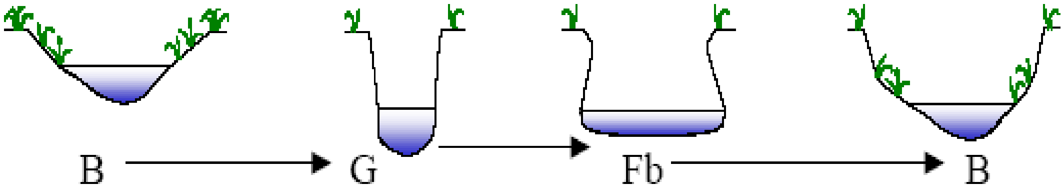


Figure 5. Stream type evolution scenario similar to Don Dahvee Creek

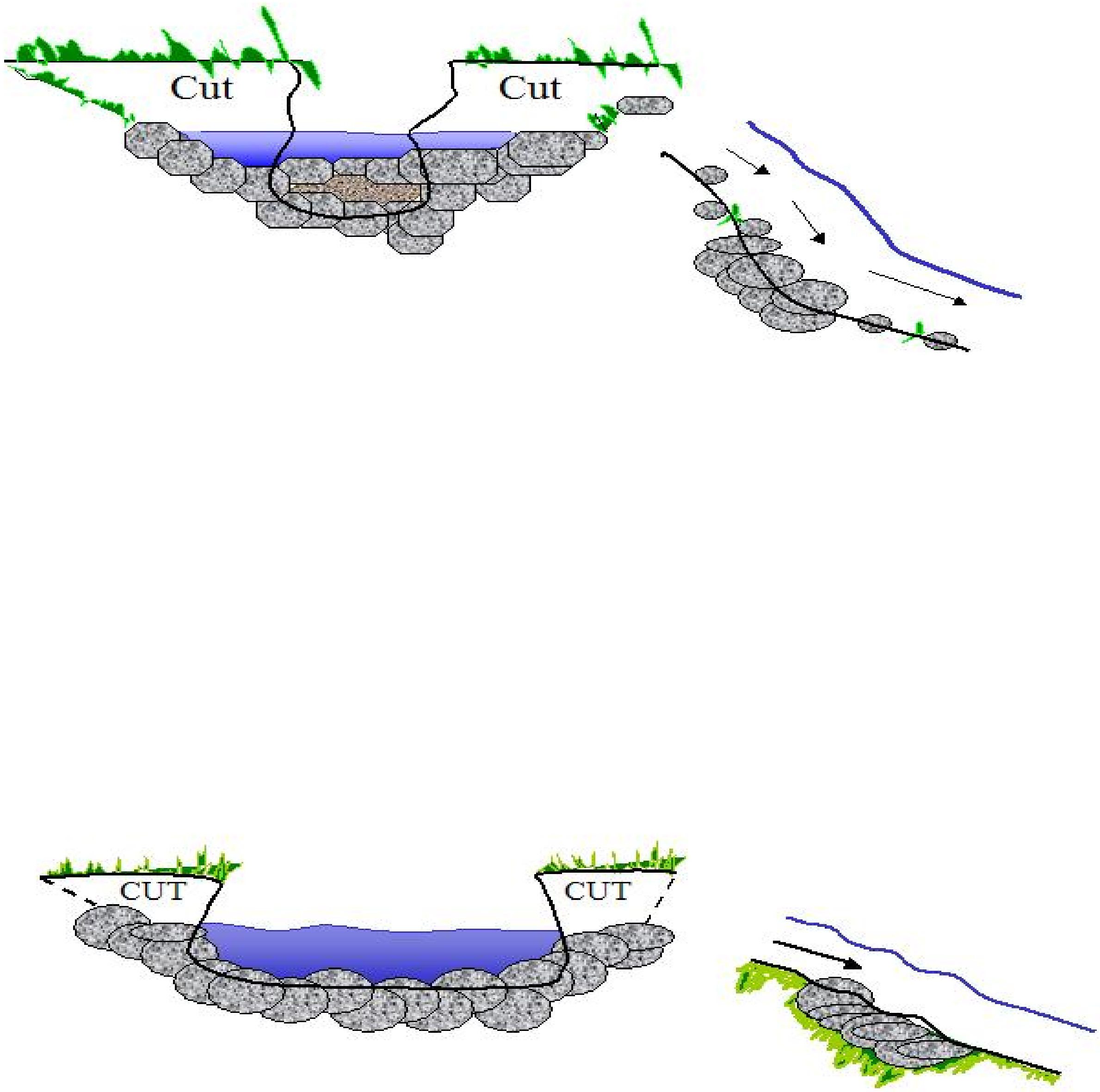
Valley Type

Valley types involve a combination of landforms, land types, soils, geology, basin relief, valley gradient, valley width, and depositional erosional history (Rosgen 1997). The general geomorphic setting that Don Dahvee Creek is located in can best be described, as is relic marine terrace with a valley width of approximately 40 meters and length of 146 meters. The total valley slope is 5.3%, from the upper culvert to the footbridge the valley slope is 6.07%, the valley slope from the footbridge to the lower culvert is 4.7%. In this valley type, Rosgen classification for a B and G stream type are associated with a “V” valley type.

Restoration

In 1997 Rosgen introduced a priority system for incised river restabilization. There are four different restoration priorities, for Don Dahvee Creek Priority 3 restoration plan is best (Fig. 6). The restoration concepts associated with priority 3 are implemented where streams are confined laterally, contained and physical constraints limit the use of priority 1 (Rosgen, 1997). Priority 3 converts the stream to a new stream type without an active floodplain, but containing a floodprone area, converting a G type to a B or F to Bc. This conversion is done by increasing width/depth, entrenchment ratio and by shaping upper slopes and stabilizing both bed and banks (Rosgen, 1997). The advantages of the priority 3 plans are the reduction of the amount of land needed to return the river to a stable form, developments located next to the river need not be re-located due to flooding potential, and improves aquatic habitat (Rosgen, 1997).

Figure 6. Priority 3 restoration design



buildings and paved parking lots (Haltiner, 1996). The creek channel is now 12-15 feet deep in many places and high volumes of sediment have been conveyed to Lake El Estero requiring lake dredging in the mid 1980's (Haltiner, 1997) and as recently as the spring of 2003 dredging in the La Mirada sediment basin was conducted (personal communication, J. Gonzales, January, 2004).

The major storms of the last few years, following major droughts in the late 1970's and 1986-1991 period have re-initiated creek erosion throughout the central coast region (Haltiner, 1997). There has been some erosion control done at the creek; concrete slabs have been placed at the culvert in the upper reach to act as erosion control as well as the construction of a single rock check dam across the channel, located downstream in the Don Dahvee greenbelt area (Haltiner, 1996).

The Project

The goal of this study was to determine the discharge, and erosion taking place in the study reach of Don Dahvee Creek. Don Dahvee Creek remains at low flow conditions throughout most of the year with the exception of winter rain events when large amounts of water enter the system. It is hypothesized that during these large rain events excess sediment is produced and large amounts of bank erosion takes place. Geomorphic data including bank and bed erosion rates, bed geometry, and cross-sectional geometry were collected, during low-flow conditions, in order to recommend a long-term restoration and monitoring program to the City of Monterey. This documentation was used to answer the question of whether Don Dahvee Creek is incising, widening and generating excess sediment through erosion processes. In order to test the hypothesis that a large amount of erosion is taking place during high-flow events SSC samples were taken during low-flow conditions in order to eliminate any erosion problems during normal low-flow conditions.

METHODS

Suspended Sediment

Suspended sediment samples were taken using a DH48 sampler when water flow was deep enough, when water flow was not deep enough a grab sample was scooped into a sample bottle. Seven samples were chosen in relation to cross section surveys. Each sample was taken in the middle of the channel at 7, 20, 52, 70, 85, 110 and 146 meters, upstream from the lower culvert. To determine concentration of sediment in each water sample, a filtration process was used following the geology capstone protocol. A summary of this protocol can be seen below.

After each mass was recorded the weight was entered into Excel. To determine the amount of sediment in each sample the equations used were as follows, the dry mass of sediment, filter paper and tin was subtracted from the dry mass of filter paper and tin to determine the amount of solids. To determine the amount of water the total bottle, water and sediment weight was subtracted from the dry mass of the bottle and the total amount of solids. Dividing the amount of water by the density of water and then dividing again by one thousand found volume of water in liters. The total SSC in grams per liter was found by dividing the total amount of solids from the volume of water. The total amount of suspended sediment concentration for each sample site was then entered in to a regression model using Excel.

