# Appendix M Hydrology Studies

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January 14, 2006

Client-Matter: 24876-030

**BY OVERNIGHT COURIER**

Gayle Ackerman
City of Lake Forest
25550 Commercentre Drive, Suite 100
Lake Forest, CA 92630

**Re: Hydrology Studies**

Dear Gayle:

Enclosed please find copies of reports prepared by Dr. Stanley Trimble on the Borrego Canyon Wash. These reports were prepared for the County of Orange to examine the condition of the Borrego. We would request that the City and EIP consider this information in its preparation of the Opportunity Study Area EIR as it pertains to the hydrology of the Borrego.

Very truly yours,

Susan K. Hori
Manatt Phelps & Phillips LLP

cc w/out encls:
Scott Smith, Esq., Best Best & Krieger
Gene Spindler, Shea Properties

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AUG 1 7 2005

# Recent Erosion in the Baker Ranch Gully, Borrego Canyon Wash, Orange Co.,CA

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DRAFT

## Executive Summary

This study is an update of an earlier report (Trimble 2004) and is a measured estimate of recent erosion from the 3800 feet (1160 m) of the Baker Ranch gully described in that report. This gully enlarged almost 50% during the period 2002-2005 with about 40 acre-feet of sediment having been eroded. However, because the greatest storms by far were during the winter of 2004-2005, most of the erosion occurred during that short period. This much sediment clearly affects downstream channels as well as contributing to sedimentation in Newport Bay. While the large woody debris (tree trunks) present in the gully may provide some minor bank protection, their general effect is to direct turbulent flows onto gully walls and exacerbate erosion.

## Introduction

This study is an update of the report to Orange County entitled "Channel Modification, Urbanization, and Channel Instability in Borrego Canyon" dated November 2004 (Trimble, 2004). In that report, I demonstrated that a 3800 feet (1160m) reach of artificial channel, relatively stable since the mid-1960s, had been destabilized by upstream urbanization with approximately 75 acre-feet (93,000 m3) of sediment having been removed, mostly during the period 1998-2002. This study reports on changes since approximately 2000 that are the result of heavy rains during the winter of 2004-2005.

## Methodology

Primary confidence was placed in resurveys of earlier topographic profiles (Figure 1). The baseline dates for these profiles ranged from 1998 to 2004 so that the measurements cannot be exact. However, most of the heavy rainfall events occurred during the very wet winter of 2004-2005 so that was when most of the recent erosion occurred, a presumption that is borne out continuing reconnaissance over the period 1998-2005 and by photographic evidence.

## Results

The degree of change depended on the location within the gully. In the uppermost reach, the induration of the gully bottom and walls continued to mitigate erosion there. The gully at Profile 4 did not expand at all (Figure 1). Further upstream from Profile 3, the gully had already been hardened and stabilized as part of the upstream urbanization BMPs (Trimble 2004). Thus, the upstream-most reach of the channel showed little change over the past 2 years or so. In the next downstream reach, there was much more

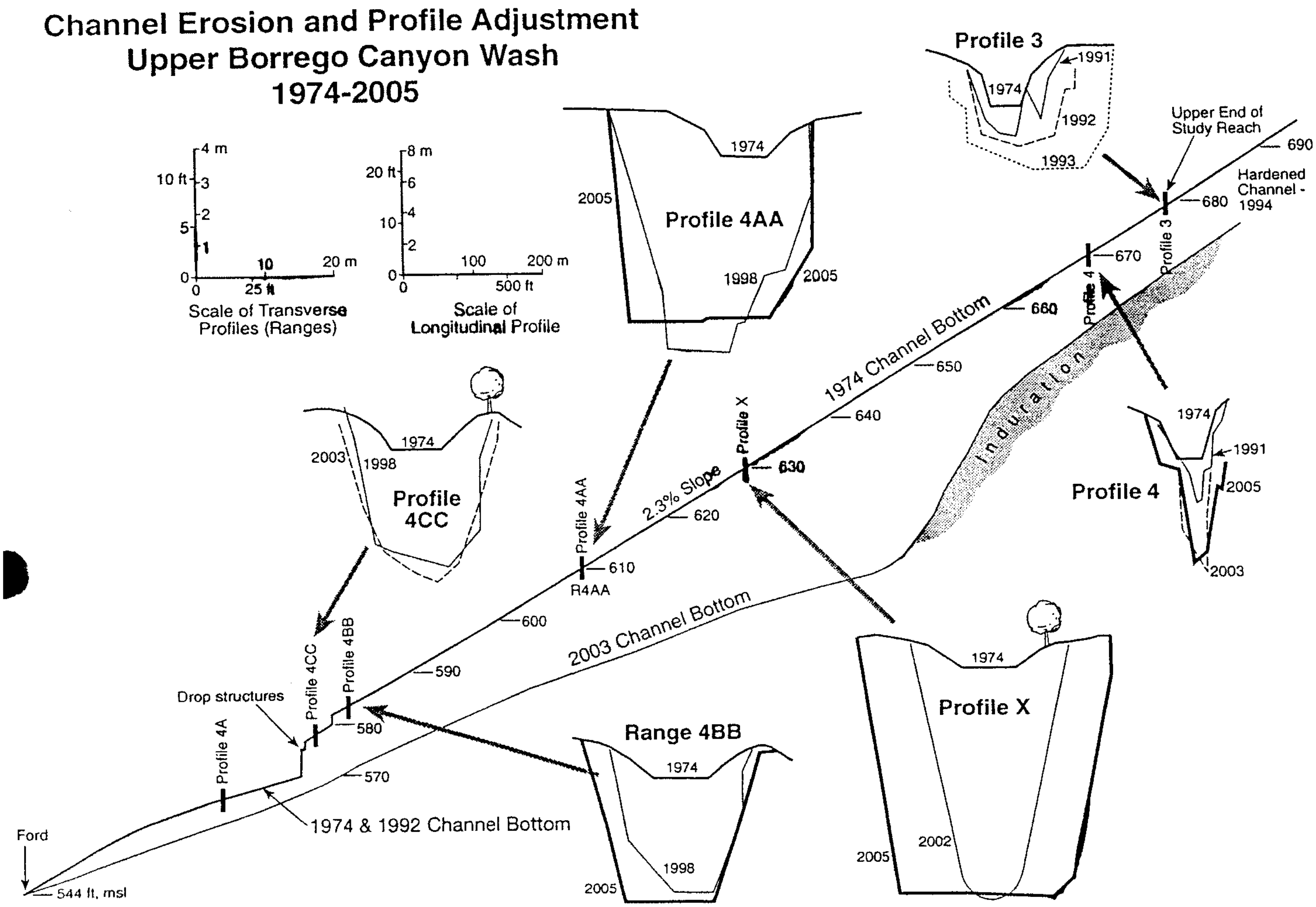

Channel Erosion and Profile Adjustment
Upper Borrego Canyon Wash
1974-2005
Scale of Transverse Profiles (Ranges)
Scale of Longitudinal Profile
Profile 3
Upper End of Study Reach
Hardened Channel - 1994
Profile 4AA
Profile 4CC
Profile 4
Profile X
Range 4BB
1974 Channel Bottom
2003 Channel Bottom
1974 & 1992 Channel Bottom
2.3% Slope
Induration
Drop structures
Ford
544 ft, msl
R4AA

Figure 1

significant erosion with Profile X having been expanded to twice its 2002 size (Figure 1). This occurred in part because several tree trunks had been washed into a configuration which directed flow into the left bank (Figure 2). In turn, this flow was deflected across to the right bank, destabilizing the reach (Figure 3). The resulting stream bed load from this eroded sediment had two local effects. First, it partially filled the channel at Profile 4AA. But more significantly, it caused the stream to widen thus promoting severe bank erosion and creating near-vertical gully banks (Profile 4AA, Figure 1, Figure 4). This process continued, but at a lower rate, to the end of the gully. In the lower reach, Profile 4BB is probably typical with pronounced lateral erosion and an overall expansion of about 45%.

## Discussion

The recent net loss of sediment from this gully was about 40 acre-feet or about 63,000 cubic yards (49,000 cubic meters). A large portion of this is sand that is deposited in downstream channels and must be removed by the County. The remainder, composed of smaller sizes, is mostly transported to Newport Bay. Since the Bay is normally dredged after about 500,000 cubic yards (380,000 cubic meters) of sediment have accumulated, it is clear that if only a portion of this sediment is transported to the Bay, it would make a significant contribution to sedimentation in Newport Bay.

## Conclusions

The initial trenching of the Baker Ranch gully might not have been foreseen but it is clear that the gully now continues to be a prolific sediment source which must be controlled. The obvious long-term solution is a hardened channel but a temporary mitigation might be to first remove the large woody debris (mostly tree trunks) which help destabilize the channel, and then perhaps build rip-rap sediment control structures within the gully.

## References

Trimble, S. W. 2004. "Channel Modification. Urbanization, and Channel Instability in Borrego Canyon Wash, Orange County, CA", Unpublished report for the Orange County Environmental Resources Section of Resources and Development Management.

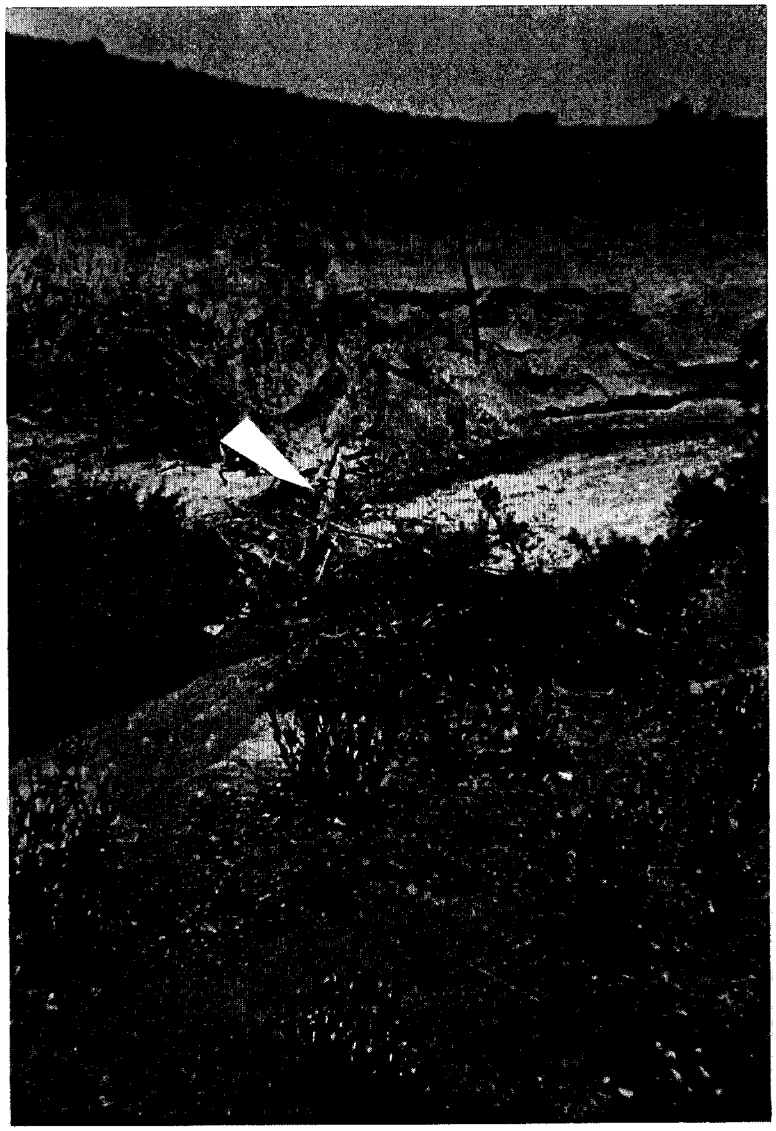
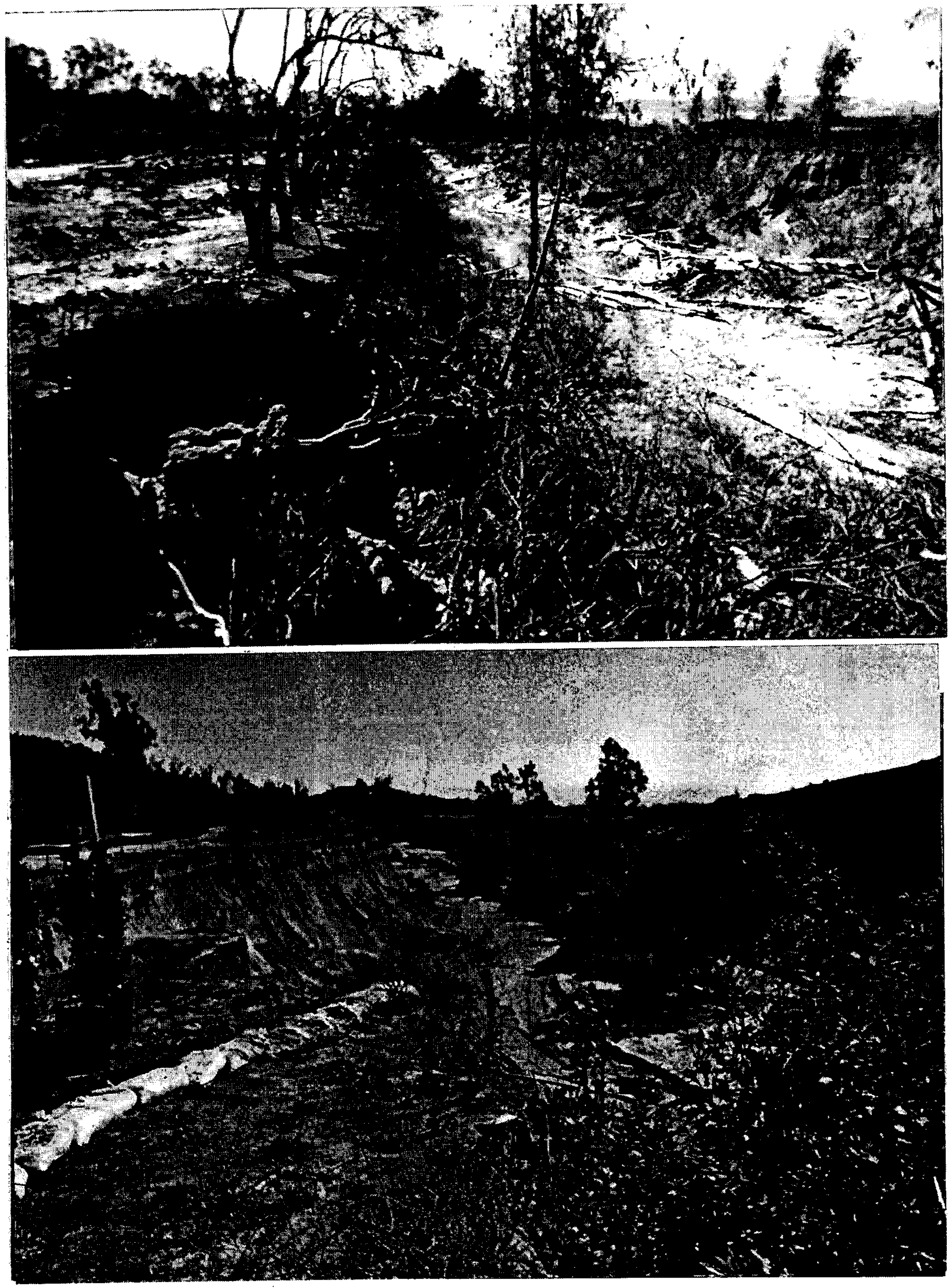


Figure 2. Debris dam of tree trunks (arrow) deflecting flow to the left bank (foreground). Approximately 300 feet (90 m) upstream of Profile X. Flow of stream is to the left.

A



B

Figure 3. Channel widening at Profile X about 100 feet (30m) downstream of figure 2. View is looking downstream. A. 1998. Note U-shaped channel and dead trees on top of left bank in foreground. B. 2005. Note bank in foreground has been eroded away and that banks are much steeper.

A

B

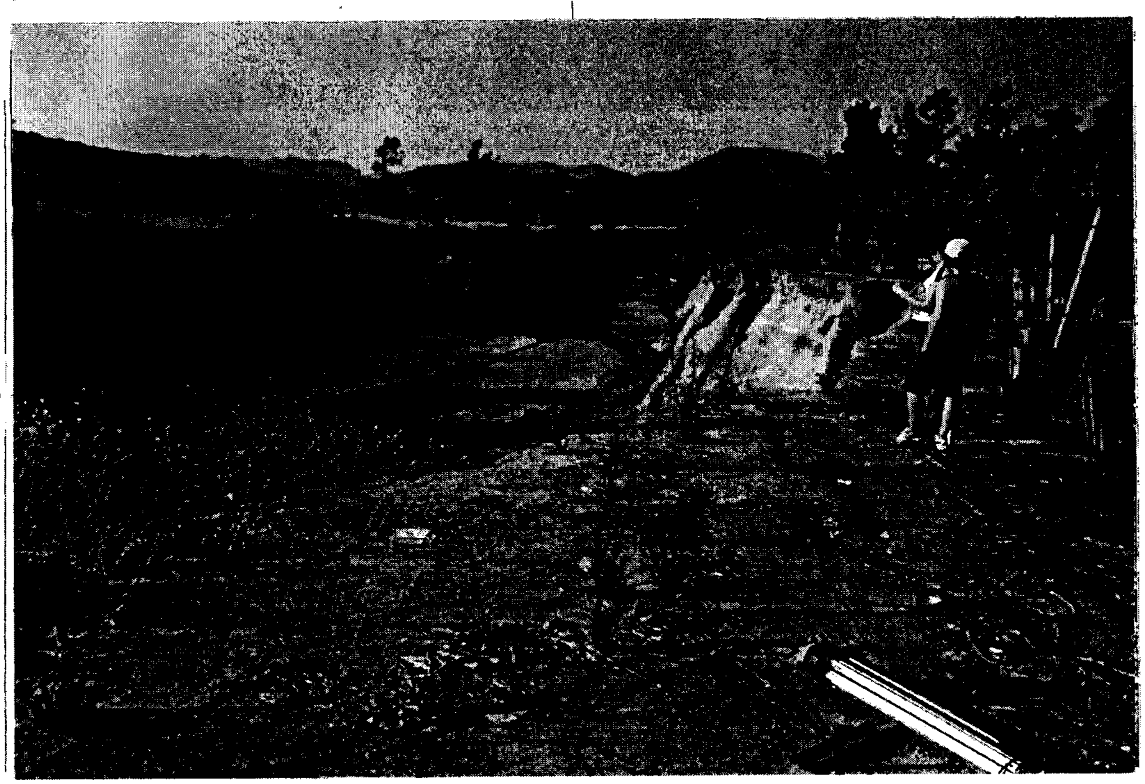


Figure. 4. Looking upstream near Profile 4AA. A. 1998. Note failed bank and tree trunks on far side (right bank). B. 2005. Note material on far bank has been removed by stream erosion and that the channel has been widened with steeper, high banks.

# Channel Modification, Urbanization, and Channel Instability in Borrego Canyon Wash, Orange County, CA

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UCLA

November, 2004

**Channel Modification, Urbanization, and Channel Instability in Borrego Canyon Wash, Orange County, CA.**

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Department of Geography
UCLA

**Executive Summary**

Borrego Canyon Wash is a foothill stream ultimately flowing into Newport Bay about 80 miles (50 km) south of Los Angeles. In the early 1960s, a braided reach of 0.8 mi (1.3km) draining 2.5 mi2 (6.7 $km^2$ ) was converted to agriculture with a constructed straight single channel. Gradient was slightly decreased by a drop structure at the lower end. This arrangement was fairly stable until the early 1990s when increased runoff from urbanization began to erode the channel. By 1997 when 23.5 % of the basin was urbanized, storm runoff from a 25yr event was calculated to have increased by about 22% but such an estimate has many uncertainties.

Similar storms occurred in 1969 and 1997 with both 24 hr and 48 hr amounts at about the 25yr magnitude. While the 1969 storm did little damage, the drop structure and new channel were breached in 1997 with degradation of up to 22 ft (7m ) and some channel cross sections increasing in area by about 10x. Only the presence of induration at a depth of about 6-12 ft (2-4m) in the upstream reach prevented more extreme erosion. Directly downstream is a reach of 1500 ft (450m) where lateral erosion of old floodplain sediments caused cut bank retreat of up to 200ft (60m), 1992-2003. Together, both reaches produced about 113 acre-feet (140,000m3) of sediment, much of it coarse sand which was deposited within 1.2 mi (2km) downstream.

Increases of stream power, as calculated from the increase of discharge, do not appear to be large enough to initiate the rapid channel erosion. It may be that the increase of stream discharge was underestimated and/or the increase of water density as the result of sediment from upstream channel erosion increased steam power significantly.

**Introduction**

As urban area continues to expand throughout the developed world, stream channel erosion becomes a more important research topic (NRS, 1997,1999). Until recent years, most of the research was done in humid region, but the hydrology and fluvial geomorphology of urbanized areas is increasingly being investigated. In particular, the stream channels of the rapidly urbanizing San Diego Creek in Orange California have been under intensive investigation since 1981. Using air photo analysis, Hoag (1983) showed that much of the sediment flowing into Newport Bay was the direct result of eroding channels for the period 1938-1983. Using much more precise field measurements over an additional decade, Trimble (1997) demonstrated the contribution of channel erosion to the filling of Newport Bay was on the order of two-thirds of the total. Trimble (2003) further showed that for much of the San Diego Creek basin, earlier artificial channel creation and enlargement had set the stage for much of the channel erosion and instability and that urbanization with its attendant increased runoff, only exacerbated the problem. Climate variability apparently played little role.

Other channels, especially in the foothills, had been modified only slightly before urbanization started. Federico (2003) studied Serrano Creek, a small tributary located in the eastern end of the San Diego Creek basin. Although urbanization was underway there by the late 1970s, it was during the 1980s and early 1990s that much of the basin was developed. Likewise, the channel remained relatively stable until the early-mid 1990s when the enhanced runoff from a series of wet years, culminating in the large storms of 1997-98, severely eroded the streambed and banks, in many places threatening home sites. Federico was able to demonstrate the connection between increasing urban area and rates of channel erosion, and showed that historically earlier storms equal to those of 1997-98 had failed to destabilize the channel.

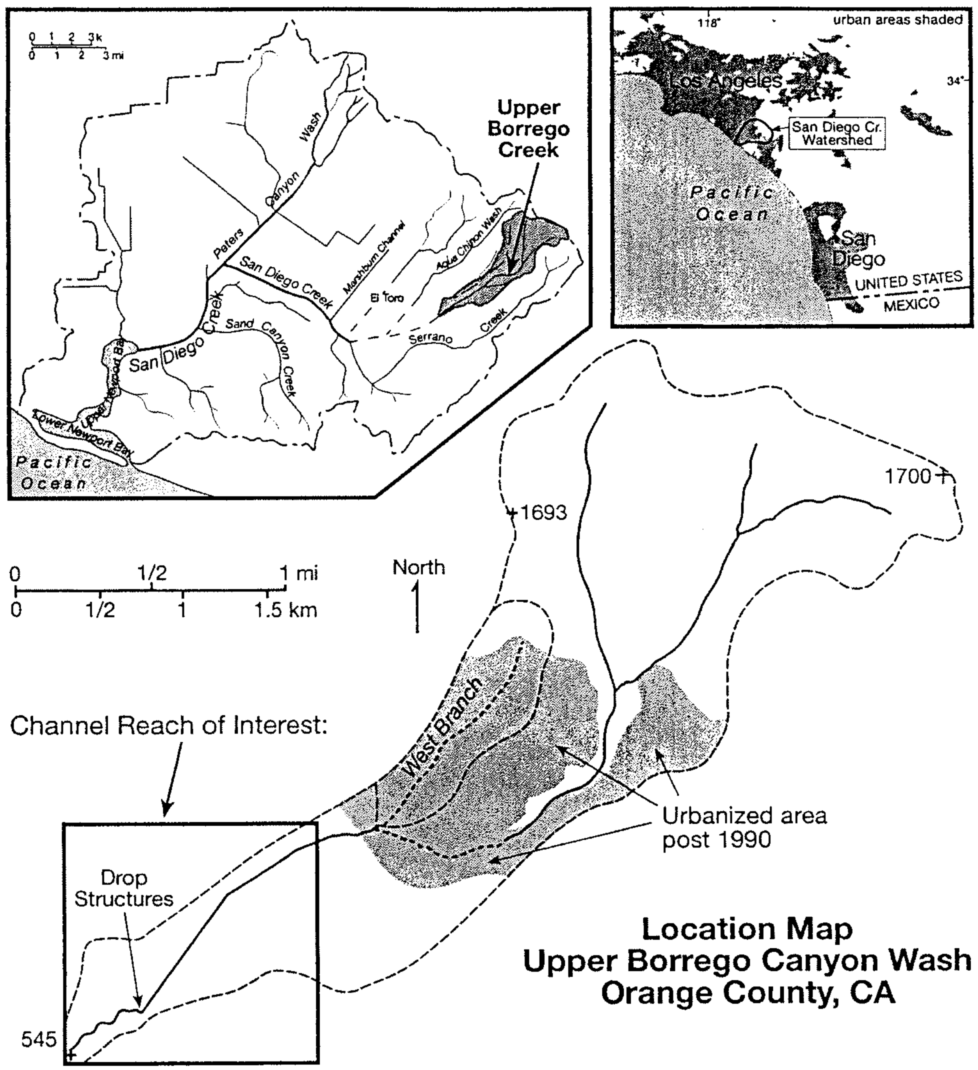
Borrego Creek is adjacent to Serrano Creek, being the next stream to the east. The two streams are fairly similar in size and shape and relief and have similar geology and soils, but the relief is higher and proportion of the basin urbanized is much lower. Borrego Canyon Wash underwent channel erosion more severe than that suffered by Serrano Creek and this paper attempts to show why.

**Description of the Study Area.**

Borrego Canyon Wash drains westward from the Santiago Hills flowing into San Diego creek and ultimately into Newport Bay. The portion of the basin above the study reach drains about 2.5mi2 (6.7km2) is about 3.5 miles (5.6 km) long and drops about 1150 feet ( 350m) in that distance although much of the drop is in the upper third of the basin (Fig 1). Originally, the lower third of the stream was braided with as many as 3 broad and widely separated channels (Fig. 2, 1938). The geology of the basin is deeply weathered marine and non-marine Tertiary sedimentary rocks, mostly shales, siltstones and sandstones. Quaternary deposits form slopewash, terraces and old floodplains (Ca. Div. Of Mines and Geol., 1974, 1984).

**Channel Condition and Modifications, 1952-1992.**

Between 1952 and 1967, a 0.8mi (1.3km) reach of braided floodplain near the lower end of the basin was converted to cropland (Fig. 2, 1983). The stream was moved to the north side of the floodplain at the upper end and next to the property line with the Navy base for the lower end. The channel was fashioned into two straight reaches with a uniform gradient of 2.4% and given a trapezoidal cross-section approximately 4 ft (1.2 m) deep with a bottom up to 25 ft. (8m) wide and gently sloping sides (Fig. 3). The increase in slope from 2.1 % to 2.4% caused by straightening was partially removed by 2 drop



Upper Borrego Creek
urban areas shaded
118°
34°
Los Angeles
San Diego Cr. Watershed
Pacific Ocean
San Diego
UNITED STATES
MEXICO
Peters Canyon Wash
San Diego Creek
Marshburn Channel
Agua Chinon Wash
El Toro
Serrano Creek
Sand Canyon Creek
Upper Newport Bay
Lower Newport Bay
Pacific Ocean
1693
1700
0 1/2 1 mi
0 1/2 1 1.5 km
North
Channel Reach of Interest:
West Branch
Urbanized area post 1990
Drop Structures
545
Location Map
Upper Borrego Canyon Wash
Orange County, CA


Figure 1

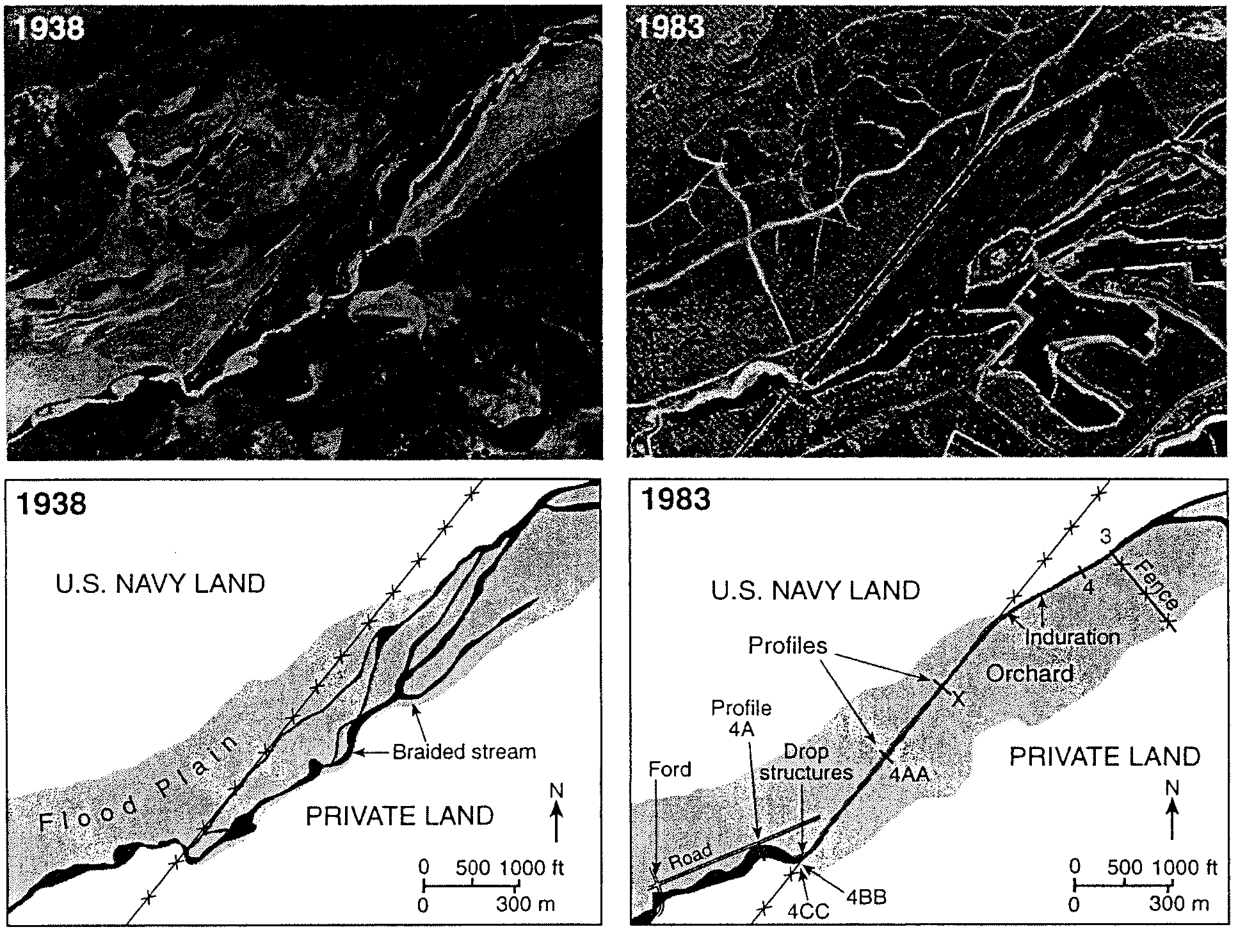
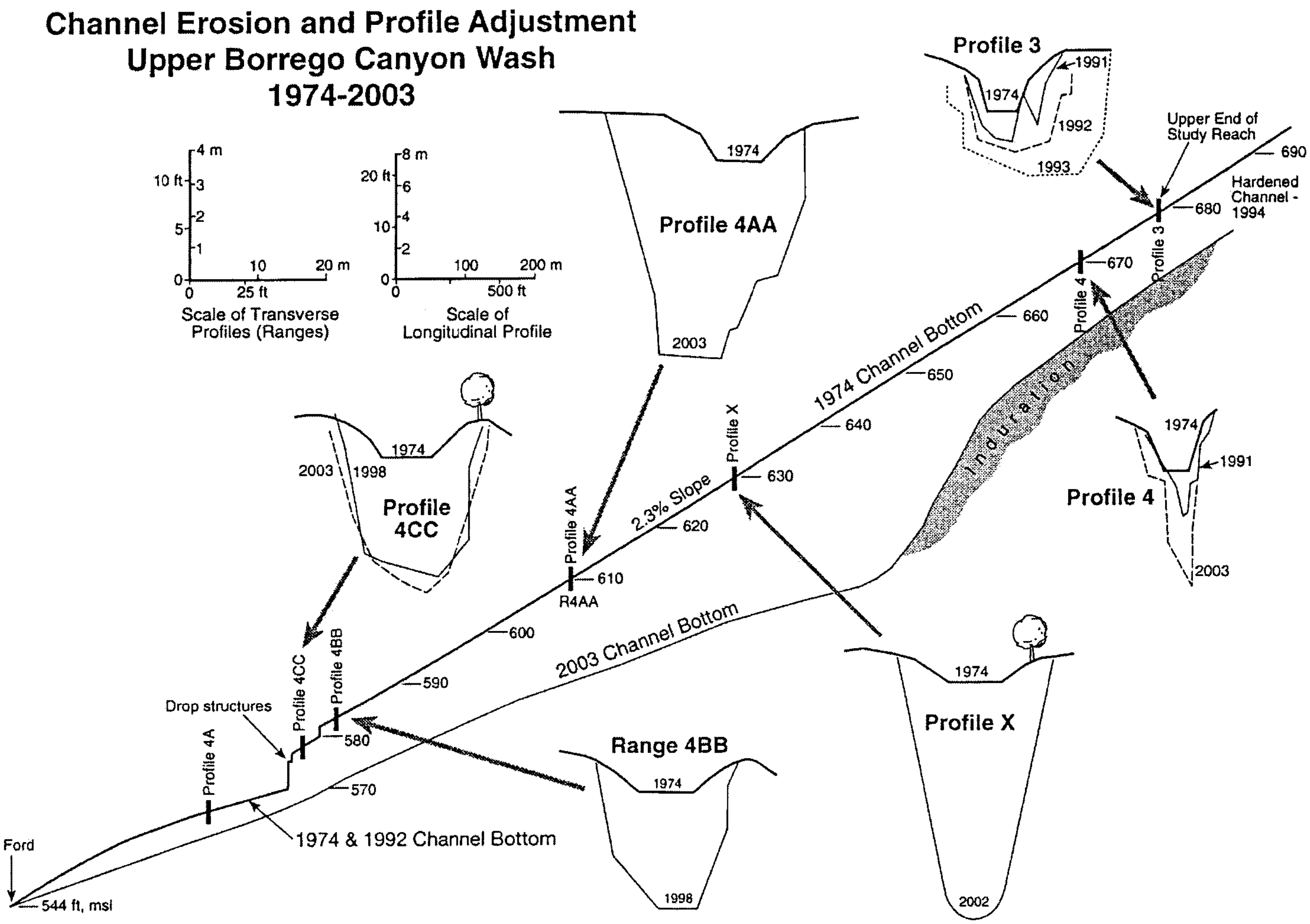



Figure 2. Tranformation of a reach of Borrego Wash from a braided configuration to a single channel with agriculture.


Channel Erosion and Profile Adjustment
Upper Borrego Canyon Wash
1974-2003
Scale of Transverse Profiles (Ranges)
Scale of Longitudinal Profile
Profile 3
Profile 4AA
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Upper End of Study Reach
Hardened Channel - 1994
1974 Channel Bottom
2003 Channel Bottom
1974 & 1992 Channel Bottom
2.3% Slope
Induration
Drop structures
Ford
544 ft, msl
R4AA

Figure 3

structures at the lower end, decreasing the slope from 2.4% to 2.3%(Fig. 3). This combination proved to be relatively stable up to 1992 when urbanization was well underway and a wet period of greater rainfall began (Fig.4).

Downstream of the drop structures, the floodplain widened to about 3000 ft (1 km) and the gradient decreased from 2.4% to 1.6% (Figs. 3 and 5). The channel configuration for this reach was a broad (300ft, 100m) braided arroyo wash with steep walls about 7 ft (2m) high set into the south side of the broad floodplain. As taken from air photos and a 1974 USGS flood survey, this broad channel also remained remarkably stable over the period 1952-1992.

**Urbanization, 1990-1997.**

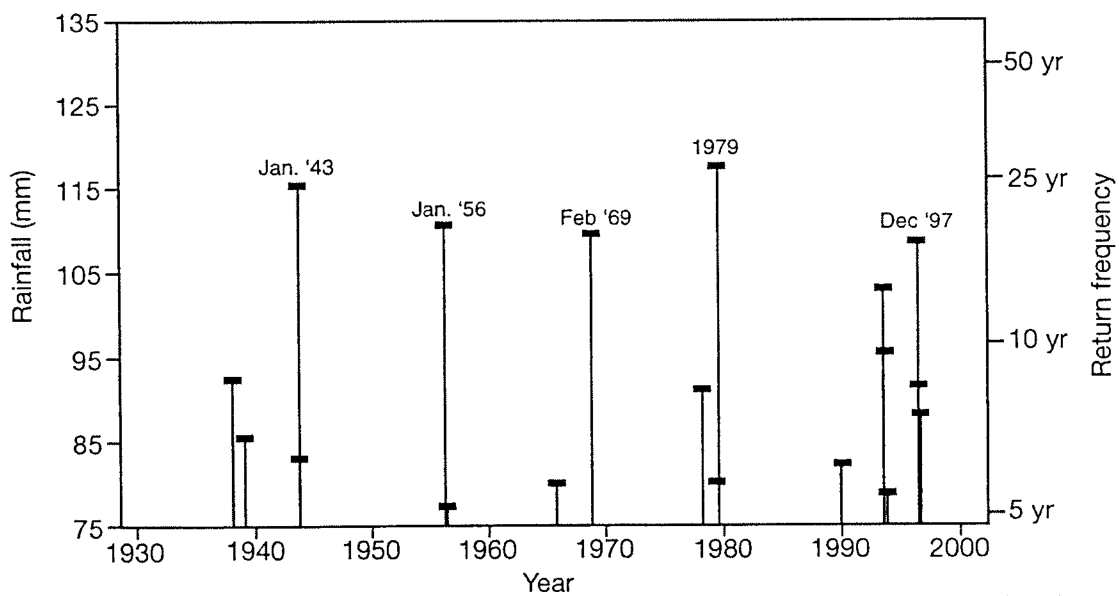
Urban development composed of single family dwellings, duplexes, commercial, industrial, and roadways was started in 1990 and by early 1992 covered much of the lower end of the watershed (Fig. 1). About 85 % of the unnamed tributary coming in from the east (termed here "west branch") was urbanized and the channel was transformed into in a box culvert (Fig. 1). The lower portion of the main channel (downstream of Foothill Boulevard) was also put in a box culvert, but there is about 1500feet (450m) of earthen channel between the outlets of these two box culverts and the upstream end of the study reach. . The entire urban area is quite steep and is well drained to the stream channels.

**Channel Erosion, 1992-1998.**

After a prolonged period of little rainfall (1984-1991) and little channel change, rains early in 1992 doubled the cross-sectional area of the channel at the upper end of the modified channel which up that time had changed little from its built form (Profile 3, figs. 3 and 6). The next year,1993, heavier rains again doubled the channel size. and much of this material was deposited downstream of the drop structure (Fig.5). Upstream of Profile 3 for about 1000feet (300 m), there was severe channel erosion, but that reach was hardened with concrete and stabilized in late 1993. Changes downstream in the Navy Base were not measured for the period 1993-1998 because of inaccessibility so that there is no exact baseline but reconnaissance of the reach 1992-1997 suggested only relatively moderate erosion, with the broad channel having eroded vertically no more than about 4 feet (1.2m).

However, the 1997-98 storms washed out the downstream drop structure dropping the base level at least 4 feet (1.2 M). Vertical incision upstream moved rapidly and 2500 feet (800m) upstream had deepened to over 14 feet (4.3 m) during this single season. Further headward erosion was curtailed only by an indurated channel bottom where the new channel had been cut close to a hillside. The deep incision destabilized the wet banks, burdened as they were by mature eucalyptus trees, the high banks failed, and channel cross sections increased by a factor of up to ten (Figs.7 and 8).