Discharge

Discharge was measured from both the upper and lower culvert using a bucket to capture flow and a stopwatch to record time.

Field Surveys

Prior to the survey, the area of the creek was inspected for benchmarks and what sections of the creek were going be surveyed. The first cross section was surveyed on the north side of the footbridge in April 2003. This location was chosen because it captured the steep banks of the upper reach and the channel bottom. The 50 meter tape was secured at 0 meters on the west side of the creek valley at the sidewalk on Munras Avenue and was secured on the east side of the channel at approximately 40 meters. The benchmark used was Monterey city well U-19 located approximately 2.5 meters on the north side of the walkway. This point was assigned an elevation of 1.32 meters in figure 6. The rod was placed directly over the triangle engraved on the well cover to establish instrument height. The second cross section was done approximately 36 meters downstream from the north side of the footbridge. On both sides of the creek a total of 12 pieces of re-bar were driven flush against the bank walls. Three pieces of re-bar were driven in on both sides of the bank walls 1.2 meters downstream from the footbridge, and three on both sides of the bank walls approximately 25 meters downstream from the footbridge.

The longitudinal profile was surveyed on two separate days. On April 11, 2003 the lower reach was measured, the 50-meter tape was run from the footbridge (0 meters) approximately 36 meters downstream, and measurements were taken every 2 meters. The upper reach was measured April 28, 2003. The 50-meter tape was placed at the footbridge (0 meters) upstream 18.9 meters. Measurements were taken at each significant break in slope in the channel bottom.

Eight cross-section surveys were completed along the 146-meter reach of Don Dahvee Creek in January 2004. Utilizing the benchmarks and data previous collected, these cross-section surveys were completed on January 17th and 18th (Fig. 7,8,9). These surveys were taken using a auto level #u009261, stadia rod and 50m tape, five sites were chosen in the upper section of the study reach at the upper culvert 0 meters, 7, 20, 42, 52 meters working downstream from the culvert and three sites at the lower section of the study reach, at the footbridge, 70 meters, 25 meters downstream from the footbridge and at the entrance to the lower culvert, 146 meters. The cross sectional data was analyzed by plotting each cross-section in Excel in order to calculate bankfull geometry.

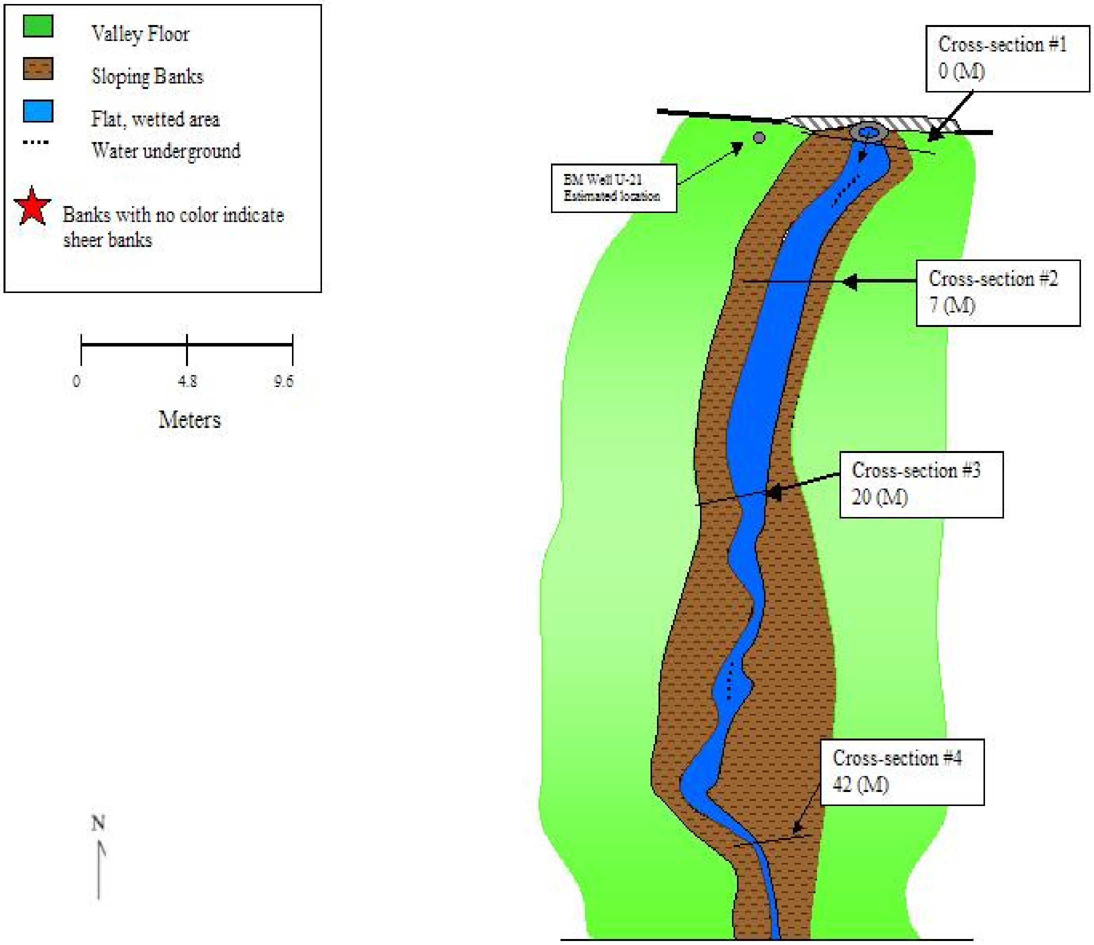


Figure 7. Location of benchmarks and cross section for study reach of Don Dahvee Creek (begin 0 meters at the culvert, end at approximately 46 meters).

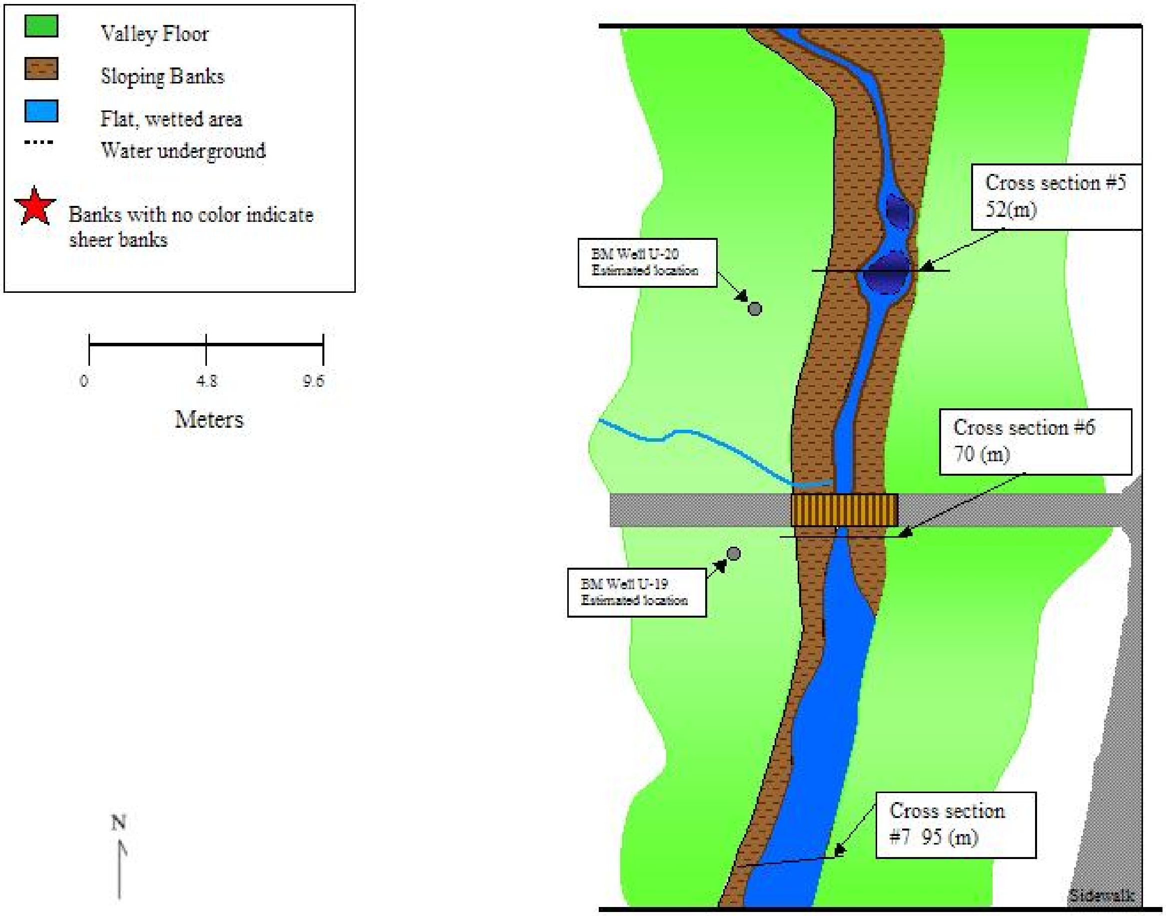


Figure 8. Location of benchmarks and cross section for study reach of Don Dahvee Creek (begin 46, end at approximately 94 meters).