**Daily Rainfall > 75 mm -- Orange County Precipitation Stations #176 and #130 (Approx. 3-4 km south of study area. Water Years 1928-2001**
(Note multiple single year peaks)




Modified from Frederico (2003)

Figure 4

## Bank Erosion 1952-2003
## Downstream of Drop Structures

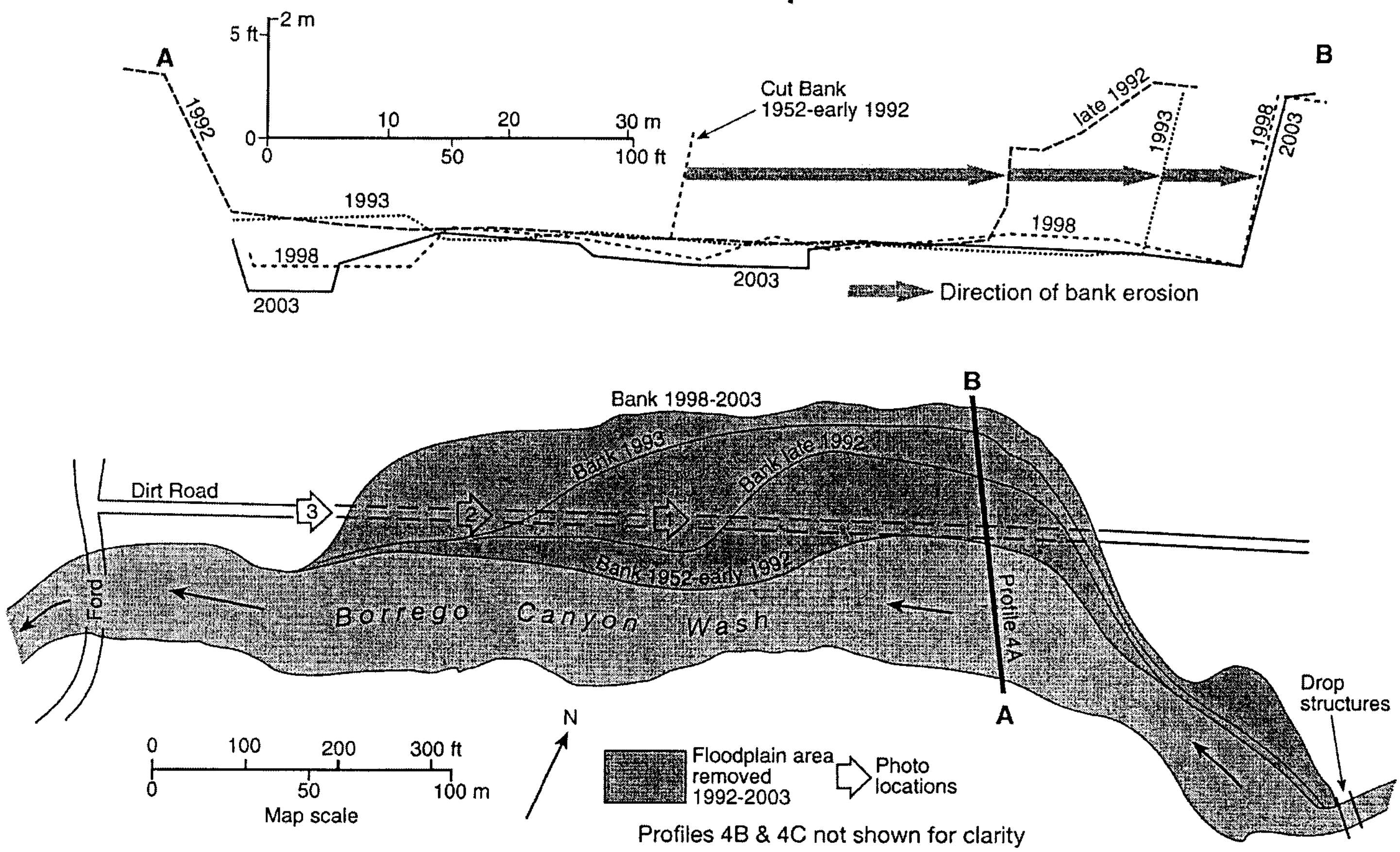



Figure 5

A

B

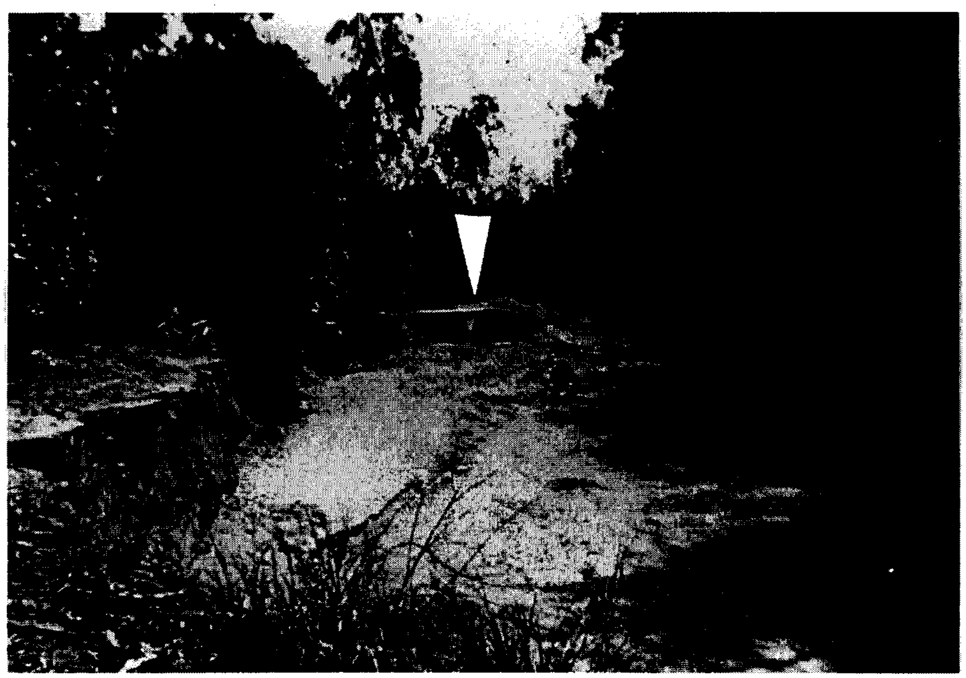


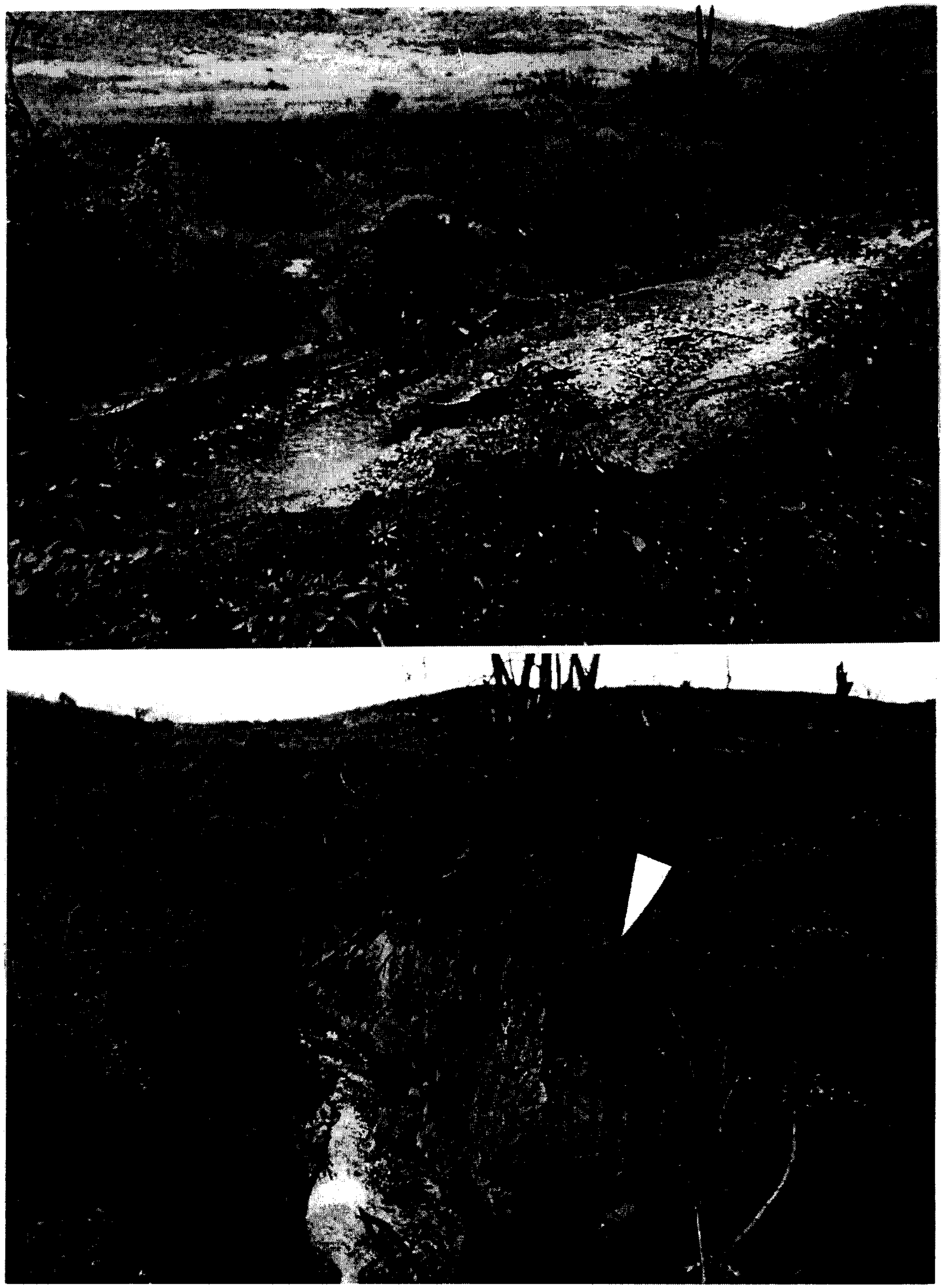
Figure 6. Looking downstream just below Profile 3. A. 1991. Note channel is still roughly trapezoidal. B. 1992. Channel has eroded the left bank by several meters removing the road and the first row of orange trees. The bank is 6 feet (2m) high. Note person standing by bank (arrow.)

A

B

Figure 7. Incised channel upstream from drop structure, December, 1998. A. Looking upstream near Profile 4AA. Note failed bank on far side. B. Looking downstream near Profile X.

A



B

Figure 8. Incised channel upstream of drop structure, 2001. A. At approximate location of Figure 7A. The photo suggests further vertical channel erosion with further slumping of banks. B. Looking downstream near Profile 4 showing the narrow channel incised into the indurated material. Note superposed remnant of old channel bottom (arrow).

Downstream in the reach below the drop structure, the 1992 flood breached the right bank which had been relatively stable since about 1952, making it retreat about 80 feet (24 m). The next year,1993, another large area of floodplain was removed and again in 1998 (Fig.5 and 9).

Such was the power of the flows that not only was the material removed from the gully but in the downstream reach, there was up to 2.5 feet (0.8 m) of vertical scour (fig.5). Subsequent flows since 1998 have removed another 1.2 feet (0.4 m). All of these effects decrease downstream to the ford (Figs. 2 and 5) where base level is maintained by a concrete structure. The total material removed form these two reaches is estimated to be 113 acre feet (140,000 M3). Below the ford, the erosion again dominated an indeterminate distance sownstream but can be clearly seen at a profile 800 feet (240m) downstream of the stream ford where a maximun of about 5 feet ( 1.5m) of vertical erosion occurred (Fig. 10).

**Hydrologic Effects of Urbanization**

Because there was such a dramatic time correlation between the onset of urbanization and channel erosion. I first investigated the hydrologic effects of the urbanization. Because most large storms over the historical period have not exceeded the 24hr-25-yr magnitude (Fig. 4), that appeared to be an appropriate frequency to investigate. For the developed condition, Bein, Frost and Associates ( 1985) had estimated the 25-yr, Qp at about 2200 cfs ( 63 cms).

For the undeveloped condition, I developed a 25-yr Qp using the *Orange County Hydrology Manual* (OCEMA, 1986) and especially the simplified method of deriving peak flows in Section L. The variables were obtained or derived as shown below.

Tc, Time of concentration. Bein, Frost and Associates (1993) give a Tc of 31.67 minutes about 0.5 mi (0.8km) upstream of the study area. From this, I estimated a Tc of 35 minutes at the head of the study area.

Fp, composite soil hydrologic groups where A=0.4, B=0.3, C=0.25 and D=0.2. Of the 1596 acres of the basin, 13% are B, 51% are C and 36% are D, the composite value of Fp is 0.24.

Ap, proportion of the basin still pervious. For the undeveloped condition, I assumed the basin to be 100% pervious.

Fm, catchment maximum loss rates, = apFp=0.24

Y, catchment runoff yield attributed to development, =0

Y, catchment low loss fraction, = 1-Y=1.0

Now using Curve L-11 (25yr, <1 mi2) and Curve L-12(25yr, 5 mi2), a composite unit Qp of 1.15 cfs/acre was obtained. Thus, the undeveloped 1596 acre watershed should have given a peak flow of about 1800 cfs (51cms). Therefore, the developed Qp of 2200 cfs

A

B

C

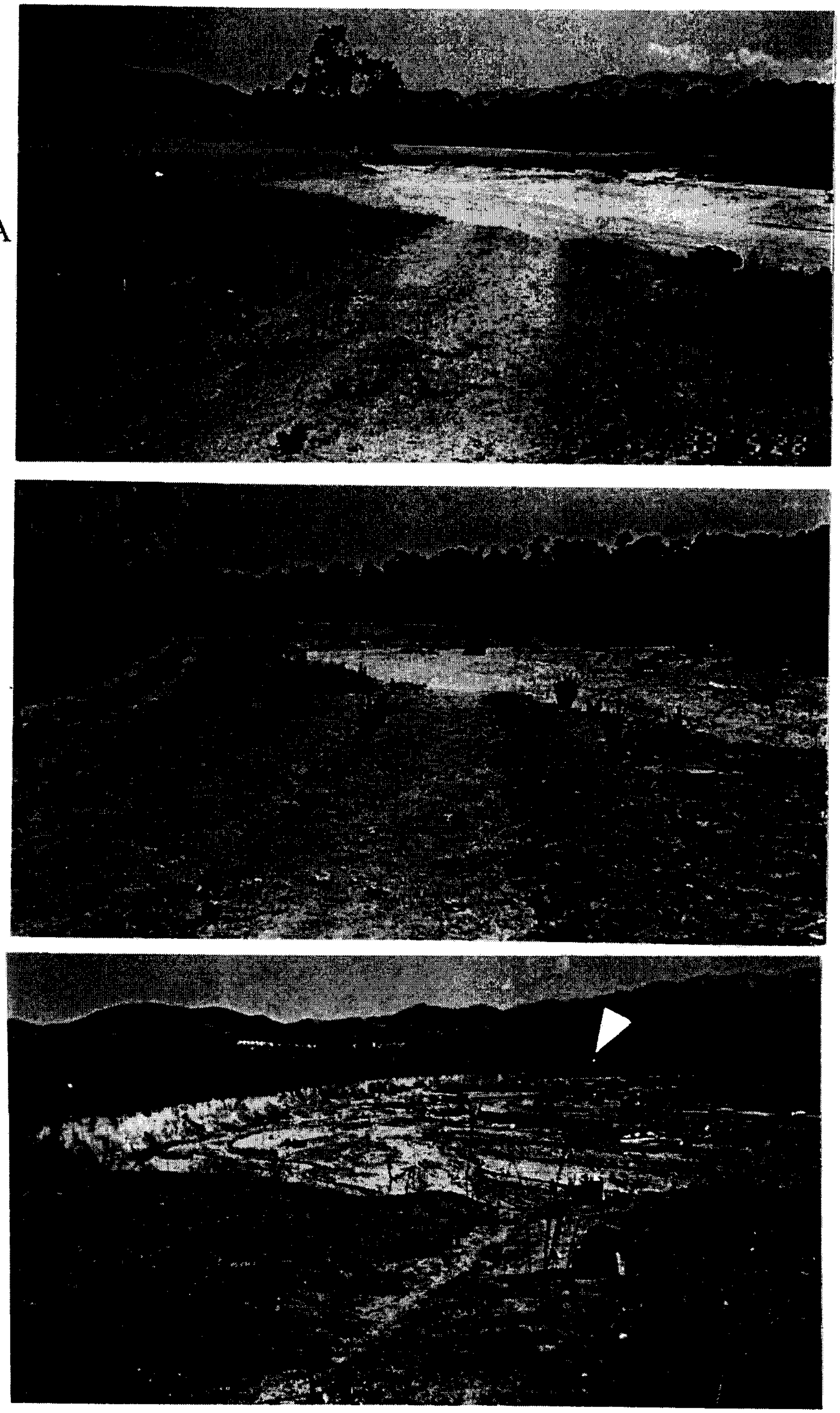


Figure 9. Photos along road looking upstream on right bank with photo position retreating as the result of bank erosion. For locations, see Fig. 5. For reference, note live oak to left on bank in A and B. In C, tree has been eroded away. A. 1992. B. 1993. C. 2003. Arrow in C. marks the road on far side.

## Borrego Canyon Wash
## Profile 4D
800 ft (240m) downstream of ford

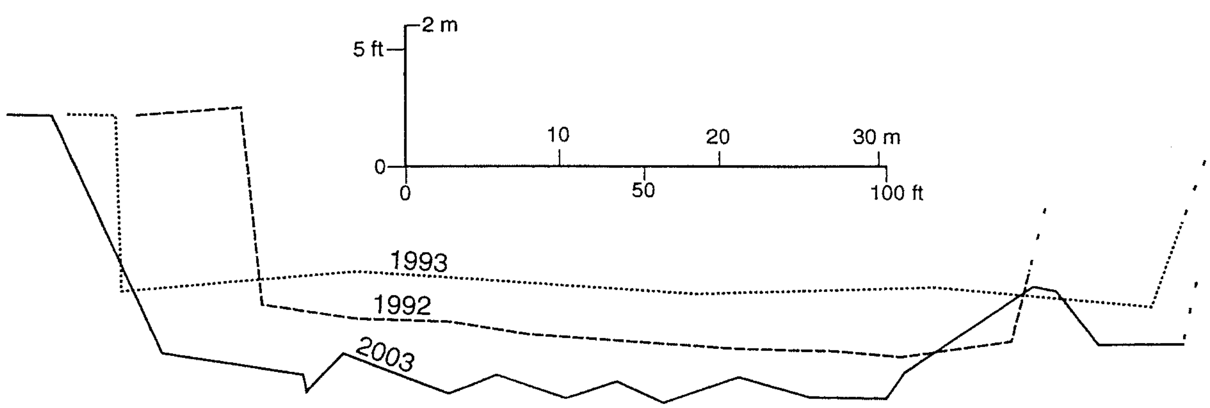



Figure 10

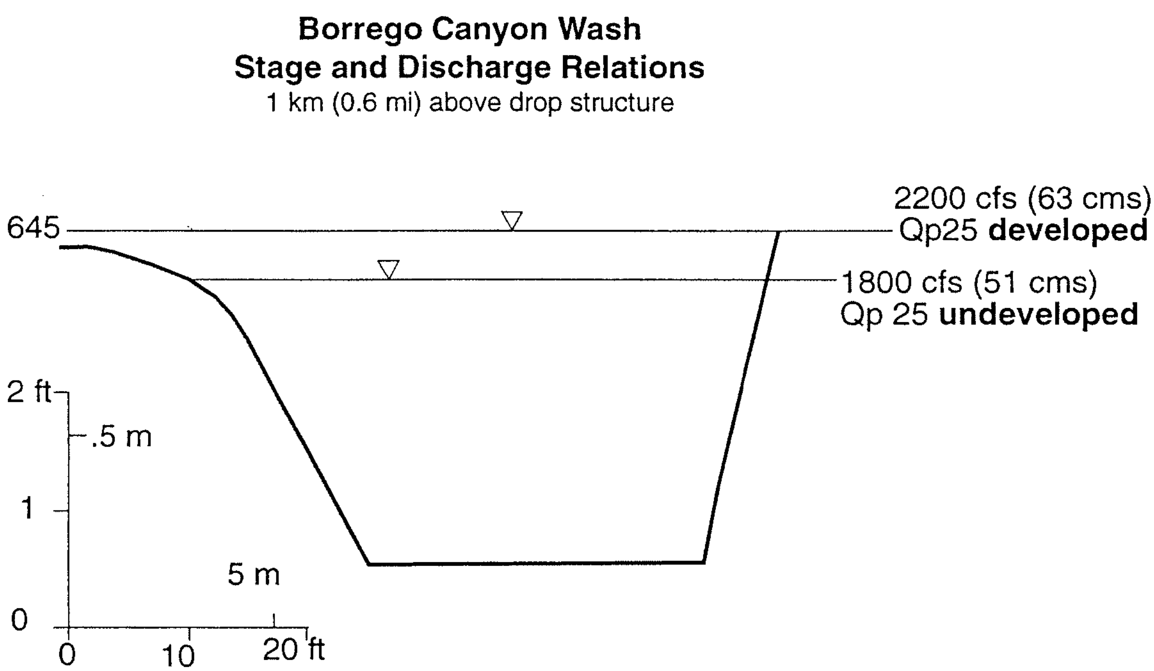

Borrego Canyon Wash
Stage and Discharge Relations
1 km (0.6 mi) above drop structure
645
2200 cfs (63 cms)
Qp25 developed
1800 cfs (51 cms)
Qp 25 undeveloped
2 ft
.5 m
1
0
5 m
0
10
20 ft

Figure 11

suggests that development has increased the 25yr Qp about 22%. This increase appears to be modest, especially in light of the classic Hollis (1975) model which indicates that 20% urbanization of a catchment should increase the 25yr Qp about 100%. In the adjacent Serrano Creek basin, however, Federico (2003), using the TR55 method as presented in Ward and Trimble( 2004) estimated that it would require about 50% urbanization to double the 25 yr Qp. An important consideration in Borrego Creek is that most soils there have low infiltration capacities so the effects of urbanization tend to be minimized. And while it does not show up in this analysis, the location of urbanization is so close to the study area, that it surely would affect mostly the rising limb of the hydrograph. For example, the highly urbanized west branch (Fig 1) has a Tc of only 18.8 minutes so the effect of having urbanized this sub basin might be more to elongate the hydrograph rather than increasing the peak.

**Stream Power**

The effect of this increase of discharge is shown in Figure 11, a channel cross section located about 0.6mile (1km) above the drop structure. I have calculated water level stages, velocities, and depths for Qp25 for both the developed and the undeveloped conditions. Slope remains the same in both cases.

Since the problem is to understand why the channel began to erode so rapidly after urbanization, I now examine stream power, one measure of a stream's ability to erode its channel. Unit stream power (W) is the power of a stream per unit width of channel,

W=yuds where
y=unit weight of water in kg/m3
u=mean velocity in meters/sec.
d=depth in meters
s=slope, dimensionless

We now know all the factors for each discharge except unit weight. Since it is unknown and not easily measured or estimated, I'll simply assume that in both cases the sediment load, and thus the density of the water, is the same, a reasonable estimate being 1100kg/m3.

Stream Power for Qp25, undeveloped:

W=yuds =1100kg/m3 (5.2m/sec) 0.76m (0.023)= 100 kg/sec/m

Stream Power for Qp25, developed:

W=yuds =1100 kg/m3 (5.8m/sec) 0.88m (0.023)= 129 kg/sec/ m

Thus, we see only about a 30% increase in stream power for the urbanized condition. This is a significant increase but seemingly unlikely to be adequate to initiate the sort of channel erosion described although increases of stream power tend to increase the ability of a stream to carry any size particle as some power function (Leopold and Emmett, 1976). In any case, the channel of the study area did erode disastrously after urbanization. It is impossible to know exactly why but I can offer 3 possible reasons why this happened.

1. It is possible that I have underestimated the increase of Qp25 caused by urban development. This could be because either the before or after estimate is incorrect, or perhaps both are incorrect.

2. If there were a great increase in water density by added sediment load for the higher discharge, the stream power would increase commensurately. Such an increase of sediment load could come from accelerated upstream channel erosion. Perhaps significantly, I have good evidence that sediment loads and presumably sediment concentrations were increasing as the channel incision began. As the result of urbanization, the channels just downstream of the urbanized area and above the study were eroding rapidly in the period 1991-93. For example, see Profile 3 (Fig. 3) at the upstream end of the study reach which doubled in size 1991-92 and again in 1992-93 (Fig.6). Erosion rates at the profile were probably representative of the reach directly above the study area.

## Conclusions

This reach of Borrego Wash has undergone extraordinary change over the period since urbanization began. While the calculated increases of runoff and stream power are not as great as expected, the fact that flow events which had before urbanization passed through the wash with little resulting change now create almost catastrophic changes strongly suggests that urbanization is the cause. While peak stream power was calculated to increase on 30%, the actual value may have been higher due to increased water density from suspended sediment. Another factor could have been the elongated hydrograph witht the longer duration of the force being the significant process rather than the only moderate increase of peak force.

## References

Bein, Frost, and Associates Engineering. 1985. *Hydrology Report, Borrego Canyon Facility F20, Upper Watershed to Irvine Boulevard.*

Bein, Frost, and Associates Engineering. 1993. *OCEMA Facility No. 20, Borrego Canyon Wash, Regional Hydrology Map within Foothill Ranch.* 1"= 400 feet.

California Division of Mines and Geology.1974. Geology of the south half of the El Toro quadrangle, Orange County, CA. *Special Report* 110, Sacramento.

California Division of Mines and Geology, 1984. Engineering Geology of the north half of the El Toro quadrangle, Orange County, CA.*Open-File Report* 84-28, Sacremento.

Federico, Felicia. 2003. Urbanization, precipitation and channel changes, Serrano Creek Watershed, Orange County, CA. unpublished MA thesis, Department of Geography, University of California, Los Angeles.

Hoag, Barbara. 1983. Channel erosion as a source of sediment in Newport Bay, CA, unpublished MA thesis, Department of Geography, University of California, Los Angeles.

Hollis, G. E. 1975. The effect of urbanization on floods of different recurrence intervals. *Water Resources Research* **11**: 431-435.

Leopold, L.B. and Emmett, W.W. 1976. Bedload measurements, East Fork River, Wyoming. *Proceedings of the national Academy of Sciences, USA* 75:1000-1004.

National Research Council. 1997. *Watershed Research in the U.S. Geological Survey.* Washington, DC, National Academy Press.

National Research Council. 1999. *New Strategies for America's Watersheds*. Washington, DC, National Academy Press.

Orange County Environmental Management Agency. 1986. *Orange County Hydrology Manual.* Santa Ana, CA.

Trimble, S. W. 1997. Contribution of stream channel erosion to sediment yield from an urbanizing watershed. *Science* **278**:1442-1444.

Trimble, S. W. 2003. Historical hydrographic and hydrologic changes in the San Diego Creek watershed, Newport Bay, CA. *Journal of Historical Geography* **29**: 422-444.

Ward, A. and Trimble, S.W. 2004. *Environmental Hydrology.* Boca Raton,FL, CRC Press.

# FIELD RESEARCH REPORT FOR
# SAN DIEGO CREEK CHANNEL STUDY

**SPRING 2001**

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## EXECUTIVE SUMMARY

Field research on channel erosion was conducted in the San Diego Creek Watershed during April and May, 2001. A total of 8 profiles have been destroyed since 1998, but 2 new ones were installed and another old one was recovered. There are now 64 viable profiles on channels liable to erosion. Channel erosion since 1998 has been minor. Upper Borrego Wash, the greatest problem identified in the 1998 study, has changed little since then and remains extremely unstable. Erosion damage from the 1997-98 floods in Upper Serrano Creek, largely missed in the 1998 study, was studied and found to be at the same magnitude as that in Upper Borrego Wash. Both channels clearly have been affected by the rapid upstream urban development. Roadside ditches have largely been stabilized. There continues to be a potential flooding problem where surface channels transporting large woody debris enter subsurface channels.

**Field Research Report for San Diego Creek Channel Study, Spring 2001**

1. Introduction. Field research was conducted in the San Diego Creek Watershed in April and May, 2001. The purposes were (1) to inventory channels in light of urban development and construction, and (2) to inspect channel conditions. The last inspection was done in Fall 1998.

2. Recovery of Profiles. Due to construction, channel protection, and wildlife protection, the net number of profiles decreased to 64 in 2001. The following profiles were permanently lost.

Profiles Permanently Lost:

| Name | Location | Cause |
|---|---|---|
| Bee 1 | Map, H-6 | Rip-rap |
| Kim Cr A | Map, E-9 | Road construction |
| Marshburn 1A | Map, H-5 | Subsurface routing |
| Marshburn 1 | Map, H-6 | Subsurface routing |
| Marshburn 2 | Map, H-6 | Subsurface routing |
| Myford 1 | Map, D-5 | Subsurface routing |
| Sand Canyon 3 | Map, D-9 | Wildlife habitat protection |
| SDC C | Map, H-10 | Construction |

3. New Profiles. Two new profiles were installed this year. The first is SDC Range 3RA just downstream from Irvine Center Drive (Map, H-10). This profile replaces an earlier profile that was lost to construction that had continued for several years. The second new profile is lower Serrano Creek 2RR which replaces the current profile 2R, which was invalidated by earth moving. Another

profile was reestablished this year. Upper Serrano Profile 2R, located in a Lake Forest residential area upstream from Trabuco Blvd., was first established in 1986. Ensuing construction and lack of access caused its abandonment in the late 1980s. However, we were able to reestablish it this year (see Section 6).

4. Channel Erosion Since 1998. There was little significant erosion at any profile since the channel inspection of Fall 1998 (Trimble, 1998). However, there had been severe erosion in Upper Serrano Creek from floods of 1997-98 that was not reported in Trimble, 1998 (see Section 6).

5. Upper Borrego Wash. As reported in the 1998 Field Report (Trimble, 1998), Upper Borrego Wash channel had been severely eroded downstream of Foothills Ranch development. This reach was carefully inspected this year and appears to have changed little since late 1998. Profile 4A (Map, J-7) was resurveyed this year and showed little net change. As pointed out in the 1998 field report, this reach is extremely unstable but there has been no attempt to stabilize it. Of particular note are the high (20-30 feet) steep banks, in many places laden with heavy tree carcasses. A wet year would produce not only huge amounts of sediment, but also further destabilize the banks, releasing huge logs which could possibly block the downstream subsurface reaches of Borrego Wash (beneath the former El Toro air base). In my view, this is presently the most serious channel erosion problem in the San Diego Creek basin.

6. Upper Serrano Creek. Profiles were installed in Upper Serrano Creek starting in 1984. Our extensive work during the period 1984-86 indicated that Serrano Creek, relative to many other channels in the San Diego Creek basin, was quite stable. Urban construction and lack of access by the late 1980s caused abandonment of Profile 2R located about 1000 feet upstream of Trabuco Blvd.

Another profile in this reach was just downstream from Trabuco. It was eroding severely by the early 1990s but was given a heavy rip-rap treatment and therefore abandoned about 1995. This left a long reach with no profiles (approximately 2 miles between profiles D and 1B2) so the severe erosion of part of that reach from the 1997-98 storms was left unobserved and unmeasured. Fortunately, and with the kind assistance of Mr. Matt Rayl of the Serrano Creek Conservancy, we were able to carry out a detailed reconnaissance of this reach.

Also with the assistance of Mr. Rayl, we were able to recover and resurvey Profile 2R, originally surveyed in September 1986. The recovery and survey were not perfect because there had been some reshaping of the local area and our landmarks and benchmarks were gone. However, I am certain that the resurvey was close to the original elevation and alignment. It indicated that the channel cross-section had more than doubled (from 780 $ft^2$ to 1765 $ft^2$). Our reconnaissance suggested that Profile 2R may be representative of erosion damage of about a mile of Upper Serrano Creek. Rounding the net erosion at Profile 2R to 1000 $ft^2$ and assuming about 5000 ft of channel were similarly affected, the total volume eroded would be about 5 million $ft^3$, or about 115 acre-feet. This compares with the 50 acre-feet estimated to have been eroded during the same period from just the Baker Ranch portion of Upper Borrego Wash (Trimble, 1998).

7. Effects of Urbanization on Channel Erosion. Our early (1984-86) work in Upper Serrano Creek and Upper Borrego Channel (upstream of the Navy Reservation) indicated that they were quite stable relative to many other channels of the San Diego Creek basin so our priorities were placed elsewhere. It is important to note that the stability of these channels had existed for decades. Upper Serrano Creek, in particular, was tree-lined and was arguably the most stable and attractive

channel in the entire San Diego Creek Watershed. Both channels were destabilized only after urban development had taken place upstream. There are probably few clearer instances anywhere of a causal relationship between rapid, extensive urbanization and rapid, severe channel erosion. Even in the rest of SDC, the reasons for channel erosion are more diffuse with agriculture, drop in base level, and channel disturbance playing large roles.

8. Roadside Ditches. Little evidence of recent erosion was seen in roadside ditches. This is a great improvement over conditions described in the 1998 report. Many reaches had been treated with rip-rap, in particular an especially unstable reach on Irvine Blvd. (Map, G-6).

9. Surface to Subsurface Channels. As noted in several previous reports (e.g., Trimble, 1998), a matter of concern has been the transition from surface to subsurface channels, especially where the surface channels are located in the wooded foothills area. An example noted in 1998 was the Upper Borrego Wash where large logs are being eroded from the Baker Ranch reach and transported towards the subsurface intake located just upstream of Irvine Blvd. Another example noted this year is where Badlands Storm Channel enters a long subsurface reach (beneath new urban development) just upstream of Portola Parkway (Map, G-3). Woody debris from these surface channels could conceivably block the subsurface channels, causing flooding in urban streets. It is recommended that grills or screens be installed just upstream of all such inlets to preclude large woody debris from entering subterranean channels.

## REFERENCE

1. Trimble, S.W. 1998. Field Research Report for San Diego Creek Channel Study. Santa Ana, CA. County of Orange, Public Facilities and Resources Department. 2000.

**Appendix 1**

Profile Inventory, 1998-2001 (see channel map for legend to conditions)

| Channel Name | Profile No. | Map Grid | 1998 Cond. | 2001 Cond. |
|---|---|---|---|---|
| Badlands | 1 | G-2 | 3+ | 3 |
| " | 2 | G-3 | 3+ | 3 |
| " | A | F-4 | 3+ | 3 |
| Bee | 1 | H-6 | 2+ | destroyed, rip-rap |
| Borrego | 1 | L-6 | 2+ | 2+ |
| " | 3R | K-7 | 2+ | 2+ |
| " | 3A | J-7 | 5+ (new) | 5+ |
| " | 3B | J-7 | 5+ (new) | 5+ |
| " | 3C | J-7 | 5+ (new) | 5+ |
| " | 4A | J-7 | 5 | 5 |
| " | 4B | J-7 | no access | 5 |
| " | 4C | J-7 | " | 5 |
| " | 4D | J-7 | " | 4 |
| " | 5 (5R) | J-8 | 4, new profile | 4 |
| Borrego Trib. (F21) | A | J-7 | no access | no access |
| Golf Course | 2 | F-3 | 2 | 2 |
| " | 1 | F-3 | 2 | 2 |
| Hicks | A4 | H-4 | 3 | 3 |
| " | A2 | H-4 | 3 | 3 |
| " | A1 | H-4 | 3 | 3 |
| " | B | H-4 | 4+ | 4 |
| Hicks | 1 | G-4 | 2+ | 2+ |
| " | 1A | G-4 | 2+ | 2+ |
| " | 2 | F-4 | 2+ | 2+ |
| " | 3 | F-4 | 2+ | 2+ |
| " | 4 | F-4 | 2+ | 2+ |
| " | 5 | F-4 | subsurface | subsurface |
| " | 6 | F-4 | subsurface | subsurface |
| Hicks trib. | A3 | H-4 | 3 | 3 |

**Appendix 1, continued**

Profile Inventory, 1998-2001 (see channel map for legend to conditions)

| Channel Name | Profile No. | Map Grid | 1998 Cond. | 2001 Cond. |
|---|---|---|---|---|
| Hines | A | H-5 | 5 | 3 |
| " | B | H-5 | 5 | 4 |
| " | 1 | G-5 | 3+ | 4 |
| " | 2 | G-5 | 3+ | 4 |
| " | 3 | G-6 | 3+ | 4 |
| " | 4 | G-6 | 3+ | 4 |
| " | 5 | G-6 | 3+ | 4 |
| " | 6 | G-6 | 3+ | 4 |
| Kim Creek | 1 | E-9 | 4+ | 4 |
| " | 2 | E-9 | 4+ | 4 |
| " | 3 | F-9 | 4+ | 4 |
| " | 4 | F-9 | 4+ | 4 |
| " | A | E-9 | 4 | destroyed by new road |
| Little Joaquin | 1B | G-2 | 3 | 3 |
| " | 1 | G-2 | 4 | 4 |
| " | 1A | G-2 | 4+ | 4+ |
| Marshburn | 1A | H-5 | 4 | destroyed, subsurface |
| " | 1 | H-6 | 3 | " |
| " | 2 | H-6 | 3 | " |
| " | 3R | F-8 | 1 | 1 |
| Myford | 1 | D-5 | 2 | destroyed, subsurface |
| Peters Canyon Wash | 16 | C-6 | 2 | 2 |
| PCW Div. Canal | 1-7 | F-3-4 | construction | 2 |
| " | 1-2 | F-3 | construction | 2 |

**Appendix 1. continued**

Profile Inventory, 1998-2001 (see channel map for legend to conditions)

| Channel Name | Profile No. | Map Grid | 1998 Cond. | 2001 Cond. |
|---|---|---|---|---|
| Sand Canyon | 3 | D-9 | 2 | destroyed, wildlife refuge |
| " | 2 | D-9 | 2 | 2 |
| " | 1A | C-8 | 2+ | 2+ |
| San Diego Creek | C | H-10 | 2+ | destroyed, construction |
| " | 2R | F-8 | 1 | 1 |
| " | 3R | F-8 | 1 | 1 |
| " | 3RA | F-8 | | 2 |
| Serrano | A | L-8 | 2+ | 2+ |
| " | B | L-8 | 2+ | 2+ |
| " | B2 | K-8 | 2+ | 2+ |
| " | C | K-8 | 2+ | 2+ |
| " | D | K-8 | 2+ | 2+ |
| " | 1B2 | J-9 | 2+ | 3 |
| " | 1B | I-9 | 2+ | 2+ |
| " | 2RR | H-9 | 5 | 5 |
| " | 3R | H-10 | 2+ | 3 |
| Serrano Trib. | 1 | H-9 | 3 | 3 |
| " | 2 | H-9 | 3 | 3 |
| Simonek | 1R | G-6 | 3+ | 3+ |
| " | 3 | F-7 | 3+ | 3+ |
| " | 4 | F-7 | 3+ | 3+ |
| Total Profiles | | | 68 | 64 |

# FIELD RESEARCH REPORT FOR
# SAN DIEGO CREEK CHANNEL STUDY

**FALL, 1998**

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# EXECUTIVE SUMMARY

Field research on channel erosion was conducted in the San Diego Creek Watershed during October, November and December 1998. A total of 35 profiles have been destroyed since October 1997, but 2 of these were replaced and others eventually can be. Channel erosion during the last year was significant but not severe except on Borrego and Serrano Creeks. In the reach of Borrego Creek downstream of Foothill Ranch, the combination of urban runoff and a failed grade control structure has caused massive channel erosion and the channel is presently very unstable. Serrano Creek had a severely eroding reach between Dimension Drive and Trabuco Road, but no quantities can yet be ascertained. Roadside ditches are collectively a significant source of sediment. The new foothill floodwater retention structures will be excellent sediment traps and could thus provide estimates of erosion rates from the foothill areas. To that end, it is recommended that profiles for sediment measurement be installed in each of the foothill basins.

**Field Research Report for San Diego Creek Channel Study, Fall, 1998**

1. Introduction. Field research was conducted in the San Diego Creek Watershed in October, November and December 1998. The purposes were (1) to inventory channels in light of urban development and construction and (2) to inspect channel condition with regard to the wet year of 1997-98.

2. Recovery of Profiles. Due to construction, highway building and local disturbances, the net number of profiles decreased from 98 in 1997 to 68 in 1998 (Appendix 1). A total of 35 profiles were lost between October 1997 and December 1998. These losses may be placed into two categories. The first of these consists of profiles permanently lost to new channel construction for urban development or to road or other construction. In this category, 30 profiles were lost.

A. Profiles Permanently Lost:

| | |
|---|---|
| Hicks | 5, 6 (Map, F-4) |
| Rattlesnake | 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15 (Map, E-4, F-4) |
| Peters Canyon Wash | 13, 14 (Map, E-4) |
| PCW Diversion Canal | 1-7, 1-2 (Map, F-3-4) |
| McCoy | 1, 2R (Map, G-3) |
| Sand Cyn Blvd Ditch | 1, 2 (Map, F-8) |
| Trimble | 1 (Map, G-2) |

Most of these losses are due to the building or projected building of housing estates or transportation corridors. The greatest loss was along Rattlesnake Wash which has been rerouted underground. Much of the area north of Interstate 5 between Culver Drive and Jamboree Road (Map, E, F, - 3, 4) is under development and Peters Canyon Wash downstream of Bryan Road is being converted to a concrete channel similar to that already completed between Bryan Road and Irvine Boulevard. Portola Parkway has been built alongside and over upper Rattlesnake Wash and will be extended from Culver Drive to Jamboree Road (Map, G-3).

The second category of lost profile is that of those temporarily lost to local construction or other disturbance such as removal or destruction of range end markers and benchmarks. There were 5 profiles in this category.

B. Profiles Temporarily Lost:

| | |
|---|---|
| San Diego Creek | 5, 5A, and 6 (Map, E-8) |
| Borrego | 5 (Map, J-8) |
| Serrano | 2 (Map, H-9) |

The last "natural" reach of San Diego Creek, between Sand Canyon Avenue and Jeffrey Road (Map, E-8) is now being enlarged and will presumably be given the same configuration as the reaches immediately upstream and downstream. If given a soft bottom as expected, one or more profiles will be installed when possible.

The profiles on Borrego and Serrano were replaced at a location as close as possible to the old ones (see next section).

3. New Profiles. Five new profiles were added this year, partly to replace those disturbed. These were:

| | |
|---|---|
| Serrano | 2R (Map, H-9) |
| Borrego | 3A, 3B, 3C, 5R (Map, K-7) |

The profile notes are enclosed as a separate appendix. The Borrego profiles are discussed in section 5.