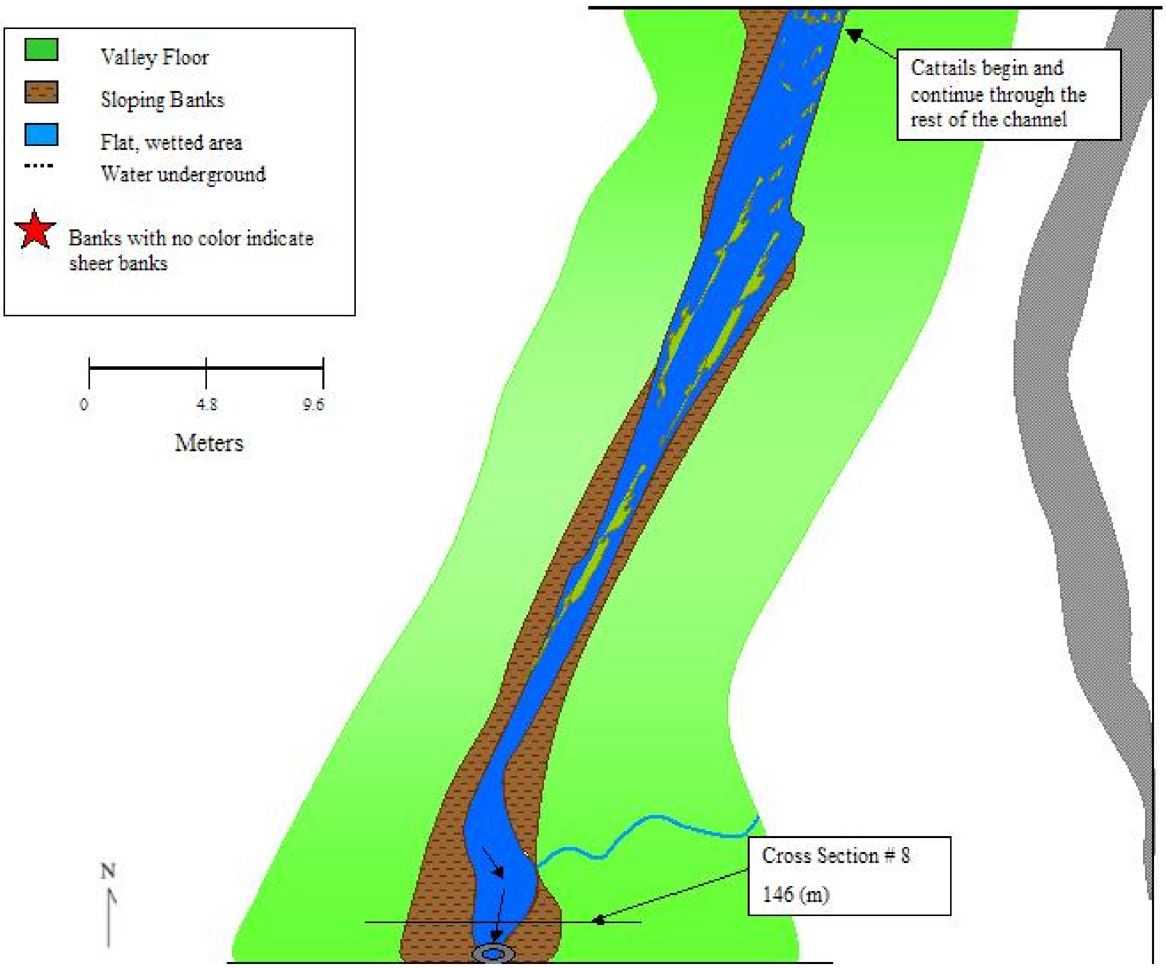


Figure 9. Location of benchmarks and cross section for study reach of Don Dahvee Creek (begin 96 meters, end at approximately 146 meters).

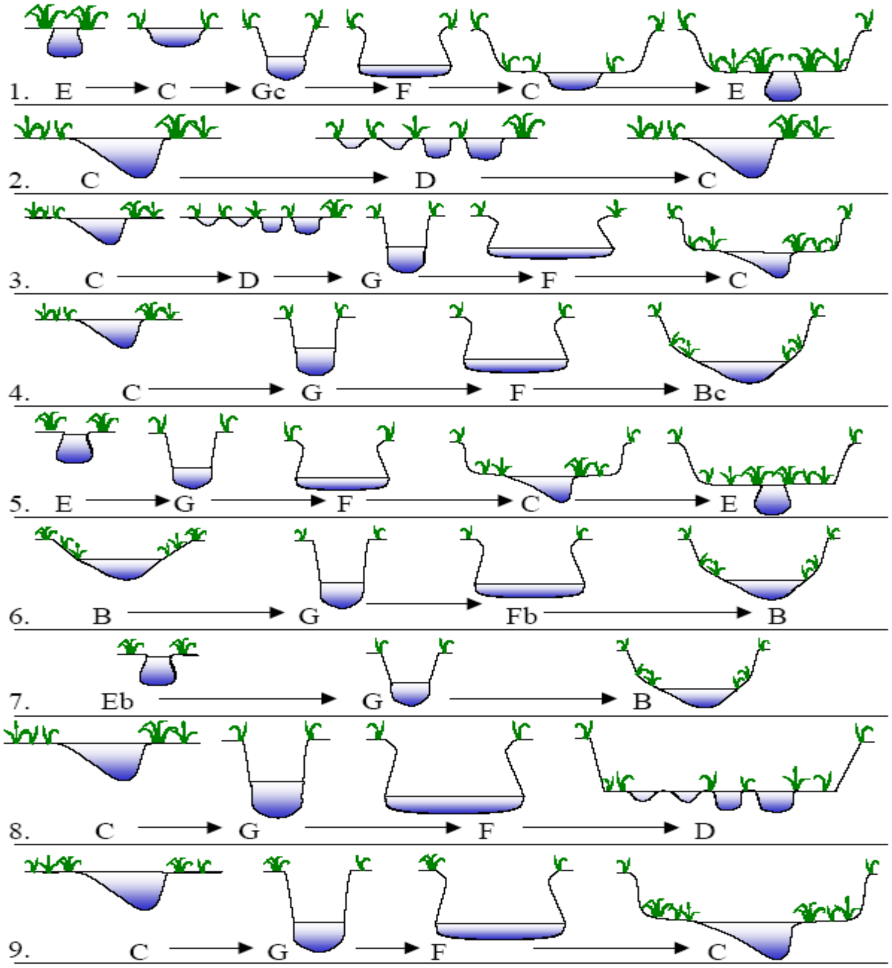


Figure 10. Rosgen stream evolution scenarios

The difference in net aggradation or degradation at the cross-sections located at the footbridge was found by subtracting overall area between 2003 and 2004. A longitudinal profile was taken on February 29, 2004. A 100-meter tape was run from the upper culvert to the footbridge and from the footbridge to the lower culvert. Using an auto-level measurements were taken at each break in slope or area of interest.

RESULTS

Sediment

A regression model between suspended sediment concentration (g/l) (Appendix A) and distance downstream (m) was used to determine whether or not Don Dahvee Creek is exporting sediment from its bed and banks or storing sediment (Appendix B). Table 1 clearly shows that there is not a significant relationship between distance and the amount of sediment being generated. When the regression slope is positive the creek is generating sediment if the slope is negative the creek is sequestering sediment.

Table 1. Regression model results

Date	Regression Slope	R-Squared	P-Value Intercept	N
December 9, 2004	261	0.022	0.78	7
February 4, 2004	24.8	0.078	0.54	7
February 14, 2004	166	0.021	0.75	7
February 17, 2004	207	0.172	0.35	7
February 22, 2004	78.4	0.106	0.48	7
March 2, 2004	145	0.054	0.61	7

Discharge

The discharge results were .03 cf/s at the upper each and .01 cf/s at the lower reach, using a simple budget analysis it was found that 0.02 cfs is being lost due to infiltration.

$$\text{Qin} - \cancel{\text{ET}} - \text{Qout} - \text{I} = \cancel{\text{S}\Delta}$$

So

$$\text{Qin} - \text{Qout} = \text{I}$$

Evapotranspiration and change in surface storage were both assumed zero because there are no data on ET and it is assumed that there is no change in surface storage over the time of this study.

Cross-sections

Cross sections taken at the footbridge in 2003 and 2004 were compared (Fig. 11). It was found that there was overall aggradation of 1.2 meters. The average hydraulic radius for 2003 and 2004 at the footbridge was found to be 0.49 m. A longitudinal profile was measured to show the shape of the channel and calculate the slope, the average slope is 2% (Fig. 12). All 2004 cross-sectional data are located in Appendix C. Bank pins that were placed at the 2003 footbridge cross-section could not be relocated.

Figure 11. Comparison of net aggradation between 2003-2004 at the footbridge.

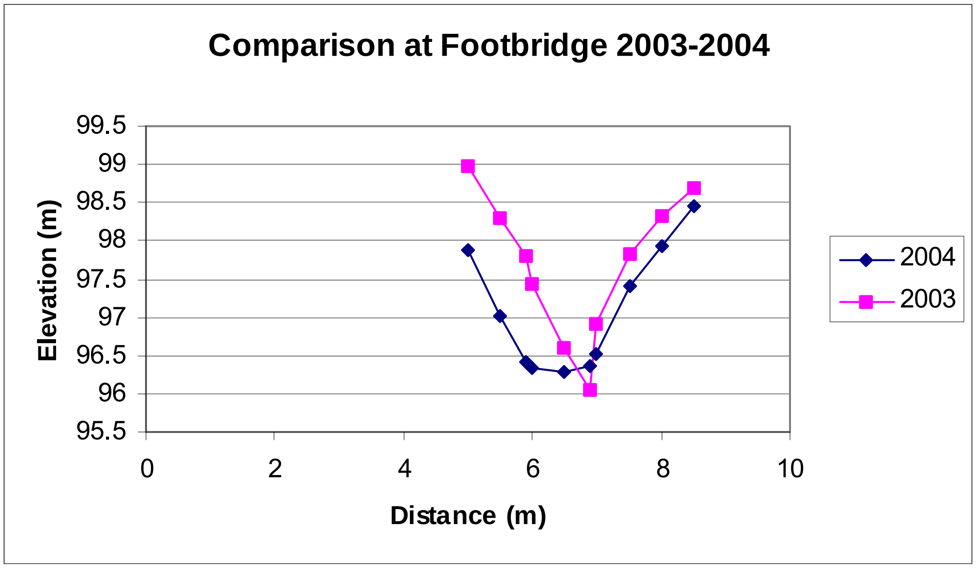
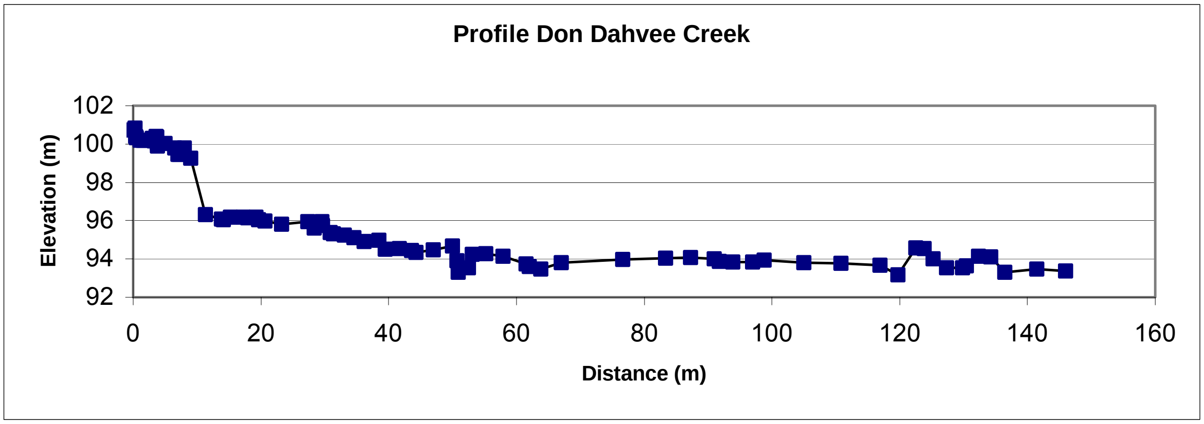


Figure 12. February 29, 2004 longitudinal profile of Don Dahvee Creek



Discussion

It was hypothesized that during large rain events excess sediment is produced and large amounts of bank erosion takes place at the study reach of Don Dahvee Creek. Because data were collected only during low-flow conditions, the question of how much large rain events impact the creek remains unanswered. However erosion from low-flow conditions was minimal.

The study reach of Don Dahvee Creek is eroding because of the steep, raw banks of the creek over the long-term. Repeat surveys indicate that annual bank erosion is occurring. The study reach is apparently following Rosgen's typical evolutionary cycle of a stream that was once a B-type and will continue to erode its banks until it becomes a B-type again (Fig. 5).

The results of the regression model for SSC show that there is no significant difference between the amount of sediment in the water entering and leaving the stream reach during low-flow conditions. The P-values from the regression of SSC against distance downstream are much greater than .01; therefore, we fail to reject the null hypothesis at 99% confidence, leading to our conclusion that the stream banks are not generating sediment during low-flow conditions, nor is the stream reach sequestering SSC. These results also show that the amount of sediment being liberated varies throughout the upper and lower reaches. Therefore no relationship can be drawn between the length of the channel and the movement of sediment.

From the data comparison of the 2003 and 2004 cross-sections it was found that the lower portion of the creek is aggrading its bed and widening its banks, emulating a natural river, trying to regain some semblance of equilibrium (Fig. 13).

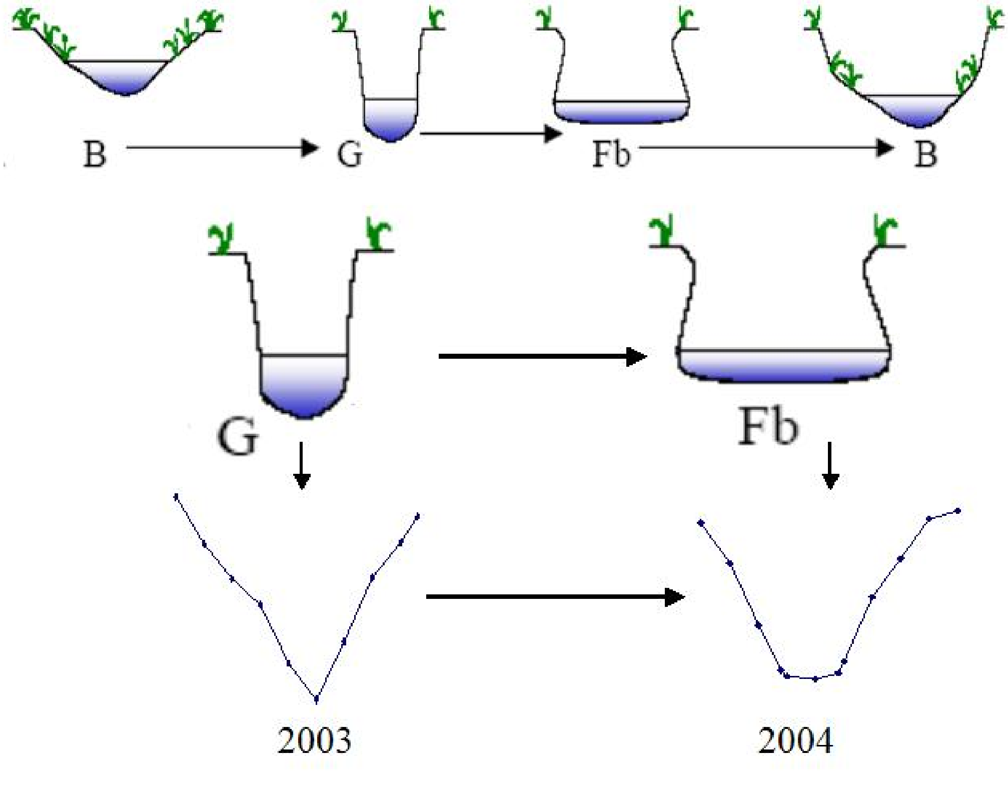


Figure 13. Evolution of Don Dahvee Creek. Don Dahvee creek is following the typical evolutionary pattern of an incised stream eroding its banks to reach equilibrium. In this figure the cross section at the footbridge is evolving from a G stream type to an Fb and will eventually return to a B stream type.