4. Channel Erosion Since 1997. Channel erosion has been potentially measurable over most of the basin, but erosion rates can be termed severe only in Borrego Wash and parts of Serrano Creek (see following section).

5. Upper Borrego Wash. Borrego Wash downstream of the Foothills Ranch development (Map, J-7) has undergone extremely severe channel disruption over the past year. The overall problem appears to be increased runoff from the impervious urban development upstream but the more immediate cause is the failure of a grade control structure at the downstream end of Baker Ranch. Upstream from the failed dam for about 2500 feet, the channel has enlarged from one of about 10 feet deep and 40 feet wide (based on upstream Profiles 3 and 4 in 1991), to one which in its largest reach is 25 feet deep and about 100 feet wide with an average of about 20 feet deep and 80 feet wide. The average channel sizes suggest that the current channel is about four times larger than the 1991 channel or an increase of about 900 $ft^2$ in cross-section. Thus, the 2500 feet reach has furnished approximately 50 acre-feet of sediment since 1991. The present channel is extremely unstable having near-vertical sides which in many places still have heavy, mature Eucalyptus trees on them. Many channel sides have already collapsed from the weight of the trees and collapse of other large sections of bank appears imminent. It is suggested that these trees be removed both to reduce bank collapse and also to keep the woody debris from the channel. Not only can such large woody debris help further destabilize the channel, it can also be transported downstream to the point that Borrego Creek is routed beneath part of the Marine Base. While this most unstable reach of Borrego Creek is on Baker Ranch, it flows along the mutual property line with the Navy Reservation and

some of the collapsing banks are on Navy property. Three profiles were installed on this reach for future comparison (Borrego 3A, 3B, 3C).

Immediately downstream of Baker Ranch on the Navy Reservation, Borrego Creek has continued to widen and severely erode its banks. Profile 4A, about 500 feet downstream from Baker Ranch, was resurveyed. The right bank on the outside of a meander bend, which had eroded about 70 feet in 1992-93, has lost another 25 feet since 1993 but there was little change in elevation of the stream bed. Lack of entry permission to the Navy Reservation made it impossible to survey or even thoroughly inspect profiles 4B, 4C and 4D, but severe erosion of the right bank has clearly occurred over a 1000 feet reach downstream from Profile 4A. This bank averages about 7 feet high. Assuming a conservative estimate of 50 feet of bank retreat over this 1000 feet reach since 1992, the eroded material would be about 8 acre-feet.

Much of the eroding sediment from this reach, plus the massive amounts from the previously described Baker Ranch reach have filled the downstream channel. Extensive sediment removal from Borrego Creek upstream from Trabuco Road has completely disrupted a long reach of channel. Profile 5 was destroyed in the process but it was replaced for future comparison (Profile 5R). Lack of entry permission precluded inspection of the lower reach on the Navy Reservation and it may well have experienced accretion similar to the reach above Trabuco Road. In summary, the reach of Borrego Creek extending from Foothills Ranch to well within the Navy Reservation is highly disturbed and capable of producing large amounts of sediment. Much of this sediment was deposited in the reach above Trabuco Road, and an unknown amount may have been excavated.

6. Serrano Creek. Two reaches of Serrano Creek underwent severe erosion. The first of these lies in Lake Forest between Dimension Drive and Trabuco Road (Map, I-8). Although a profile was installed there in 1985, access to the profile was curtailed in 1993 by development. However, a report from Wildan Associates (1998) indicates that the channel in this reach has recently degraded 3-5 feet and unstable vertical banks are common. Unfortunately, that work utilizes no surveyed profiles so a more precise assessment of channel erosion is not yet available.

The other severely eroded reach of Serrano Creek is the channel directly upstream of Interstate 5 (Map, H-9). Because the profile markings (monuments) had been destroyed at Serrano Profile 2, a new profile was installed approximately 300 feet downstream where more permanent monuments were available. This new profile shows a channel approximately 80% larger than the 1993 channel at the old profile. An estimated increase in channel size of about 50% since 1993 would appear to be reasonable for the 1/4 mile above the interstate. This would be about 50 $ft^2$ of channel cross-sectional area, so this quarter-mile reach has furnished about 66,000 $ft^3$ (50 $ft^2$ x 1320 ft) or about 1 1/2 acre-feet of sediment since 1993. The 1/4 mile of channel upstream of this reach has also eroded, but apparently much less.

7. Roadside Ditches. It was observed that many roadside ditches had eroded severely during the past year. Specific examples noted are along Irvine Blvd. across from the Marine Air Base (Map, H-6), along Labert Road (Map, H-6), and along Trabuco Road (Map, G-6). While the amount of sediment from any one reach is not great, the collective amounts for the entire basin may be quite significant so that measures to control roadside erosion such as grade control

structures might be considered. In the past, profiles have been installed across roadside ditches, but most of these were destroyed within the year. None remain.

8. Measurement of Foothill Sediment Yields. A major unresolved question of sediment management has been the contribution of the foothill areas. Thus, it would be beneficial to monitor the sediment accumulation behind the new Foothill floodwater retention structures (dams). This could be done relatively inexpensively by establishing monumented profiles across the sediment accumulation zones. These surveyed profiles would be similar to those used in channel studies but spaced much closer together.

## REFERENCES


1. S.W. Trimble, 1997. Field Research Report for San Diego Creek Channel Study, Fall, 1997. County of Orange, Public Facilities and Resources Department. Santa Ana, CA.
2. Wildan Associates, 1998. The Serrano Creek Collaborative Use Plan. Anaheim, CA.

## Appendix 1

Profile Inventory, 1997-98 (see channel map for legend to conditions)

| Channel Name | Profile No. | Map Grid | 1997 Cond. | 1998 Cond. |
|---|---|---|---|---|
| Badlands | 1 | G-2 | 3 | 3+ |
| " | 2 | G-3 | 3 | 3+ |
| " | A | F-4 | 3 | 3+ |
| Bee | 1 | H-6 | 2 | 2+ |
| Borrego | 1 | L-6 | 2 | 2+ |
| " | 4R | K-7 | 2 | 2+ |
| " | 4AA | J-7 | n/a | 5+ (new) |
| " | 4BB | J-7 | n/a | 5+ (new) |
| " | 4CC | J-7 | n/a | 5+ (new) |
| " | 4A | J-7 | 5 | 5 |
| " | 4B | J-7 | 5 | no access |
| " | 4C | J-7 | 5 | " |
| " | 4D | J-7 | 5 | " |
| " | 5 (5R) | J-8 | 3 | 4, new profile |
| Borrego Trib. (F21) | A | J-7 | no access | no access |
| Golf Course | 2 | F-3 | 2 | 2 |
| " | 1 | F-3 | 2 | 2 |
| Hicks | A4 | H-4 | 3 | 3 |
| " | A2 | H-4 | 3 | 3 |
| " | B | H-4 | 4 | 4+ |
| Hicks | 1 | G-4 | 2 | 2+ |
| " | 1A | G-4 | 2 | 2+ |
| " | 2 | F-4 | 2 | 2+ |
| " | 3 | F-4 | 2 | 2+ |
| " | 4 | F-4 | 2 | 2+ |
| " | 5 | F-4 | 4 | subsurface |
| " | 6 | F-4 | 4 | subsurface |
| Hicks trib. | A3 | H-4 | 3 | 3 |

**Appendix 1, continued**

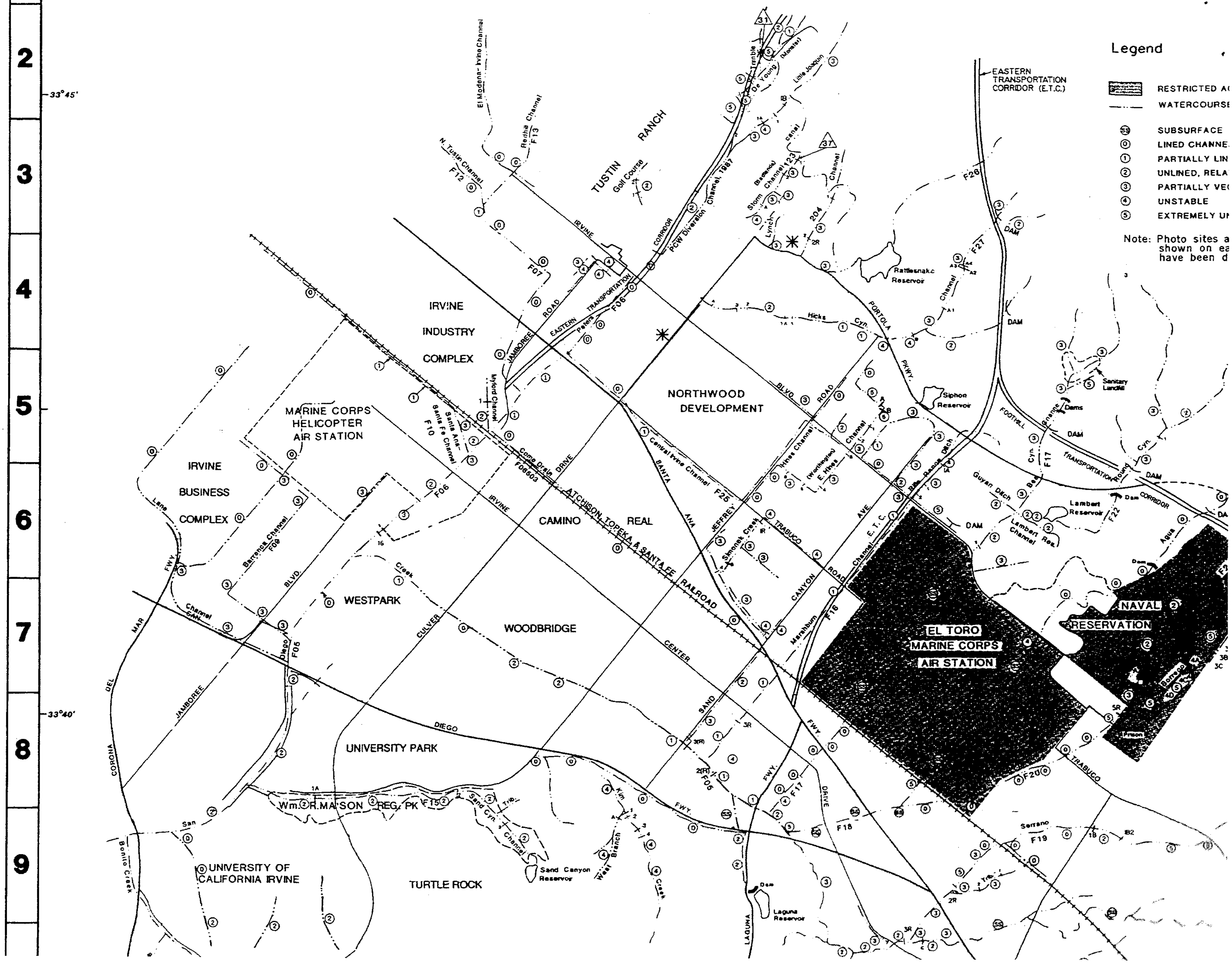
Profile Inventory, 1997-98 (see channel map for legend to conditions)

| Channel Name | Profile No. | Map Grid | 1997 Cond. | 1998 Cond. |
|---|---|---|---|---|
| Hines | A | H-5 | 5 | 5 |
| " | B | H-5 | 5 | 5 |
| " | 1 | G-5 | 3 | 3+ |
| " | 2 | G-5 | 3 | 3+ |
| " | 3 | G-6 | 3 | 3+ |
| " | 4 | G-6 | 3 | 3+ |
| " | 5 | G-6 | 3 | 3+ |
| " | 6 | G-6 | 3 | 3+ |
| Kim Creek | 1 | E-9 | 4 | 4+ |
| " | 2 | E-9 | 4 | 4+ |
| " | 3 | F-9 | 4 | 4+ |
| " | 4 | F-9 | 4 | 4+ |
| " | A | E-9 | 4 | 4 |
| Little Joaquin | 1B | G-2 | 3 | 3 |
| " | 1 | G-2 | 4 | 4 |
| " | 1A | G-2 | 4 | 4+ |
| Marshburn | 1A | H-5 | 4 | 4 |
| " | 1 | H-6 | 3 | 3 |
| " | 2 | H-6 | 3 | 3 |
| " | 3R | F-8 | 1 | 1 |
| McCoy | 1 | G3 | 3 | subsurface |
| " | 2R | G-3 | 3 | subsurface |
| Myford | 1 | D-5 | 2 | 2 |
| Peters Canyon Wash | 13 | E-5 | 3 | subsurface |
| " | 16 | C-6 | 3 | 2 (rip-rap) |
| PCW Div. Canal | 1-7 | F-3-4 | 2 | construction |
| " | 1-2 | F-3 | 2 | construction |
| Rattlesnake | 1-6 | F-4 | 4 | subsurface |
| " | 9-15 | E-5 | 3 | subsurface |
| Roadside Ditch Sand Canyon Blvd. | 1 & 2 | F-8 | 1 | monuments destroyed |

**Appendix 1, continued**

Profile Inventory, 1997-98 (see channel map for legend to conditions)

| Channel Name | Profile No. | Map Grid | 1997 Cond. | 1998 Cond. |
|---|---|---|---|---|
| Sand Canyon | 3 | D-9 | 2 | 2 |
| " | 2 | D-9 | 2 | 2 |
| " | 1A | C-8 | 2 | 2+ |
| San Diego Creek | C | H-10 | 2 | 2+ |
| " | 2R | F-8 | 1 | 1 |
| " | 3R | F-8 | 1 | 1 |
| " | 5 | E-8 | 2 | construction |
| " | 5A | E-8 | 2 | construction |
| " | 6 | E-8 | 2 | construction |
| Serrano | A | L-8 | 2 | 2+ |
| " | B | L-8 | 2 | 2+ |
| " | B2 | K-8 | 2 | 2+ |
| " | C | K-8 | 2 | 2+ |
| " | D | K-8 | 2 | 2+ |
| " | 1B2 | J-9 | 2 | 2+ |
| " | 1B | I-9 | 2 | 2+ |
| " | 2R | H-9 | 3+ | 5 |
| " | 3R | H-10 | 2 | 2+ |
| Serrano Trib. | 1 | H-9 | 3 | 3 |
| " | 2 | H-9 | 3 | 3 |
| Simonek | 1R | G-6 | 3 | 3+ |
| " | 3 | F-7 | 3 | 3+ |
| " | 4 | F-7 | 3 | 3+ |
| Trimble | 1 | G-2 | 1 | construction |
| Total Profiles | | | 98 | 68 |



Legend
RESTRICTED A
WATERCOURSE
SUBSURFACE
LINED CHANNE
PARTIALLY LIN
UNLINED, RELA
PARTIALLY VE
UNSTABLE
EXTREMELY U
Note: Photo sites a shown on ea have been d
EASTERN TRANSPORTATION CORRIDOR (E.T.C.)
TUSTIN RANCH
NORTHWOOD DEVELOPMENT
IRVINE INDUSTRY COMPLEX
MARINE CORPS HELICOPTER AIR STATION
IRVINE BUSINESS COMPLEX
WESTPARK
WOODBRIDGE
CAMINO REAL
UNIVERSITY PARK
TURTLE ROCK
UNIVERSITY OF CALIFORNIA IRVINE
EL TORO MARINE CORPS AIR STATION
NAVAL RESERVATION
ATCHISON TOPEKA & SANTA FE RAILROAD
Wm. R. MASON REG. PK
Rattlesnake Reservoir
Siphon Reservoir
Lambert Reservoir
Sand Canyon Reservoir
Laguna Reservoir
Sanitary Landfill
33°45'
33°40'
2
3
4
5
6
7
8
9

where it is equally strong. Although presumably these latter wear surfaces are homologous with wear surfaces 5 and 1, respectively, of Crompton, there are no evident boundaries between them. Some evidence of wear surface 2 may be present on the anterior slope of the protoconid of $M_1$, but there is only the slightest evidence of wear surface 3 and none of wear surface 4 on the anterior and posterior sides, respectively, of the hypoconid. This distribution of wear facets might be expected of a fully tribosphenic mammal in which the unknown upper molars had prominent protocones with major wear surfaces on their tips together with their anterior and posterior slopes. In addition, these upper molars had well-developed wear surfaces on the paracrista (wear surface 1a of Crompton) or preparaconule crista (wear surface 1b of Crompton), or both. Unlike $M_{1-2}$, the $M_3$ is not damaged. Wear facets 1, 5, and 6 of Crompton are present but more subdued than on $M_{1-2}$. There is no sign of wear facets 2-4 on $M_3$.

16. Z. Kielan-Jaworowska, A. W. Crompton, F. A. Jenkins *Nature* **326**, 871 (1987).
17. W. A. Clemens and J. A. Lillegraven, *Contrib. Geol. Univ. Wyo. Spec. Pap.* **3**, 55 (1986).
18. P. M. Butler, *Biol. Rev.* **65**, 529 (1990); R. L. Cifelli, in (5), pp. 205–215.
19. L. G. Marshall and Z. Kielan-Jaworowska, *Lethaia* **25**, 361 (1992).
20. Recent evidence suggests that Early Cretaceous Gondwanan dinosaur assemblages, too, were more cosmopolitan than previously thought [P. C. Sereno *et al.*, *Science* **266**, 267 (1994); P. C. Sereno *et al.*, *ibid.* **272**, 986 (1996)].
21. T. H. Rich *et al.*, in *Vertebrate Palaeontology of Australasia*, P. Vickers-Rich, J. M. Monaghan, R. F. Baird, T. H. Rich, Eds. (Pioneer Design Studio in cooperation with the Monash University Publications Committee, Melbourne, 1991), p. 1005; C. H. Watts and P. R. Baverstock, *Aust. J. Zool.* **42**, 711 (1994).
22. The holotype of *Tingamarra porterorum* is a right, lower molar identified as Infraclass Placentalia, Order ? Condylarthra by H. Godthelp *et al.* [*Nature* **356**, 514 (1992)] from the Tingamarra Local Fauna in southeastern Queensland reported as Early Eocene in age. Identification of this specimen as a placental has been questioned by F. S. Szalay [*Evolutionary History of the Marsupials and an Analysis of Osteological Characters* (Cambridge Univ. Press, Cambridge, 1994) and M. O. Woodburne and J. A. Case [*J. Mamm. Evol.* **3**, 121 (1996)]. Furthermore, Woodburne and Case question the Early Eocene age of the Tingamarra Local Fauna, suggesting it may be Late Oligocene or Early Miocene.
23. R. Morgan, *Mem. Geol. Surv. NSW Palaeontol.* **18**, 1 (1980)
24. R. Helby, R. Morgan, A. Partridge, *Assoc. Australasian Palaeontol. Mem.* **4**, 1 (1987).
25. P. F. Green, "Fission track dating of zircons from a sample of Otway Group from Spout Creek, Eastern View" (1989) [unpublished GEOTRACKTM report 172].
26. F. M. Gradstein *et al.*, *J. Geophys. Res.* **99**, B12, 24051 (1994).
27. A. W. Crompton, in *Early Mammals*, D. M. Kermack and K. A. Kermack, Eds. (Academic Press, New York, 1971), pp. 65–87.
28. A. G. Smith, D. G. Smith, B. M. Funnell, *Atlas of Mesozoic and Cenozoic Coastlines* (Cambridge Univ. Press, Cambridge, 1994), p. 41.
29. W. A. Clemens, *Paleobios* **33**, 1 (1980), J. A. Lillegraven *J. Paleontol.* **50**, 437 (1976).
30. R. L. Cifelli, *J. Vertebr. Paleontol.* **10**, 346 (1990); W. A. Clemens, *Univ. Calif. Publ. Geol. Sci.* **94**, 1 (1973); R. C. Fox, *Can. J. Earth Sci.* **16**, 114 (1979).
31. R. J. Emry, J. D. Archibald, C. C. Smith, *J. Paleontol.* **55**, 953 (1981).
32. J.-L. Ledoux, J.-L. Hartenberger, J. Michaux, J. Audre, L. Chaler, *CR Seances Acad. Sci. Paris Ser. D* **262**, 1925 (1966).
33. L. A. Nessov, D. Sigogneau-Russell, D. E. Russell *Palaeovertebrata* **23**, 51 (1994).
34. Z. Kielan-Jaworowska, T. M. Bown, J. A. Lillegraven, in *Mesozoic Mammals: the First Two-Thirds of Mammalian History*, J. A. Lillegraven, Z. Kielan-Jaworowska, W. A. Clemens, Eds. (Univ. of California Press, Berkeley, 1979), p. 221; J. A. Lillegraven and M. C. McKenna, *Am. Mus. Novit.* **2840**, 1 (1986).
35. B. E. Wagstaff and J. McEwen Mason, *Nat. Geogr. Res.* **5**, 54 (1989).
36. G. V. R. Prasad, J. J. Jaeger, A. Sahni, E. Gheerbrant, C. K. Khajuria, *J. Vertebr. Paleontol.* **14**, 260 (1994).
37. D. W. Krause *et al.*, *Nature* **368**, 298 (1994).
38. I. R. McLachlan and I. K. McMillan, *Spec. Publ. Geol. Soc. S. Afr.* **6**, 161 (1979); C. A. Forster, personal communication.
39. J. F. Bonaparte *Nat. Geogr. Res.* **6**, 63 (1990).
40. F. J. Goin, A. A. Carlini, R. Pascual, *Actas IV Congr. Argent. Paleontol. Bioestratigr. Mendoza* **2**, 43 (1986).
41. G. W. Rougier, J. R. Wible, J. A. Hopson, *J. Vertebr. Paleontol.* **12**, 188 (1992).
42. T. E. Mourier *et al.*, *Bull. Soc. Geol. France Ser. 8* **2**, 171 (1986).
43. T.H.R and P.V.-R. acknowledge the long-term support of the Committee for Research and Exploration of the National Geographic Society. We thank J. Archibald, J. Bonaparte, W. Clemens, A. Crompton, F. Goin, J. Hopson, Z. Kielan-Jaworowska, D. W. Krause, J. Lillegraven, M. McKenna, R. Pascual, D. Sigogneau-Russell, R. Sloan, F. Szalay, L. Van Valen, M. Woodburne, and two anonymous reviewers for helpful commentary on this manuscript and F. Coffa, C. de Groot, A. Dyer, D. Gelt, R. Jackson, P. Littlefield, S. Morton, I. Stewart, and P. Trusler for technical assistance.

27 May 1997; accepted 9 October 1997

# Contribution of Stream Channel Erosion to Sediment Yield from an Urbanizing Watershed

Stanley W. Trimble

**Stream channel erosion has long been suspected as the major contributor to long-term sediment yield from urbanizing watersheds. For San Diego Creek in southern California, measurements from 1983 to 1993 showed that stream channel erosion furnished $10^5$ megagrams per year of sediment, or about two-thirds of the total sediment yield. Thus, because channel erosion can be a major source of sediment yield from urbanizing areas, channel stabilization should be a priority in managing sediment yield.**

Stream channel erosion can be the major source of sediment in urbanizing watersheds, with deleterious downstream effects (*1*). Increased storm runoff and stream channel changes resulting from urbanization have long been a concern, and work over the past three decades suggests that the relative contribution of long-term channel erosion to downstream sediment yield is substantial (*2–4*). However, the lack of hard data prompted the National Research Council to designate long-term channel erosion rates and sediment budgets for urbanizing watersheds as priority research needs (*5*). Additionally, much less is known about the geomorphologic effects of urbanization in arid regions than in humid regions (*6*). In most arid urban areas, irrigation increases antecedent soil moisture in vegetated areas, further increasing storm runoff. Moreover, urban development may, within the basin, displace rather than replace irrigated agriculture, so that agricultural impacts remain. Here I present data from an urbanizing basin in southern California and examine the role of channel erosion in augmenting sediment yield.

San Diego Creek, which drains a 288-$km^2$ basin in Orange County, California (Fig. 1), supplies sediment to Newport Bay, which is considered to be one of the primary estuarine wildlife habitats in the state. Urbanization has been rapid (Fig. 1) and is typical of many areas in the United States, especially the Southwest. A federal Clean Water Act study of the basin in 1981 concluded that the sediment sources were agriculture, steep foothills, and construction. Channel erosion was considered unimportant (*7*).

I began a long-term study of channel changes in the San Diego Creek watershed after a brief geomorphologic analysis (*8*) of the area in 1981 suggested that erosion from the largely earthen channel system could be a major contributor of sediment. An initial channel study using historical methods and aerial photogrammetry indicated that from the late 1930s to the early 1980s channel erosion supplied more than one-fourth of all sediment yield, but there were many uncertainties, especially regarding total sediment yield from the basin (*9*). Starting in 1983, I surveyed and installed 196 monumented (more or less permanently marked) channel cross-sections (profiles) at intervals along earthen channels of all types and sizes (Fig. 1). Over time, some profiles were invalidated by disturbance, and problems of property accessibility delayed or prevented measurements in some places. Thus, profiles had to be monitored annually, and new profiles were added as required throughout the decade (*10*). As a cooperator in the study, Orange County annually surveyed the downstream zones of sediment accumulation—trunk channels and in-channel sedi-

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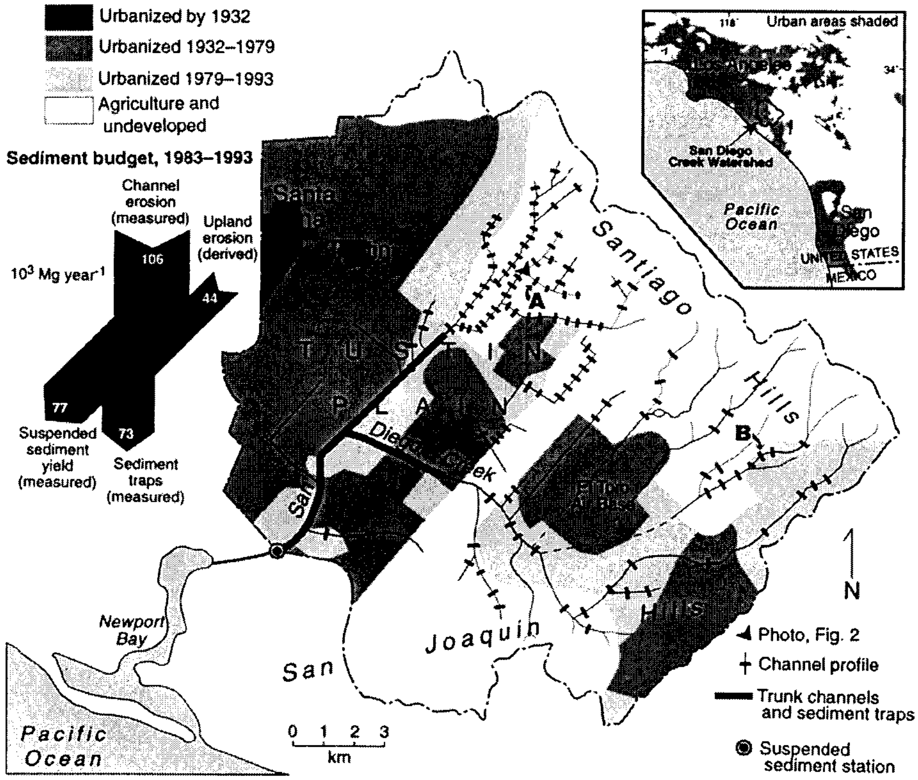


**Fig. 1.** San Diego Creek, showing the earthen stream channel network and the expansion of urban land, 1932–93. Paved channels and channels lying upstream from reservoirs were not included in the study. The cross-sectional channel profiles shown are those remaining in 1993. Sediment yield is that measured at the station plus accretion in the trunk channels and sediment traps. Inset is the sediment budget (balance). A and B indicate the profiles shown in Fig. 3.

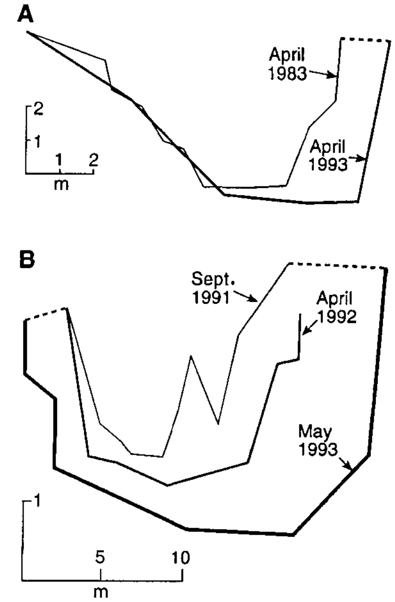


**Fig. 3.** Surveyed stream channel profiles. (**A**) Hicks Canyon Wash profile 6, 1983 and 1993 (Fig. 2). The rate of erosion at this profile was 0.47 $m^3$ $year^{-1}$ per meter of channel. At a bulk specific gravity of 1.44, this would be 0.7 Mg $m^{-1}$ $year^{-1}$, a local erosion rate that was slightly less than the decadal mean for this type of channel. (**B**) Extreme erosion of Borrego Canyon Wash profile 3, directly downstream from an urbanizing area during the wet years of 1992–1993. The rate of erosion was about 20 $m^3$ $m^{-1}$ $year^{-1}$ or about 29 Mg $year^{-1}$ per meter of channel. This reach has since been stabilized. See Fig. 1 for locations.

A B

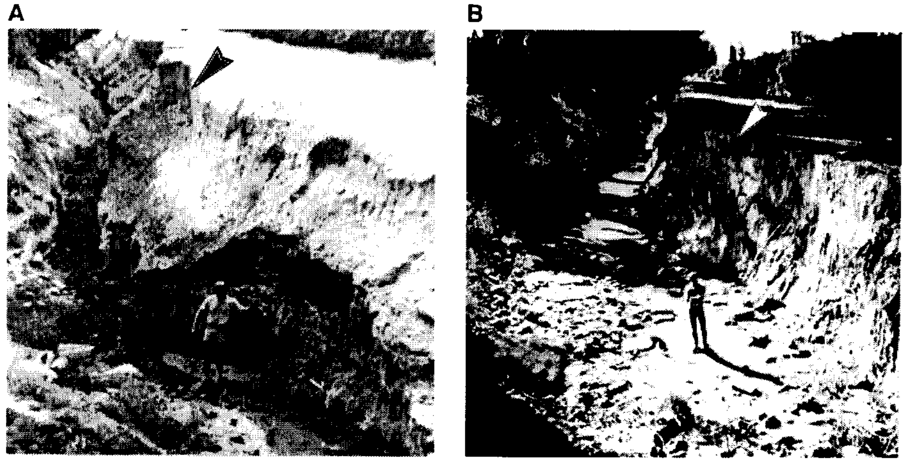

**Fig. 2.** An example of stream channel erosion in Hicks Canyon Wash, looking southeast at the confluence with Rattlesnake Canyon Wash (Fig. 1). (**A**) 1979. (**B**) 1993. A person stands at approximately the same location in both photographs. Note the retreat of the cut bank to the right. Arrows mark the location of surveyed profiles in 1983 and 1993 (Fig. 3).

ment traps (Fig. 1)—and kept an account of all sediment removed. The county also maintained a full-time suspended sediment measuring station about 2 km upstream of Newport Bay (Fig. 1).

All 108 usable profiles remaining in 1993 were resurveyed. The results indicated that the net average rate of channel erosion was $106 \times 10^3$ Mg $year^{-1}$ between 1983 and 1993. Time-lapse photography (Fig. 2) and the survey results (Fig. 3) give graphic evidence of channel enlargement. During the same period, net accretion in the trunk channels and sediment traps was $73 \times 10^3$ Mg $year^{-1}$; and suspended sediment yield at the station was $77 \times 10^3$ Mg $year^{-1}$, constituting a total sediment sink and efflux of $150 \times 10^3$ Mg $year^{-1}$(see sediment budget, Fig. 1). Thus, channel erosion accounted for about two-thirds of the measured sediment yield from San Diego Creek. Average erosion rates show few signs of declining, and new development may locally accelerate channel erosion (Fig. 3B). Hence, amelioration of channel erosion is an appropriate management strategy for sediment control, but little had been done by 1993.

The usually perceived problem with stream channel erosion is that it has deleterious downstream effects in streams, lakes, and estuaries. However, the erosional process itself is also problematic because channel enlargement is often lateral, thus removing substantial areas of valuable urban land; damaging parkland, bridges, and other infrastructure; and making channels unsightly (*2, 4*) (Fig. 2).

The process of sediment loss in urbanizing basins is analogous to the formation of arroyos that occurred in the Southwest in the late 18th and early 19th centuries (*12*). However, rather than grazing or climatic change, the present cause is the greater magnitude and frequency of peak stream flow in response to impervious urban surfaces. This study joins a growing literature on the role of sediment storage in general; and, in particular, shows that sediment storage loss from stream channel erosion over varied geographic regions can be a major source of sediment yield (*13*). In such cases, sediment yield per unit area can actually increase with basin area rather than decrease, as is commonly perceived.

Suspended sediment measuring stations in sand-bed channels can underestimate total sediment loads (*14*), and this may be the case for San Diego Creek. If substantial, the additional sediment yield could relegate channel erosion to a somewhat smaller proportion of total sediment yield but probably no less than half. Erosion of earthen channels will remain a substantial source of sediment yield from urban stream systems until proper ameliorative measures are taken.

## REFERENCES AND NOTES


1. S. Trimble, in preparation.
2. M. Wolman, *Geogr. Ann.* **49A**, 385 (1967).
3. M. Wolman and A. Schick, *Water Resour. Res.* **3**, 451 (1967); L. Leopold, *U.S. Geol. Surv. Circ. 554* (1968); *Geol. Soc. Am. Bull.* **84**, 1845 (1972); W. Graf, *ibid.* **11**, 690 (1975); G. Hollis and J. Luckett, *J. Hydrol.* **30**, 351 (1976); W. Graf, *Water Resour. Res.* **13**, 459 (1977); C. Arnold, P. Boison, P. Patton, *J. Geol.* **90**, 155 (1982); H. Chang and D. Stow, *J. Hydrol.* **99**, 201 (1988); F. Ebisemiju, *Appl. Geogr.* **9**, 273 (1989); R. Neller, *Environ. Geol. Water Sci.* **14**, 167 (1989); C. Roberts, in *Floods: Hydrological, Sedimentological, and Geomorphical Implications*, K. Beven and P. Carling, Eds. (Wiley, Chichester, UK, 1989), pp. 57–82; D. Booth, *Water Resour. Bull.* **26**, 407 (1990); K. Gregory, R. Davis, P. Downs, *Appl. Geogr.* **12**, 299 (1992); F. Odermerho, *Prof. Geogr.* **44**, 332 (1992).
4. T. Hammer, *Water Resour. Res.* **8**, 1530 (1972).
5. National Research Council, *Watershed Research in the U.S. Geological Survey* (National Academy Press, Washington, DC, 1997).
6. R. Cooke, D. Brunsden, J. Doornkamp, D. Jones, *Urban Geomorphology in Drylands* (Oxford, UK, 1982); W. L. Graf, *Fluvial Processes in Dryland Rivers* (Springer-Verlag, Berlin, 1988); M. Newson, *Land, Water and Development* (Routledge, London, 1992).
7. Boyle Engineering Corporation, *Hydrologic Analysis, Newport Bay Watershed, San Diego Creek Comprehensive Stormwater Sedimentation Control Plan*, Part II, Task II-A, Technical Memorandum (San Diego, CA, 1981).
8. S. Trimble, *Geomorphic Analysis, Newport Bay Watershed, San Diego Creek Comprehensive Stormwater Sedimentation Control Plan*. Part II, Task II-B, Technical Memorandum (Boyle Engineering, San Diego, CA, 1981).
9. B. Hoag, thesis, University of California, Los Angeles (1983).
10. The 1983–85 annual reports are on file at the Environmental Studies Section, Orange County Environmental Management Agency (OCEMA), Anaheim, CA. The 1986–93 reports are included in the Annual Reports, San Diego Creek Sediment Monitoring Program (OCEMA, Santa Ana, CA).
11. S. Trimble, in *San Diego Creek Sediment Monitoring Program Annual Report, 1992–1993* (OCEMA, Santa Ana, CA, 1994), appendix B. Available at www.geog.ucla.edu/faculty/trimble.html.
12. R. Cooke and R. Reeves, *Arroyos and Environmental Change in the American Southwest* (Clarendon Press, Oxford, UK, 1977).
13. S. W. Trimble, *Science* **188**, 1207 (1975); S. A. Schumm, M. P. Mosley, G. L. Zimpfer, *ibid.* **191**, 871 (1976); S. W. Trimble, *ibid.*, p. 871; W. Dietrich and T. Dunne, *Zeits. Geomorphol. Suppl.* **29**, 191 (1978); H. Kelsey, *Geol. Soc. Am. Bull.* **91**, 190 (1980); S. W. Trimble, *Science* **214**, 181 (1981); F. Swanson, F. Janda, T. Dunne, D. Swanston, Eds., *Sediment Budgets and Routing in Forested Drainage Basins* (U.S. Department of Agriculture, Forest Service General Technical Report PNW141, 1982); R. Meade, *J. Geol.* **90**, 235 (1982); P. Patton and P. Boison, *Geol. Soc. Am. Bull.* **97**, 369 (1986); J. Phillips, *Am. J. Sci.* **287**, 780 (1987); M. Church and O. Slaymaker, *Nature* **337**, 352 (1989); J. Knox, *Int. Assoc. Hydrol. Sci. Pub.* **184**, 157 (1989); P. Ashmore, *Prog. Phys. Geogr.* **17**, 190 (1993); A. Schick and J. LeKach, *Phys. Geogr.* **14**, 225 (1993); O. Slaymaker, *ibid.*, p. 305; S. Trimble, in *Changing River Channels*, A. Gurnell and G. Petts, Eds. (Wiley, Chichester, UK, 1995), pp. 201–215.
14. W. Emmett, R. Myrick, R. Meade, *U.S. Geol. Surv. Open-File Rep. 80-1189* (1980); W. Rose, *U.S. Geol. Surv. Water Resour. Inv. Rep. 90-4124* (1992); K. Fowler and J. Wilson, *U.S. Geol. Surv. Water Resour. Inv. Rep. 95-4135* (1997).


15. I thank the U.S. Geological Survey, Water Resources Division; the Orange County Environmental Management Agency; the California Water Resources Council; and the University of California, Los Angeles (UCLA), Faculty Senate for funding this study. This paper was improved by comments from R. Ambrose, W. W. Emmett, W. L. Graf, J. Harvey, R. Mattoni, A. Mendel, L. Smith, and M. G. Wolman. I also thank the many UCLA students who assisted me in the field research.

24 June 1997; accepted 16 October 1997


# Adatom Pairing Structures for Ge on Si(100): The Initial Stage of Island Formation


X. R. Qin and M. G. Lagally*



With the use of scanning tunneling microscopy, it is shown that germanium atoms adsorbed on the (100) surface of silicon near room temperature form chainlike structures that are tilted from the substrate dimer bond direction and that consist of two-atom units arranged in adjoining substrate troughs. These units are distinctly different from surface dimers. They may provide the link missing in our understanding of the elementary processes in epitaxial film growth: the step between monomer adsorption and the initial formation of two-dimensional growth islands.


Because of its importance in microelectronics and its unique properties, the (100) surface of silicon has been extensively investigated. Driven by the capability of the scanning tunneling microscope (STM) to view this surface easily with atomic resolution, Si(100) in particular has been used as a model to understand the atomistic mechanisms of film growth (*1*). For both Si and Ge deposition, early stages of growth at low temperatures produce many stable adsorbed dimers (called ad-dimers), that is, two atoms that clearly remain bound to each other for extended times, as well as rows of many such ad-dimers (called islands) (*2*, *3*). Following classical nucleation theory, in which growth occurs by the addition of atoms to a "critical nucleus" (*4*), it was postulated that Si or Ge monomers deposited on the Si(100) surface diffuse to form ad-dimers and that the ad-dimer is the stable nucleus from which all subsequent larger growth structures (such as the ad-dimer row islands) evolve by addition of further monomers (*2*). Intermediate structures ("diluted-dimer islands"), in which alternate ad-dimers in ad-dimer row islands are missing (*5*) and in which the remaining ad-dimers are rotated (*6*), are thought to arise from individual ad-dimers and to represent an early growth stage (*5*, *7*). Yet this evolution from single ad-dimer to any of the larger structures has not been observable, despite the intrinsic ability of the STM to do so. Hence, a critical element of understanding is missing: the atomistic pathway from the initial adsorbed monomers to the existence of stable ad-dimer row islands. The role of the ad-dimer as the essential element in this pathway has so far not been questioned.

In this report, we describe high-resolution STM observations of structures formed during the initial growth of Ge on Si(100)(2 × 1) near room temperature, in which the Ge atoms exist as two-atom units that are distinctly different electronically and structurally from any dimer in or on the surface. We show that they provide a physically reasonable link between monomer adsorption and diluted-dimer island formation. We suggest that, at least at low temperatures, ad-dimers are not part of the nucleation-growth pathway.

The experiments were performed on Si(100) with a high-quality 2 × 1 surface and a defect density of <0.5%, in an STM outfitted with an evaporation source from


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# FIELD RESEARCH REPORT
# FOR SAN DIEGO CHANNEL STUDY

**FALL, 1997**


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# EXECUTIVE SUMMARY

Field research on channel erosion and attendant processes was conducted in the San Diego Creek Watershed during October, 1997. A total of 35 profiles were lost in the 4 1/2 years since the resurveys of Spring, 1993. Of these profiles, 22 were permanently lost to highway construction and channel improvement. Another 13 profiles were temporarily lost to local construction and other disturbances. Eleven new profiles were installed this Fall, mainly to replace those destroyed. Much construction is taking place in and along channels and it is to be hoped that it will be finished before heavy rains begin. Although rainfall has been moderate since 1993, some channel erosion was observable since the last surveys. The new foothill floodwater retention structures will be excellent sediment traps and could thus provide estimates of erosion rates from the foothill areas. To that end, it is recommended that profiles for sediment measurement be installed.