The net loss of 30% of the water flow, most likely due to infiltration may be in relationship to the survey wells located along the eastern sided of the creek. Attempts were made to contact the Regional Water Quality Board, Specifically the “Underground Tank Clean-Up” task force headed by Eric Gobler, however these attempts were unsuccessful.

The creek channel at the footbridge has the largest hydraulic radius, meaning that it has a smaller amount of water in its cross-section in contact with the wetted perimeter. This creates less friction, which in turn reduces energy loss and therefore allows for greater velocity. This indicates that at the footbridge the creek is more efficient in high flow situations compared to 25 meters downstream where the hydraulic radius is extremely low. The creek at 25 meters has a smaller hydraulic radius meaning that a larger amount of water is in contact with the channel bed and bank sides. This results in greater friction, more energy loss and reduced velocity. Therefore 25 meters downstream from the footbridge the creek is less efficient than at the footbridge.

The shape of the cross-section controls the area of maximum velocity in any river channel and the point of maximum velocity at each site varied, with hydraulic radius increasing from the upper culvert to the footbridge, decreasing from the footbridge down to 25 meters and then increasing again at the lower culvert. Because Don Dahvee Creek has a slope of .02 in the upper section it can be classified as a G stream-type, the lower section, below the footbridge has a slope < .02 in the upper reach and is a Fb stream-type.

These results lead me to recommend two separate variations of priority 3 restorations. Priority restoration plan 3 would reduce the amount of land needed to return the river to a stable form, developments adjacent to the river would remain unaffected and aquatic and riparian habitat would be improved (Fig 6). For the lower 76 meters of the creek a variation of priority 2 would also be appropriate (Fig. 6) decreasing bank height, streambank erosion, reduction of sediment and the opportunity for riparian vegetation to help stabilize the banks.

The results from the data collected show that Don Dahvee Creek has generated, and will continue to generate excess sediment over the long-term. Based on geomorphology it is recognized that the upper section of Don Dahvee Creek will continue to change from a G stream-type to a B-type until it reaches some level of equilibrium. Therefore, I feel that further monitoring on the entire creek is necessary and restoration should be implemented.

The cross-sectional data and suspended sediment results provide a detailed description of this geomorphically sensitive site and can be used as an indicator of morphologic changes associated with urban watershed development, monitoring and restoration This data set can serve as a foundation for monitoring changes in the Don Dahvee greenbelt.

Acknowledgements

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Appendix A: Suspended Sediment Concentration

1st 12/9

CSS (g/liter)	mg/liter	Distance (m)
0.2304	230.3639	7
0.3128	312.8409	20
0.1442	144.1810	42
0.3317	331.6961	52
0.2409	240.8724	70
0.2163	216.2798	85

4th 2/14/04

CSS (g/liter)	mg/liter	Distance (m)
0.0771	77.106379	7
0.2237	223.70593	20
0.1958	195.77073	52
0.0253	25.285177	70
0.2742	274.17255	85
0.1641	164.06381	110
0.0650	64.957504	146

5th 2/22/04

CSS (g/liter)	mg/liter	Distance (m)
0.0875	87.5000	7
0.0682	68.2377	20
0.1009	100.9192	52
0.0894	89.4309	70
0.0803	80.2594	85
0.2260	225.9898	110

2nd 2/4/04

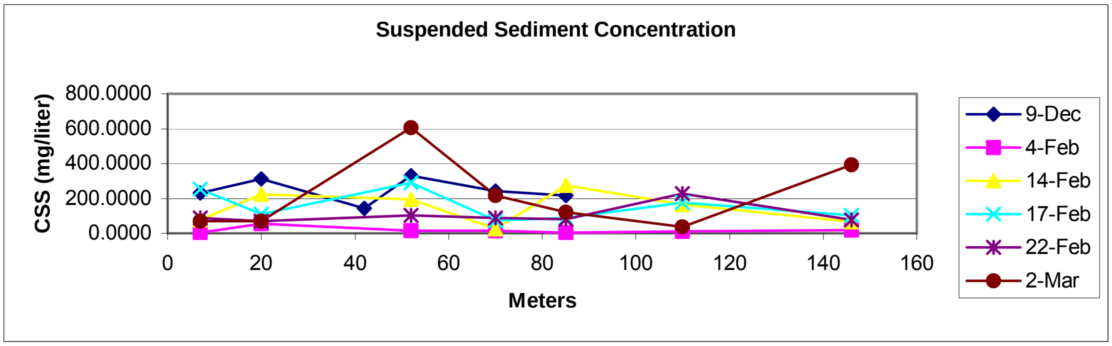
CSS (g/liter)	mg/liter	Distance (m)
0.0044	4.3905	7
0.0568	56.7577	20
0.0156	15.5946	52
0.0135	13.4574	70
0.0035	3.5000	85
0.0107	10.7000	110
0.0188	18.7742	146

3rd 2/17/04

CSS (g/liter)	mg/liter	Distance (m)
0.2535	253.4657149	7
0.1116	111.5531962	20
0.2886	288.6336693	52
0.0720	71.95875295	70
0.0890	89.03122807	85
0.1764	176.3750835	110
0.1045	104.4811496	146

6th 3/2/04

CSS (g/liter)	mg/liter	Distance (m)
0.0715	71.4806	7
0.0680	68.0162	20
0.6038	603.7725	52
0.2170	216.9863	70
0.1203	120.3439	85
0.0362	36.1735	110
0.3944	394.3780	146



Appendix B: Regression Models for Suspended Sediment Concentration

SUMMARY OUTPUT 22-Feb

Regression Statistics	
Multiple R	0.3258678
R Square	0.1061898
Adjusted R Square	-0.0725722
Standard Error	56.76296
Observations	7

ANOVA

	df	SS	MS	F	Significance F
Regression	1	1913.9816	1913.982	0.5940291	0.4756883
Residual	5	16110.168	3222.034		
Total	6	18024.149			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	78.466576	39.460537	1.988482	0.1034504	-22.969797	179.90295	-22.969797	179.90295
X Variable 1	0.3646516	0.4731232	0.770733	0.4756883	-0.8515484	1.5808516	-0.8515484	1.5808516

SUMMARY OUTPUT 14-Feb

Regression Statistics	
Multiple R	0.1457499
R Square	0.021243
Adjusted R Square	-0.1745084
Standard Error	100.06808
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1086.6826	1086.683	0.10852	0.755187
Residual	5	50068.104	10013.62		
Total	6	51154.786			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	165.67095	69.565438	2.381512	0.063047	-13.152406	344.49431	-13.152406	344.49431
X Variable 1	-0.2747645	0.8340745	-0.32942	0.755187	-2.4188176	1.8692886	-2.4188176	1.8692886

Appendix B: Continued

SUMMARY OUTPUT 2-Mar

Regression Statistics	
Multiple R	0.2333707
R Square	0.0544619
Adjusted R Square	-0.1346457
Standard Error	224.47622
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	14511.907	14511.9	0.28799	0.6145172
Residual	5	251947.87	50389.6		
Total	6	266459.78			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	145.59259	156.05163	0.93298	0.39366	-255.55023	546.73541	-255.55023	546.73541
X Variable 1	1.0040874	1.871025	0.53665	0.61452	-3.8055277	5.8137024	-3.8055277	5.8137024

SUMMARY OUTPUT 9-Dec

Regression Statistics	
Multiple R	0.147841
R Square	0.021857
Adjusted R Square	-0.22268
Standard Error	75.53593
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	509.9822	509.98221	0.08938	0.7798541
Residual	4	22822.7	5705.676		
Total	5	23332.69			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	261.7966	61.06514	4.2871701	0.01277	92.252282	431.34099	92.252282	431.34099
X Variable 1	-0.34256	1.1458	-0.2989675	0.77985	-3.5238133	2.8386996	-3.5238133	2.8386996