**Field Research Report for San Diego Creek Channel Study, Fall, 1997**

1. Introduction. Field research was conducted in the San Diego Creek Watershed in October, 1997. The primary purpose was to inventory and prepare profiles for resurvey in Spring, 1998. A wet winter is expected because of the El Niño effect and channels are expected to erode severely.

2. Recovery of Profiles. A total of 35 profiles were lost between May, 1993 and October, 1997. These losses may be placed into two categories. The first of these consists of profiles permanently lost to new channel construction or to road or other construction. In this category, 22 profiles were lost.

A. Profiles Permanently Lost:

| | |
|---|---|
| Little Coyote | 1 |
| Ashley | 1 |
| Peters Canyon Wash | 4, 5, 6, 7, 8, 10, 11, 12, 15 |
| Irvine Channel | 8, 9 |
| Bonito Canyon | 1, 2R, 3R |
| Bee Canyon | A, B |
| Hicks Canyon | C |
| Rattlesnake | 1A, 1B, 7 |

Most of these losses are due to the building of new transportation corridors and housing estates. In some cases, the roads are being built directly over and along the channels. The most obvious example is the Eastern Transportation Corridor which will cover part of upper Peters Canyon Wash (Map, E, F-3, 4) and will destroy 13 profiles there. Much of the new channel, now under construction, will be subsurface and the surface portions will be concrete down to Interstate 5.

Another highway, Portola Parkway, will be built directly over almost a mile of Rattlesnake Canyon Wash (Map, G-3). Profiles 1A and 1B have already been destroyed and, although still in place, Profiles 1 and 2 may well be destroyed before the Spring resurveys.

A large expressway, the Eastern Transportation Corridor, cuts across the Santiago Hills and across the main tributaries of San Diego Creek. The resulting large embankments spanning the stream valleys are modified to also serve as floodwater retention structures (dams). These are already in place on Hicks Canyon, Bee Canyon, Round Canyon, and Agua Chinon. This construction has destroyed Bee Profiles A and B. Additionally, profiles located upstream from the dams have lost most of their utility because most sediment from those reaches will presumably be trapped by the dams. Those profiles are Round Canyon 1 and Agua Chinon A and B.

The second category of lost profile is those temporarily lost to local construction or other disturbance. There were 13 profiles in this category.

B. Profiles Temporarily Lost:

| | |
|---|---|
| McCoy | 2 |
| Marshburn | 3, 4 |
| Serrano | 1, 1A, 2, 3 |
| San Diego Creek | B(R) |
| Borrego | 3, 4, B |
| Simonek | 1, 2 |

Most of these profiles were replaced at a location as close as possible to the old ones (see next section).

3. New Profiles. Eleven new profiles were added this year, primarily to replace those disturbed. These were:

| | |
|---|---|
| Serrano | B2D, 1B2, 2R |
| San Diego Creek | 3R |
| Borrego | 3R |
| Marshburn | 1A, 3R |
| McCoy | 2R |
| Little Joaquin | 1B |
| Simonek | 1R |

The profile notes are enclosed as a separate appendix.

4. Construction of Stabilized Channels. As mentioned earlier, new highways are being built over or near several reaches of the channel network, most notably along Peters Canyon Wash. As part of that construction, channels are being reconstructed so that when finished, they will be more stable. The forms used are concrete open channels, concrete closed conduit and drop structures in conjunction with stabilized channel sides. The concern here is that these channels were still under construction in October. Thus, there are large piles of loose soil and steep slopes which are unstable and extremely susceptible to erosion and downstream transport. If heavy rains set in before these channel reaches are stabilized, the result will be massive movement of sediment downstream.

5. Channel Erosion Since 1993. Although generally not extreme, it was clear that many channel reaches have eroded measurably since last surveyed in 1993. For example, the right abutment of old wooden railroad bridge near Rattlesnake Profile 9 no longer makes contact with the bank (Map, F-4). The most extreme

erosion was downstream of the new Lake Forest urban development on Borrego Creek. Erosion was especially remarkable on the Naval Reservation (Map, J-7).

6. Measurement of Foothill Sediment Yields. A major unresolved question of sediment management in the San Diego Creek basin has been the contribution of the foothill areas. Thus, I recommend that sediment accumulation behind the new dams be monitored. This could be done relatively inexpensively by establishing monumented profiles across the sediment accumulation zones. These surveyed profiles would be similar to those used in channel studies but spaced much closer together.

# FIELD RESEARCH REPORT, SPRING 1993:
# RATES OF CHANNEL EROSION IN THE SAN DIEGO CREEK BASIN 1983-1993:


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## APPENDIXES

# EXECUTIVE SUMMARY

Stream channel cross-sections (ranges) were surveyed starting in 1983 so that future channel erosion could be accurately measured. Despite the loss of about 80 ranges over the span of a decade, about 116 ranges remained in 1993. The period 1983-1991 was relatively dry so that relatively little channel erosion occurred. After the two relative wet water years of 1991-1993 with consequent channel erosion being observed, resurvey of the ranges was done in Spring 1993. Based on form, process, and purpose, channels were categorized into (1) minor tributaries and roadside ditches, (2) relatively non-urbanized major tributaries and urbanized tributaries with low gradients, (3) urbanized major tributaries with steeper gradients, (4) trunk channels, and (5) sediment traps near Newport Bay. The first three categories are eroding channels and furnish a minimum of about 97,000 tons of sediment per year. Of that, about 27,000 tons is deposited in Upper San Diego Creek, leaving a net erosion value of about 70,000 tons per year. This figure does not include Peters Canyon Wash below Interstate 5, and Lower San Diego Creek. Those values will be furnished by OCEMA Scour Studies. However, it is clear that channel erosion furnishes a significant proportion of the sediment transported by San Diego Creek towards Newport Bay.

# Rates of Channel Erosion in the San Diego Creek Basin, 1983-1993

## 1.0 INTRODUCTION

In 1982, I obtained a grant from the California Water Resources Center to study channel erosion in the San Diego Creek Basin and its effect on the sedimentation of Newport Bay. This grant led to the completion of an M.A. thesis in 1983 by Barbara L. Hoag under my direction. For this research, Ms. Hoag surveyed 50 cross-sectional profiles of streams (ranges) and then reconstructed the growth of channel size from 1938 by the use of photogrammetry. That study convincingly showed that channel erosion had been responsible for a large proportion of sedimentation in the Bay.

With support from the U.S. Geological Survey and Orange County EMA (OCEMA) in 1983 and 1984, I expanded the system of ranges to well over 100 (Figure 1). The intent was (1) to get more precise measurements of channel erosion than photogrammetry could provide, and (2) to obtain current rather than long-term channel erosion rates.

A series of dry years generally precluded significant channel erosion, so with the continuing support of OCEMA, I kept the profiles ready for resurvey and continued to add new ones. A major problem was that continuing urbanization, construction, and channel changes destroyed about 80 profiles over the period 1983-1993. Much of the urbanization unfortunately

MAP 2

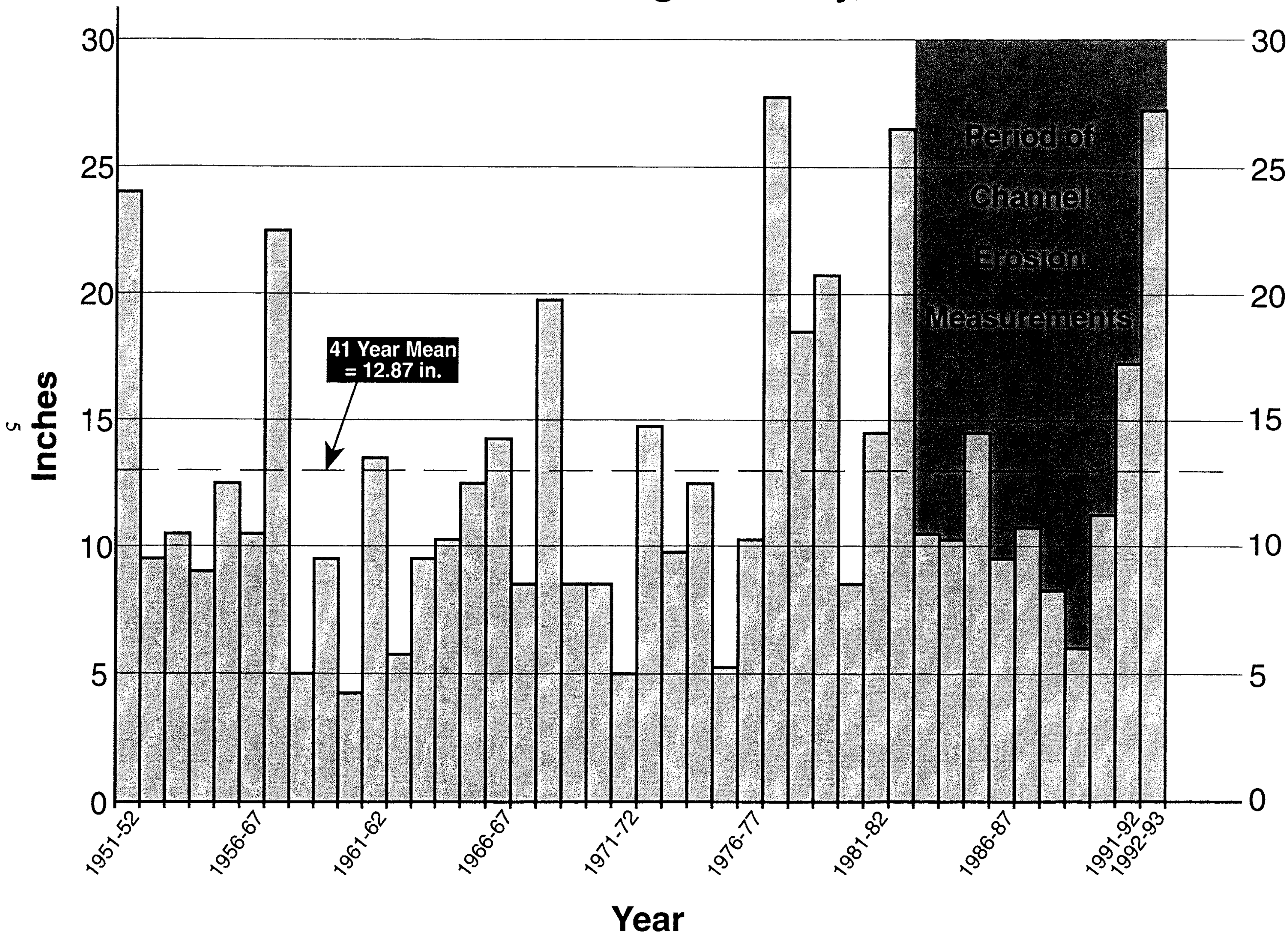
took place in the areas where the original profiles were installed so that about half of the longest-term profiles were destroyed before any usable data could be collected.

The dry period lasted from late 1983 to late 1991. Resurveys of selected ranges in 1991 showed that some channels had enlarged despite the lack of excessive rain (Trimble, 1991). The primary reason suggested for that enlargement was mass movement of oversteepened and unstable channel banks. Even moderate stormflows could then transport this material away.

The water year of 1991-1992 was wet but not extremely so. Although it was the eighth wettest year during the period 1951-1992, the total of 17.18 inches was only moderately above the average of 12.87 inches (Figure 2). However, there was enough streamflow to significantly erode stream channels, especially where urbanization was expanding rapidly (Trimble, 1992). The water year of 1992-1993 was much wetter, being the second wettest year during the period 1951-1992 with a total of 27.09 inches of rainfall (Figure 2). Although individual storms were not exceptionally great, there were several large stormflow events which eroded channels significantly. Thus, two successive wet years signaled the appropriate time to resurvey the channel ranges, many of which had been in place since the mid-1980's. Because most of the past decade was dry (Figure 2), the long-term channel erosion rates reported here probably give a minimum decadal value. However, 21 of the profiles were installed in 1991 or thereafter and reflect the higher erosion rates of the past two wet years. These new profiles provide a measure of the maximum rates of change during wet years.

Figure 2

## Annual Precipitation (July-June)
## Tustin Ranch, Orange County, California



## 2.0 METHODOLOGY

Ranges are surveyed channel cross-sections with fixed vertical and lateral control. Their location is semi-random, but significant locational constraints are access and the local presence of fixed objects such as trees, utility poles, or buildings to which datum can be affixed. Lack of access may be local (e.g., riverine wildlife area or it may be on a larger scale. For example, I did not gain legal access to the portion of Borrego Creek located on the Navy Reservation until 1992. The ranges are resurveyed after some period (e.g. at least five years) and a net average change of cross-sectional area is measured. Note that both erosion and filling can take place in the same reach, sometimes simultaneously. The measured net change of the range is considered to be a sample point in the channel system.

Ranges are generally retained unless there is a major modification directly on or near the profile or when local datum marks or monuments are lost. Upstream or downstream channel modifications which would affect the range are usually considered to be just a sample of continuing changes in the system which would affect channels. For example, an invert under Interstate 5 on Peters Canyon Wash (PCW) was lowered in 1992, probably affecting the rate of scour on sections of Peters Canyon Wash and Rattlesnake Canyon Channel upstream to Bryan Avenue (E-4, Fig. 1). Conversely, drop control structures were installed on McCoy (G-3, Fig. 1) and Kim Creek (F-9, Fig. 1), thus causing channel aggradation in some places. I believe that the effects of such alterations tend to offset one another when the larger picture is considered.

A continuing problem has been the dumping of debris along channels, especially where banks have been seriously eroded; Plate 1, see also Plate 2 in Trimble (1992). The first problem of such dumping is that it can confuse the measurements. Plate 1 gives an idea of how extensive the practice can be. Thus, measurements made along such channels are usually minimum measures of erosion. On some occasions, I can tell where material has been dumped and measure around it. In other cases, it may disqualify the range.

The second problem is that the material usually contains a large proportion of fine particles which can be entrained and transported to the Bay. Because the material is poorly sorted, larger particles are undermined, fall out into the channel, and are scattered downstream where they help destabilize the channel.

Thus, the effect of such dumping is that it reduces the measured rates of channel erosion while it increases the actual rate. Good examples of this can be found on Hicks Canyon Channel along Jeffrey Road (H-4, Fig. 1).

Of 116 viable ranges in the Basin, 3 were resurveyed in 1991 or 1992 (Borrego 2, Hines B and 1) and 93 were resurveyed in 1993. Twelve profiles (9 on Peters Canyon Diversion Channel, Golf Course 1 & 2, Trimble 1) were not resurveyed because channel changes were apparent in 1993without instrument surveys. All the above ranges are listed in Table 1. Of the remaining 6 profiles, 4 (Round Canyon 1, De Young Channel Ranges 1, D & E) were not included in Table 1 because downstream sediment traps have greatly reduced their sediment originals returned to Trimble

A

B

**Plate 1.** The Continuing Fill of Eroded Channel Sides. Hines Channel (H-5, Fig. 1) looking downstream at Range B. Photo A: The site in 1992. Note the eroded banks, especially on the left side. Photo B 1993. Note rubble and debris dumped into channel for at least 800 feet downstream. This probably was in response to rapidly-eroding banks in water year 1992-1993.

contribution to the system. The remaining 2 profiles not included in Table 1 are San Diego Creek Range A and Sand Canyon Range 1. Resurveying these would have required cutting a line of sight through riverine forest and wildlife habitat which has grown up in recent years.

Listed below are nineteen ranges which were destroyed prior to the spring study by channel improvements, local construction, or local erosion from the Winter stormflows.

| Location | Ranges |
|---|---|
| Peters Canyon Wash | 12 and 14 |
| Rattlesnake Canyon | 7 and 12 |
| Hines Channel | 1 and 6 |
| Bee Canyon | 1 |
| Borrego Canyon | 4B and 4C |
| Serrano Canyon | 1 |
| Serrano Tributary | 2 |
| San Diego Creek | 5 |
| Marshburn Channel | 3 and 4 |
| Chin | 1 |
| Sand Canyon | 2 and 3 |
| Hicks | 6 and A1 |
| McCoy | 2 |

## 3.0 RESULTS OF THE RESURVEYS

The results of the resurveys are given in Table 1 and their spatial configuration is shown in Figure 3. Note that the channels in Table 1 are grouped into the two divisions of the San Diego Creek watershed: (I) San Diego Creek other than Peters Canyon Wash, and (II) Peters Canyon Wash. These data together with my earlier work and OCEMA's continuing data collection suggest that with regard to form, process, and purpose, there are five channel types in the San Diego Creek Basin significant to sediment production and storage. They are (1) minor tributaries and roadside ditches, (2) relatively non-urbanized major tributaries and urbanized tributaries with low gradients, (3) relatively urbanized major tributaries with steeper gradients, (4) trunk channels, and (5) the sediment trap reach near Newport Bay (sediment basins 1-3). These channel types shall be discussed by category. Note that these are largely earthen channels; paved channels are not considered.

A problem with these groupings is the variance found within each type and along each stream. Such variance may be random, but often it pertains to local control such as drop structures, well-established vegetation along the channel, and the presence of bedrock or indurated material in the channel bed or banks. In Hicks Creek (G-4, Fig. 1), for example, the channel erosion rates from the foothills are low (Ranges A1-A4), but higher through the nursery reach (Ranges A-C see Figures 1 and 3). Rates then become minimal along the Northwood Reach (Ranges 1-4) but they then rise sharply between Culver Drive and the junction with

**Table 1**
Net Change and Category of Channel Profiles

I. San Diego Creek Other than Peters Canyon Wash

| Name of Range (Profile) | | Dates of Surveys | Years Duration | Net Change of Cross-Sectional Area, $ft^2/yr$ | Category of Channel (See Figure 3) |
|---|---|---|---|---|---|
| Serrano | A | 1989-93 | 4 | -0.6 | UT |
| | B | 1989-93 | 4 | +0.9 | UT |
| | C | 1991-93 | 2 | 0 | UT |
| | 1A | 1991-93 | 2 | -165 | UT |
| | 1B | 1991-93 | 2 | - 24 | UT |
| | 2 | 1986-93 | 7 | - 14 | UT |
| | 3 | 1985-93 | 8 | -5.2 | UT |
| Serrano Trib. | 1 | 1986-93 | 7 | -2.1 | MT |
| Borrego | 1 | 1990-93 | 3 | - 10 | UT |
| | 2 | 1991-92 | 1 | -320 | UT |
| | 3 | 1991-93 | 2 | -216 | UT |
| | 4 | 1991-93 | 2 | - 18 | UT |
| | 4A | 1992-93 | 1 | -290 | UT |
| | 4D | 1992-93 | 1 | 0 | UT |
| | 5 | 1991-93 | 2 | + 26 | UT |
| Borrego Trib. (F21) | A | 1992-93 | 1 | 0 | NT |
| | B | 1992-93 | 1 | - 29 | NT |
| Agua Chinon | A | 1986-93 | 7 | - 5 | NT |
| | B | 1986-93 | 7 | -0.4 | NT |
| Bee | A | 1985-93 | 8 | 0 | NT |
| | B | 1985-93 | 8 | -1.5 | NT |
| Marshburn(F16) | 1 | 1983-93 | 10 | -2.7 | NT |
| | 2 | 1983-93 | 10 | -3.0 | NT |
| Kim Creek | 1 | 1988-93 | 5 | -2.3 | NT |
| | 2 | 1988-93 | 5 | -9.0 | NT |
| | 3 | 1988-93 | 5 | -0.3 | NT |
| | 4 | 1988-93 | 5 | +3.8 | NT |
| | A | 1989-93 | 4 | -3.8 | NT |
| Bonito Creek | 1R | 1992-93 | 1 | -8.8 | NT |
| | 2R | 1992-93 | 1 | - 25 | NT |
| Sand Canyon | 1A | 1992-93 | 1 | - 21 | NT |
| S. Diego Creek | C | 1986-93 | 7 | +9.8 | TC |
| | B(R) | 1990-93 | 3 | + 24 | TC |
| | 2R | 1991-93 | 2 | +135 | TC |
| | 3R | 1990-93 | 3 | + 39 | TC |
| | 5A | 1992-93 | 1 | + 15 | TC |
| | 6 | 1983-93 | 10 | -1.8 | TC |
| Roadside Ditch Sand Cnyn.Blvd. | 2 | 1983-1993 | 10 | -0.2 | MT |