Appendix B: Continued

SUMMARY OUTPUT 17-Feb

Regression Statistics	
Multiple R	0.415168
R Square	0.172364
Adjusted R Square	0.006837
Standard Error	85.03279
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7529.2	7529.23	1.0413	0.354327
Residual	5	36153	7230.5758		
Total	6	43682			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	207.1269	59.113	3.5039028	0.01721	55.17183	359.08192	55.171827	359.08192
X Variable 1	-0.72324	0.7088	-1.0204432	0.35433	-2.545151	1.0986644	-2.545151	1.0986644

SUMMARY OUTPUT 4-Feb

Regression Statistics	
Multiple R	0.278925
R Square	0.077799
Adjusted R Square	-0.10664
Standard Error	19.09452
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	153.79	153.79332	0.42181	0.544685
Residual	5	1823	364.6007		
Total	6	1976.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	24.83197	13.274	1.8707013	0.12031	-9.290263	58.954202	-9.290263	58.954202
X Variable 1	-0.10337	0.1592	-0.6494713	0.54468	-0.512484	0.3057521	-0.512484	0.3057521

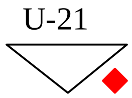
Appendix C: Cross-sectional data used in Excel

0m upper culvert			**7m downstream from upper culvert**		
1/20/2004			1/20/2004		
Dist (m)	Elev (m)	Corr. Elev.	Dist (m)	Elev (m)	Corr. Elev.
0	3.335	93.325	0	3.335	93.325
0	1.255	95.405	0	1.94	94.72
0.5	1.2575	95.4025	0.5	1.96	94.7
1	1.28	95.38	1	1.935	94.725
1.5	1.2575	95.4025	1.5	1.99	94.67
2	1.25	95.41	2	1.98	94.68
2.5	1.215	95.445	2.5	1.9875	94.6725
3	1.185	95.475	3	1.975	94.685
3.5	1.235	95.425	3.5	2.005	94.655
4	1.41	95.25	4	2.035	94.625
4.5	1.695	94.965	4.5	2.75	93.91
5	1.925	94.735	5	2.895	93.765
5.5	2.17	94.49	5.5	3.005	93.655
6	2.45	94.21	6	2.775	93.885
6.5	2.525	94.135	6.5	3.235	93.425
7	2.65	94.01	6.85	3.875	92.785
7.3	2.51	94.15	7	3.905	92.755
7.5	2.205	94.455	7.5	3.39	93.27
8	1.745	94.915	8	3.305	93.355
8.5	1.465	95.195	8.5	3.32	93.34
9	1.125	95.535	9	3.245	93.415
9.5	0.785	95.875	9.5	3.29	93.37
10	0.525	96.135	10	3.275	93.385
10.5	0.22	96.44	10.5	3.205	93.455
11	3.335	93.325	11	2.305	94.355
			11.5	1.975	94.685
			12	3.335	93.325

BM well U-21

Permanent benchmarks

Permanent benchmarks are well caps U-21, U-20, and U-19. They are located on eastern side of the creek. There are two screws on each cap and the rod was placed on the screw furthest away from the white lettering of each cap.



Appendix C: Continued

20 meters from the upper reach culvert.

1/18/2004

Dist (m)	Elev (m)	Corr. Elev.
0	1.93	96.14
0	1.4	96.67
0.5	1.405	96.665
1	1.41	96.66
1.5	1.42	96.65
2	1.46	96.61
2.5	1.455	96.615
3	1.46	96.61
3.5	1.5	96.57
4	1.675	96.395
4.5	1.865	96.205
5	2.275	95.795
5.5	3.13	94.94
6	3.77	94.3
6.5	3.79	94.28
7	3.63	94.44
7.33	3.695	94.375
7.5	3.08	94.99
8	2.685	95.385
8.5	2.435	95.635
9	1.9	96.17
9.5	1.695	96.375
10	1.625	96.445
10.5	1.565	96.505
11	1.515	96.555
11.5	1.41	96.66
12	1.345	96.725
12.5	1.23	96.84
13	1.13	96.94
13.5	1.07	97
14	0.93	97.14
14.5	0.75	97.32
15	0.575	97.495
15.5	0.365	97.705
16	0.185	97.885
	1.94	96.13

BM well U-21

42m downstream from upper culvert.

1/18/2004

Dist (m)	Elev. (m)	Corr. Elev.
0	0	99.38
0	0	98.568
0.5	0.005	98.51
1	0.01	98.525
1.5	0.015	98.505
2	0.02	98.525
2.5	0.025	98.525
3	0.03	98.51
3.5	0.035	98.505
4	0.04	98.48
4.5	0.045	98.44
5	0.05	97.785
5.5	0.055	97.34
6	0.06	96.905
6.5	0.065	96.39
7	0.07	96.345
7.33	0.0733	95.69
7.5	0.075	96.275
8	0.08	96.41
8.5	0.085	96.975
9	0.09	97.68
9.5	0.095	98.06
10	0.1	98.425
10.5	0.105	98.525
11	0.11	98.61
11.5	0.115	98.69
12	0.12	98.735
12.5	0.125	98.8
13	0.13	98.955
13.5	0.135	99.095
14	0.14	99.23
14.5	0.145	99.4
15	0.15	99.6
15.5	0.155	99.595
16		99.595
		99.38

BM well U-20

Appendix C: Continued

1/18/2004

52m downstream from upper culvert (Deep Pool).

Dist (m)	Elev (m)	Corr. Elev.
0	0.31	99.38
0	1.58	98.11
0.5	1.595	98.095
1	1.6	98.09
1.5	1.58	98.11
2	1.535	98.155
2.5	1.58	98.11
3	1.595	98.095
3.5	1.585	98.105
3.8	1.565	98.125
4	1.75	97.94
4.5	2.54	97.15
5	4.715	94.975
5.5	4.92	94.77
6	4.965	94.725
6.5	4.895	94.795
7.33	5.075	94.615
7.5	2.135	97.555
8	1.57	98.12
8.5	1.455	98.235
9	1.415	98.275
9.5	1.3675	98.3225
10	1.295	98.395
10.5	1.245	98.445
11	1.16	98.53
11.5	1.025	98.665
12	0.9	98.79
12.5	0.785	98.905
13	0.59	99.1
13.5	0.51	99.18
14	0.35	99.34
14.5	0.25	99.44
15	0.195	99.495
15.5	0.095	99.595
16	0.095	99.595
	0.31	99.38

BM well U-21

1/20/2004

Footbridge downstream side, lower reach

Dist (m)	Elev (m)	Corr. Elev.
0	0.825	98.35
0.5	0.795	98.38
1	0.7975	98.3775
1.5	0.75	98.425
2	0.755	98.42
2.5	0.745	98.43
3	0.725	98.45
3.5	0.76	98.415
4	0.755	98.42
4.5	0.76	98.415
5	1.305	97.87
5.5	2.15	97.025
5.9	2.77	96.405
6	2.84	96.335
6.5	2.88	96.295
6.9	2.81	96.365
7	2.65	96.525
7.5	1.77	97.405
8	1.245	97.93
8.5	0.71	98.465
9	0.6	98.575
9.5	0.525	98.65
10	0.49	98.685
10.5	0.485	98.69
11	0.455	98.72
11.5	0.395	98.78
12	0.33	98.845
12.5	0.275	98.9
13	0.23	98.945
13.5	0.185	98.99
14	0.1275	99.0475
14.5	0.825	98.35

BM well U-19

Appendix C: Continued
1/19/2004

25.45m downstream from foot bridge

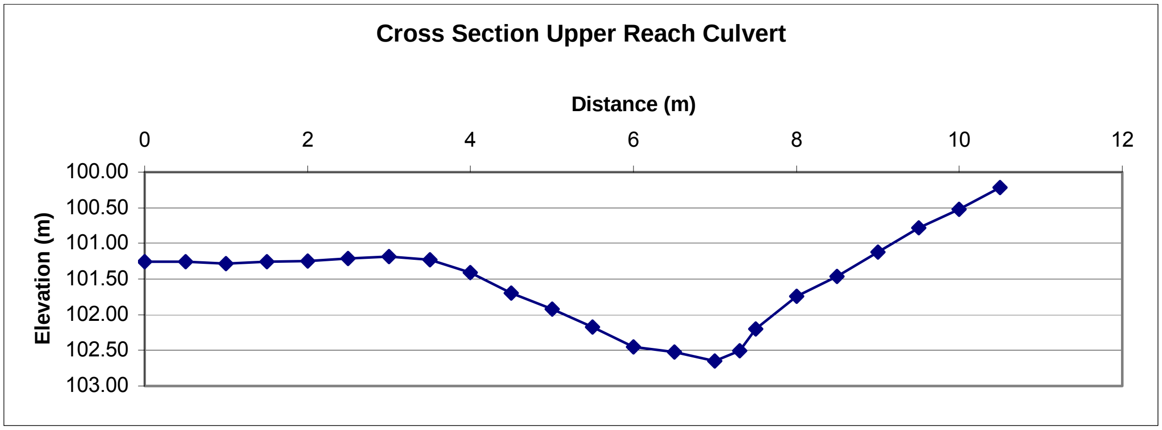
Dist (m)	Elev (m)	Corr. Elev.
0	0.115	99.77
0	1.295	98.59
0.5	1.315	98.57
1	1.3075	98.5775
1.5	1.32	98.565
2	1.35	98.535
2.5	1.4	98.485
3	1.43	98.455
3.5	1.54	98.345
4	2.07	97.815
4.5	2.17	97.715
5	2.11	97.775
5.5	2.1	97.785
6	1.995	97.89
6.5	2.08	97.805
7	2.15	97.735
7.1	1.55	98.335
7.5	1.505	98.38
	0.115	99.77

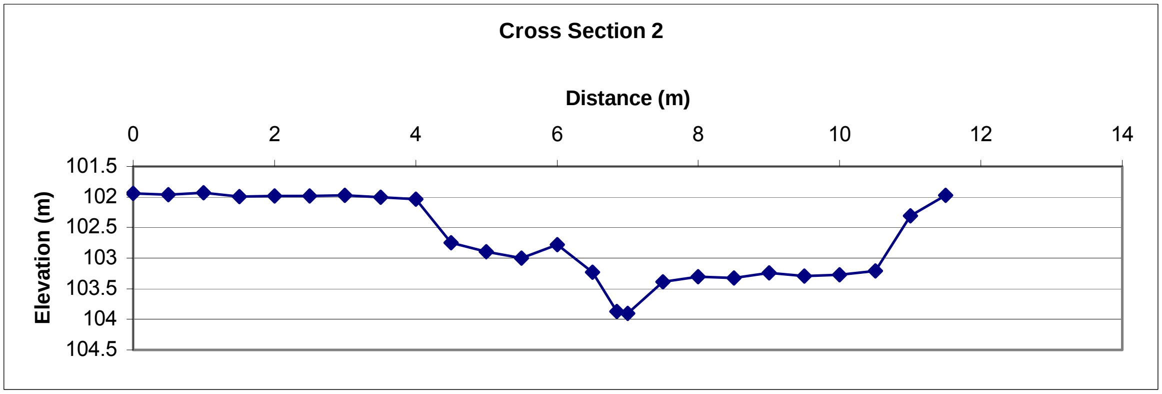
Cross section lower reach culvert

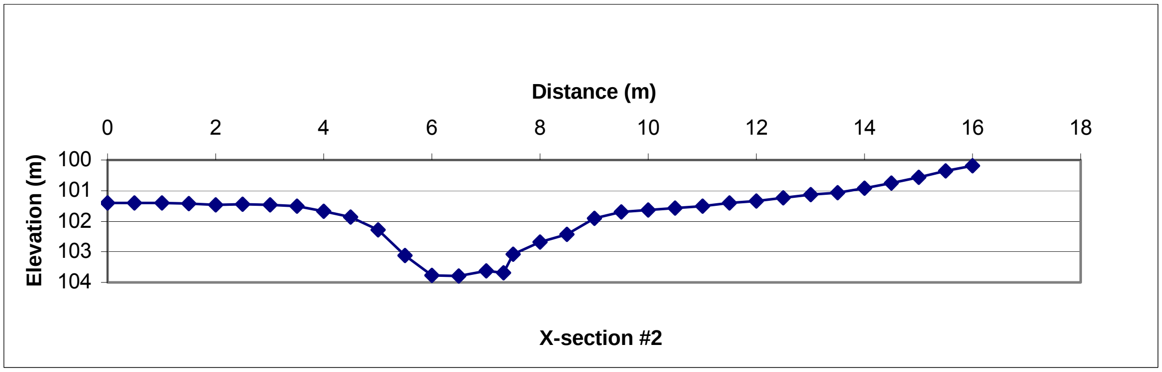
Dist (m)	Elev (m)	Corr. Elev.
0	0.115	99.77
0	3.415	96.47
0.5	3.46	96.425
1	3.455	96.43
1.5	3.365	96.52
2	3.41	96.475
2.5	3.48	96.405
3	3.55	96.335
3.5	3.635	96.25
4	3.925	95.96
4.5	4.17	95.715
5	4.54	95.345
5.5	4.64	95.245
6	4.645	95.24
6.5	4.655	95.23
6.6	4.61	95.275
7	4.15	95.735
7.5	3.62	96.265
8	3.355	96.53
8.5	3.145	96.74
9	3.16	96.725
	0.115	99.77

BM Well U-19

Appendix C: Cross-sections

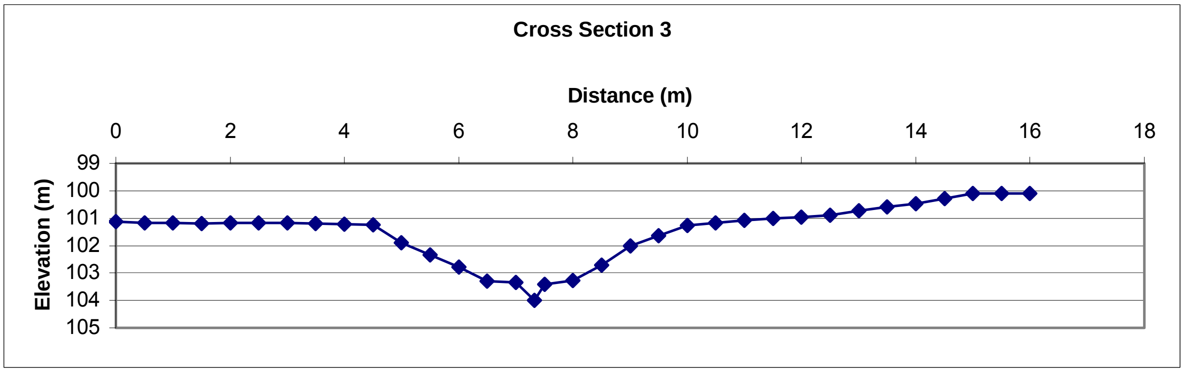

Cross Section Upper Reach Culvert

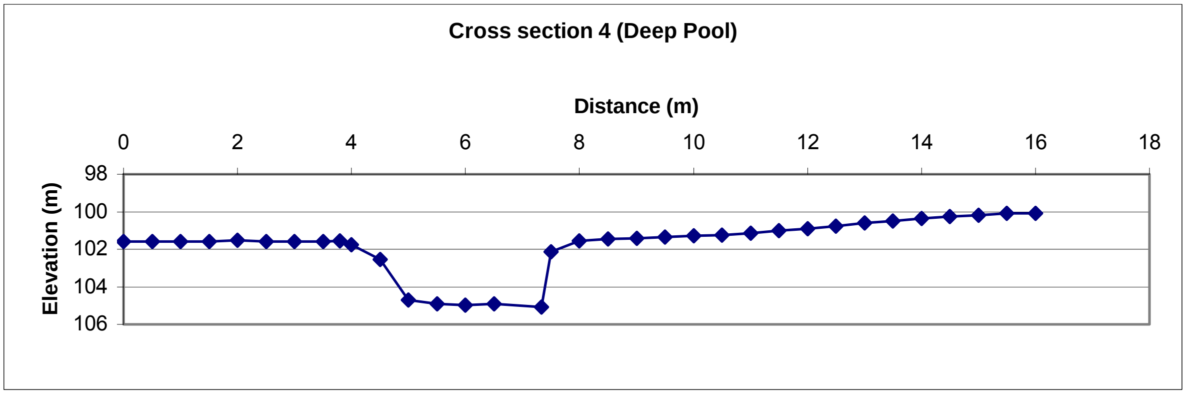

Cross Section 2

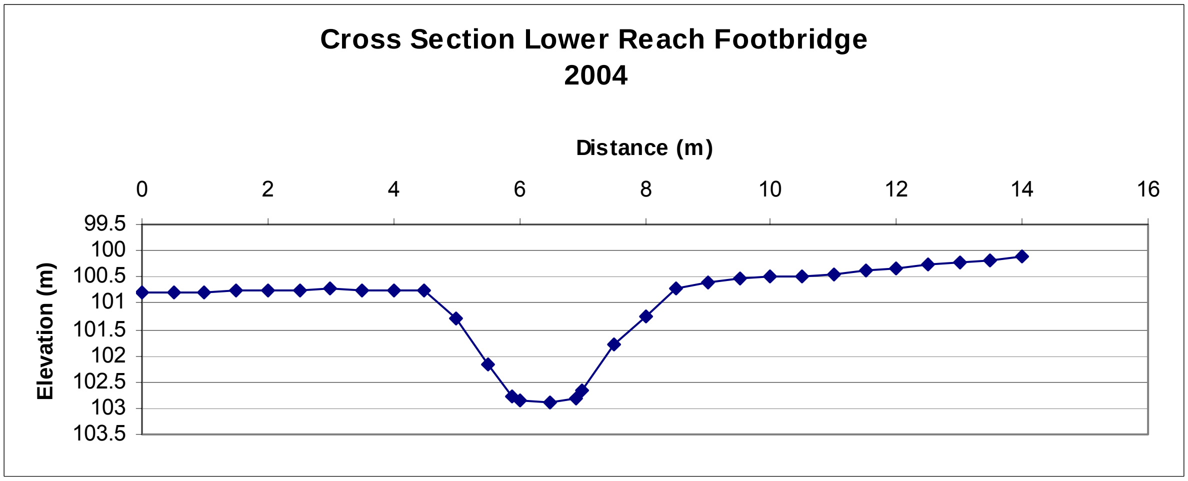


X-section #2

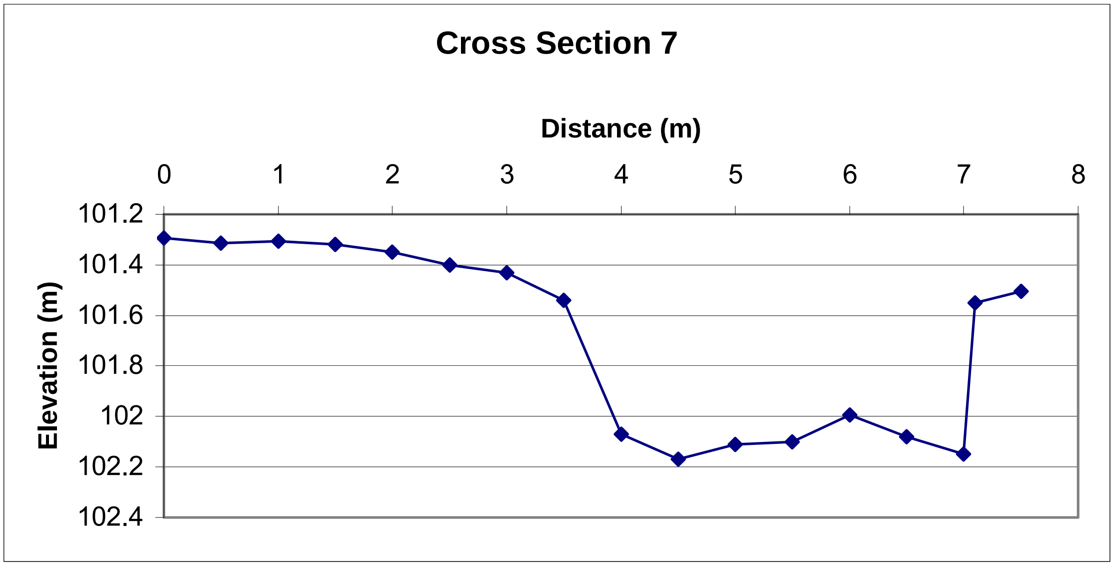
Appendix C: Cross-sections

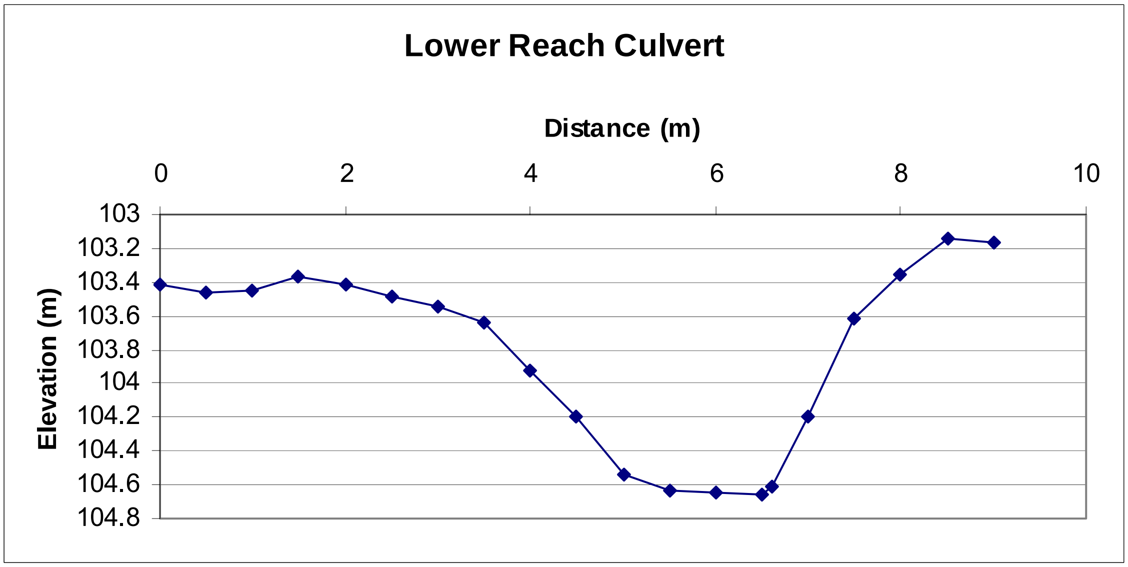






Appendix C: Cross-sections





Appendix D: Bankfull Morphology

Stream-Type G

Cross section upper culvert		
bankfull	meters	English (ft)
area	0.54	3.91
width	2.00	3.28
depth	0.27	1.19
w/d	7.45	2.75
max depth	2.65	336.23
wetted per.	1.54	5.06
R	0.35	0.77
substrate	silt/sand	

Cross section taken 7m downstream from upper culvert.		
bankfull	meters	English (ft)
area	0.58	6.19
width	4.00	13.12
depth	0.14	0.47
w/d	27.81	27.81
max depth	3.20	10.50
wetted per.	2.88	9.43
R	0.20	0.66
substrate	silt/sand	

Cross section is located 42m downstream from uuper culvert.		
bankfull	meters	English (ft)
area	0.88	9.49
width	2.50	8.20
depth	0.35	1.16
w/d	7.08	7.08
max depth	3.40	11.15
wetted per.	2.17	7.12
R	0.41	1.33
substrate	silt/sand	

52m downstream from upper culvert (Deep Pool).		
bankfull	meters	English (ft)
area	7.35	79.02
width	3.00	9.84
depth	2.45	8.03
w/d	1.23	1.23
max depth	5.00	16.40
wetted per.	9.06	29.73
R	0.81	2.66
substrate	silt/sand	

Footbridge on the downstream side, lower reach		
bankfull	Meters	English (ft)
area	4.73	50.92
width	1.50	4.92
depth	3.16	10.35
w/d	0.48	0.48
max depth	2.80	9.18
wetted per.	3.47	11.40
R	1.36	4.47
substrate	silt/sand	

25.45m downstream from foot bridge		
bankfull	meters	English (ft)
area	0.20	2.18
width	3.00	9.84
depth	0.07	0.22
w/d	44.44	44.44
max depth	2.10	6.89
wetted per.	2.16	7.10
R	0.09	0.31
substrate	silt/sand	

Appendix D: Continued

This Cross section is located 20 meters from the upper reach culvert.						**Cross section lower reach culvert**		
bankfull	meters	English (ft)				bankfull	meters	English (ft)
area	0.91	9.74				area	0.60	6.46
width	2.00	6.56				width	2.50	8.20
depth	0.45	1.49				depth	0.24	0.79
w/d	4.42	4.42				w/d	10.41	10.41
max depth	3.70	12.14				max depth	4.60	15.09
wetted per.	2.25	7.37				wetted per.	1.63	5.35
R	0.40	1.32				R	0.37	1.21
substrate	silt/sand					substrate	silt/sand	