**Table 1 (continued)**

| Name of Range (Profile) | | Dates of Surveys | Years Duration | Net Change at Cross-Sectional Area, $ft^2/yr$ | Category of Channel (See Figure 3) |
|---|---|---|---|---|---|
| | | | | II. Peters Canyon Wash | |
| Hicks | A4 | 1986-93 | 7 | -2.5 | NT |
| | A2 | 1986-93 | 7 | 0 | NT |
| | B | 1986-93 | 7 | -5.2 | NT |
| | C | 1986-92 | 6 | -3.5 | NT |
| | 1 | 1984-93 | 9 | +1.9 | NT |
| | 1A | 1986-93 | 7 | -1.3 | NT |
| | 2 | 1984-93 | 9 | +0.4 | NT |
| | 3 | 1984-93 | 9 | +0.6 | NT |
| | 4 | 1984-93 | 9 | -1.4 | NT |
| | 5 | 1983-93 | 10 | -4.2 | NT |
| | 6 | 1983-93 | 10 | -5.0 | NT |
| Hicks Trib. | A3 | 1986-93 | 7 | 0 | MT |
| McCoy | 1 | 1985-93 | 8 | +7.5 | NT |
| Golf Course | 1 | 1989-93 | 4 | 0 | UT |
| | 2 | 1989-93 | 4 | 0 | UT |
| Little Joaquin | 1 | 1984-93 | 9 | -1.8 | NT |
| | 1A | 1984-93 | 9 | -2.0 | NT |
| Trimble | 1 | 1984-93 | 9 | 0 | MT |
| Little Coyote | 1 | 1984-93 | 9 | -4.0 | NT |
| Rattlesnake | 1B | 1984-93 | 9 | 0 | NT |
| | 1A | 1984-93 | 9 | -0.7 | NT |
| | 1 | 1984-93 | 9 | -2.1 | NT |
| | 2 | 1984-93 | 9 | -4.2 | NT |
| | 3 | 1984-93 | 9 | -3.1 | NT |
| | 4 | 1984-93 | 9 | -2.5 | NT |
| | 5 | 1984-93 | 9 | -9.6 | NT |
| | 6 | 1983-93 | 10 | -2.0 | NT |
| | 9 | 1983-93 | 10 | -0.8 | NT |
| | 10 | 1983-93 | 10 | -5.0 | NT |
| | 11 | 1983-93 | 10 | -1.5 | NT |
| | 13 | 1983-93 | 10 | -7.8 | NT |
| | 14 | 1986-93 | 7 | -8.4 | NT |
| | 15 | 1983-93 | 10 | -14.6 | NT |
| | 15A | 1992-93 | 1 | -110 | NT |
| Badlands | 1 | 1984-93 | 9 | -0.4 | NT |
| | 2 | 1984-93 | 9 | -2.0 | NT |
| | A | 1984-93 | 9 | -8.9 | NT |
| Stepford | 1 | 1984-93 | 9 | -0.2 | MT |

**Table 1 (continued)**

| Name of Range (Profile) | | Dates of Surveys | Years Duration | Net Change at Cross-Sectional Area, $ft^2/yr$ | Category of Channel (See Figure 3) |
|---|---|---|---|---|---|
| Hines | A | 1991-93 | 2 | -1.2 | NT |
| | B | 1991-92 | 1 | - 64 | NT |
| | 1 | 1983-91 | 8 | -1.9 | NT |
| | 2 | 1983-93 | 10 | -1.6 | NT |
| | 3 | 1983-93 | 10 | -5.5 | NT |
| | 4 | 1983-93 | 10 | -1.1 | NT |
| | 5 | 1983-93 | 10 | -1.3 | NT |
| Simonek | 1 | 1984-93 | 9 | -2.1 | NT |
| | 2 | 1984-93 | 9 | -1.0 | NT |
| | 3 | 1984-93 | 9 | -1.0 | NT |
| | 4 | 1984-93 | 9 | -1.5 | NT |
| Irvine | 8 | 1983-93 | 10 | -7.5 | NT |
| | 9 | 1983-93 | 10 | -3.2 | NT |
| Myford | 1 | 1992-93 | 1 | 0 | MT |
| PCW | 4 | 1983-93 | 10 | -7.6 | UT |
| | 5 | 1983-93 | 10 | -8.9 | UT |
| | 6 | 1983-93 | 10 | -9.3 | UT |
| | 8 | 1983-93 | 10 | -2.3 | UT |
| | 10 | 1983-93 | 10 | -0.8 | UT |
| | 11 | 1983-93 | 10 | -5.6 | UT |
| | 13 | 1983-93 | 10 | -6.4 | UT |
| | 15 | 1992-93 | 1 | -112 | TC |
| | 16 | 1992-93 | 1 | -112 | TC |
| PCW Div.Can. | 1-7 | 1987-93 | 6 | - .3 | NT |
| PCW Div.Can. DeYoung Br. | 1-2 | 1987-93 | 6 | 0 | NT |

Notes:

108 Profiles used for calculations.

Legend:

MT = Minor Tributary or Roadside Ditch
NT = Relatively Non-Urbanized Major Tributary or Urbanized Tributary with Low Gradient
UT = Urbanized Major Tributary with Steeper Gradient
TC = Trunk Channel

Rattlesnake Creek (Ranges 5 and 6). It should be noted, however, that there is considerable variance within each of these described reaches.

3.1. **Minor Tributaries and Roadside Ditches.** (Tables 1 & 2, Figures 1 & 3) The role of roadside ditches was recognized from the inception of this study. During 1983-1985, numerous profiles and photographs were established to document the roadside ditches. Most of these sites, however, were destroyed by road widening and other construction almost as fast as they were documented. The only surviving profile is on Sand Canyon Boulevard just north of San Diego Creek (F-8, Fig. 1). It showed a ten-year average erosion of 0.2 $ft^2$/year. Minor channels elsewhere in the Basin were also documented and five of these ranges remained. They are Serrano Tributary 1, Hicks A3, Stepford 1, Myford 1 and Trimble 1 (Table 2, Figure 3). The average erosion at the above six ranges at 90 pounds per cubic foot (PCF) is 0.4 $ft^2$/year or 95 tons/mile/year. The total length of such channels is difficult to measure but I estimate it to be about 50 miles. At an average annual rate of 95 tons/mile, the estimated total annual erosion from this category channel is about 4800 tons.

3.2. **Relatively Non-urbanized Major Tributaries and Urbanized Tributaries with Low Gradients.** (Tables 1 & 3, Figures 1 & 3) Relatively non-urbanized channels which are tributary to San Diego Creek are the dominant type in the Basin and includes Agua Chinon, Borrego Tributary (F21), Bee, Marshburn, Upper Hines, Simonek, Upper San Diego, Sand Canyon, Bonito, Hicks, McCoy, Rattlesnake, Little Joaquin, Little Coyote,

**Table 2**
Average Annual Channel Changes, Minor Tributaries
and Roadside Ditches
(Est. Total Length = 50 Miles)

| Range | | Change, $Ft^2$/Year |
|---|---|---|
| Sand Canyon Boulevard | 2 | -0.2 |
| Serrano Tributary | 1 | -2.1 |
| Hicks | A3 | 0 |
| Stepford | 1 | -0.2 |
| Myford | 1 | 0 |
| Trimble | 1 | 0 |

Number of Ranges = 6 Average Change = $-0.4 ft^2$/year = 95/tons/mile/year @ 90 $lbs/ft^3$

Net Total Annual Change for 50 miles of channel = 4800 tons
See Appendix 1 for conversion factors.

and Kim Creek. Urbanized channels with low gradient such as Irvine Channel and Lane Channel are also included. Erosion from these channels can generally be described as significant but not alarming (Table 3). As in most channels, there is considerable variance among ranges and reaches as explained under "Methodology" in this report. Some ranges show sediment gain, even over periods of several years (e.g., Hicks Canyon Range 3, F-4, Fig. 1) but this is abnormal.

Generally, the long-term process in this category channel has been mild, but continuing erosion through the water-years 1983-1991, but with the erosion accelerated since 1991. A long-term view of significant channel erosion is shown by time-lapse photography of Hicks Canyon at the confluence with Rattlesnake Canyon channel (Plate 2).

There are some locations, however, which probably stored sediment during the dry period. A unique channel which deserves some explanation is Agua Chinon Creek upstream from El Toro Air Station (J-6, Fig. 1). From 1986 to 1992, the entire valley was aggrading with sand from part of the tributary foothills. Indeed, this process had been continuing for years previous to 1986 as evidenced by a buried fence line at Range A and by the fact that the root crowns of oaks in the valley were buried several feet. Many of these oaks were already dead by 1986.

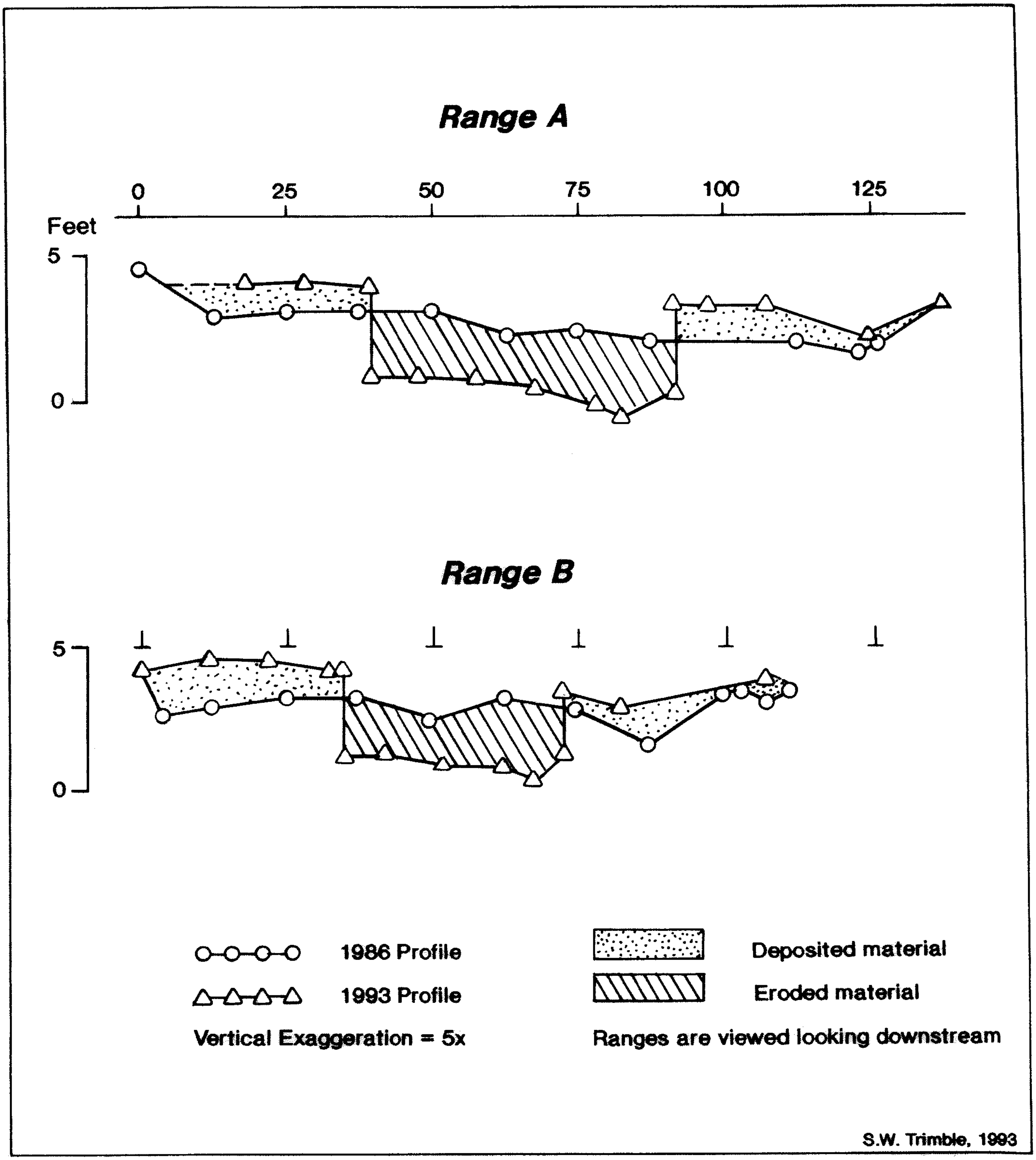
Beginning in 1992 and greatly expanding both upstream and laterally in 1993, the stream has trenched, as shown in Figure 4. At profiles A and B, more material eroded in water

Figure 4

# Aqua Chinon Creek

## Fill and Cut Sequences

## 1986 - 1993



MAP 3

original returned to Trimble

B:

**Plate 2.** Hicks Channel Looking Upstream at Confluence with Rattlesnake Canyon Channel (F-4, Fig. 1). A: 1979 B: 1993. The men stand at approximately the same location in both photographs. Note the severe retreat of the bank to the right foreground. In the background, note that sloped channel walls have become vertical on one side. This reach below Culver Drive is the most unstable partsof Hicks Channel.

years 1992-1993 than remained from the past seven years' accumulation so that there was net sediment loss (Table 1).

The reasons for this entrenchment are not clear. A facile explanation is the heavier rainfall of the past two years, but if this were the cause, the stream should have trenched during the very heavy rains of 1983 and there were no signs of that having occurred. Additionally, there appears to be no change of upstream land use which could have caused the stream erosion although an apparent reduction of cattle grazing may have played some role.

Schumm (1974) has studied similar streams which have trenched without any apparent external cause. He has proposed that such streams will aggrade until the slope reaches a critical or threshold value at which point channel erosion commences. The sediment from such eroding channels can cause serious problems downstream. In fact, the downstream underground channel of Agua Chinon is about 60 % occluded in the zone where it enters San Diego Creek (Dale Dillon, OCEMA, personal communication).

Considering all the channels in the non-urbanized category shown in Table 3, the overall average change is 6.0 $ft^2$/year or a loss of 1430 tons/mile/year. For this average, I have included the high one-year values at Rattlesnake Range 15A (E-5, Fig. 1) and Hines Range B (H-5, Fig. 1) because such critical zones do develop along channels in a wet year and it is important that they be included in the sample.

**Table 3**

Average Annual Channel Changes, Relatively Non-Urbanized Major Tributaries and Urbanized Tributaries with Low Gradients (51.9 Miles)

| Range | Change, Ft$^2$/Year | |
|---|---|---|
| Borrego Trib. (F21) | A | 0 |
| | B | - 29 |
| Agua Chinon | A | - 5 |
| | B | -0.4 |
| Bee | A | 0 |
| | B | -1.5 |
| Marshburn | 1 | -2.7 |
| | 2 | -3.0 |
| Kim Creek | 1 | -2.3 |
| | 2 | -9.0 |
| | 3 | -0.3 |
| | 4 | +3.8 |
| | A | -3.8 |
| Bonito Creek | 1R | -8.8 |
| | 2R | - 25 |
| Sand Canyon | 1A | - 21 |
| Hicks | A4 | -2.5 |
| | A2 | 0 |
| | B | -5.2 |
| | C | -3.5 |
| | 1 | +1.9 |
| | 1A | -1.3 |
| | 2 | +0.4 |
| | 3 | +0.6 |
| | 4 | -1.4 |
| | 5 | -4.2 |
| | 6 | -5.0 |
| McCoy | 1 | +7.5 |

| Range | Change, Ft$^2$/Year | |
|---|---|---|
| Little Joaquin | 1 | -1.8 |
| | 1A | -2.0 |
| Little Coyote | 1 | -4.0 |
| Rattlesnake | 1B | 0 |
| | 1A | -0.7 |
| | 1 | -2.1 |
| | 2 | -4.2 |
| | 3 | -3.1 |
| | 4 | -2.5 |
| | 5 | -9.6 |
| | 6 | - 20 |
| | 9 | -0.8 |
| | 10 | -5.0 |
| | 11 | -1.5 |
| | 13 | -7.8 |
| | 14 | -8.4 |
| | 15 | -14.6 |
| | 15A | -110 |
| Badlands | 1 | -0.4 |
| | 2 | -2.0 |
| | A | -8.9 |
| Hines | A | -1.2 |
| | B | - 64 |
| | 1 | -1.9 |
| | 2 | -1.6 |
| | 3 | -1.1 |

| Range | Change, Ft$^2$/Year | |
|---|---|---|
| Hines | 4 | -1.1 |
| | 5 | -1.3 |
| Simonek | 1 | -2.1 |
| | 2 | -1.0 |
| | 3 | -1.0 |
| | 4 | -1.5 |
| Irvine | 8 | -7.5 |
| | 9 | -3.2 |
| PCW Div. Can | 1-7 | - .3 |
| PCW Div. Can | 1-2 | 0 |
| DeYoung Br. | | |

No. of Ranges = 71   Average Change = -6.0 ft$^2$/year
= -1430 tons/mile/year
@ 90 lbs/ft$^3$

Total Annual Erosion for 51.9 miles of channel = -74,100 tons

See Appendix 1 for conversion factors.

Approximately 51.9 miles of such channels exist in the Basin. At an average loss of 1430 tons/mile/year, the average total sediment produced by this category channel is 74,100 tons/year.

3.3. **Urbanized Major Tributaries with Steeper Gradients** (Tables 1 & 4, Figures 1 & 3) This category results from extensive upstream urbanization which increases stormflow. With steeper channel gradients, the greater stormflow can cause very high rates of erosion. Three streams in the San Diego Creek Basin have been affected by this process during the past few years. They are Borrego Creek, Serrano Creek, and Peters Canyon Wash (Table 4). Each of these deserves attention because of the different conditions found there.

Both Borrego and Serrano Creeks have been affected by an expansion of Lake Forest called Foothills Ranch. It was started about 1989 and now covers several hundred acres. Very permeable, sandy marine sediments have been generally rendered waterproof by pavement and roofs so that stormflow is much greater. The steepness of the urban area also affects stormflow peaks. Borrego Creek has been much more affected for two reasons: (1) because more of the urbanized land is tributary to it, and (2) because Borrego Creek is more vulnerable, having a wider, erodable valley with little bedrock or vegetational protection.

**Table 4**

Average Annual Channel Changes, Urbanized Major Tributaries with Steeper Gradients (11.5 miles)

| Range | | Change, $ft^2$year |
|---|---|---|
| Serrano | A | -0.6 |
| | B | +0.9 |
| | C | 0 |
| | 1A | -165 |
| | 1B | - 24 |
| | 2 | - 14 |
| | 3 | -5.2 |
| Borrego | 1 | - 10 |
| | 2 | -320 |
| | 3 | -216 |
| | 4 | - 18 |
| | 4A | -290 |
| | 4D | 0 |
| | 5 | + 26 |
| Golf Course PCW | 1 | 0 |
| | 2 | 0 |
| PCW | 4 | -7.6 |
| | 5 | -8.9 |
| | 6 | -9.3 |
| | 8 | -2.3 |
| | 10 | -0.8 |
| PCW | 11 | -5.6 |
| | 13 | -6.4 |

A. All Ranges — No. of Ranges=23 Average Change= -46.8 $ft^2$/year =-11,100 tons/mile/year @ 90 lbs/$ft^3$

Total Annual Change for 11.5 miles of channel =-127,650 tons

B. PCW Ranges Only for Long-Term Average — No. of Ranges=7 Average Change= -5.8 $ft^2$/year = 1,390 tons/mile @ 90 lbs/$ft^3$

Total Annual Change for 11.5 miles of channel = -16,000 tons

C. Serrano & Borrego Ranges Alone For Wet-Period Averages — No. of Ranges=14 Average Change= -101 $ft^2$/year = -24,000 tons/mile @ 90 lbs/$ft^3$

Total Annual Change for 11.5 Miles of Channel= -276,000 tons

See Appendix 1 for conversion factors.

3.3.1. Erosion in Borrego Creek (J-7, Fig. 1) during the water years of 1991-1993 has been alarming, with cross-sections of one reach eroding at rates of 200-300 $ft^2$ per year or 48,000-72,000 tons/mile/year (Figure 5, Table 4). At Range 3, about 1500 feet downstream from the urban area, channel capacity doubled during water year 1991-1992 and doubled again last year. Range 2 also doubled in 1991-1992, (Trimble, 1992) but the cross-section of sediment lost was greater than the 2-year loss at Range 3. Just downstream, however, is a zone controlled by bedrock and vegetation so that absolute enlargement of Range 4 was limited to a much smaller cross-section (18 $ft^2$/year). Still further downstream, the valley becomes wider and is filled with easily erodable material (Plate 3). There, Range 4A lost 290 $ft^2$ this last year. As noted in earlier reports (e.g., Trimble, 1991), the profuse movement of sand causes the channel to braid so that vulnerable banks are undermined and eroded. That accounts in part for the destabilization of the right bank in Range 4A. Beyond this point, however, the stream is so overladen that it cannot transport all the eroded sediment. Thus, at Range 4D, about 1500 feet downstream, there is massive deposition and stream braiding. This destabilizes the erodable high banks on both sides and massive chunks are eroded away. The reported net change of 0 at Range 4D (Table 4) masks the gross changes which have occurred (almost 400 $ft^2$ have been both gained and lost). Downstream at Range 5, about 500 feet above Trabuco Road, filling has occurred during the last two years (Figure 3, see also Trimble 1992, Figure 1). In summary, channel

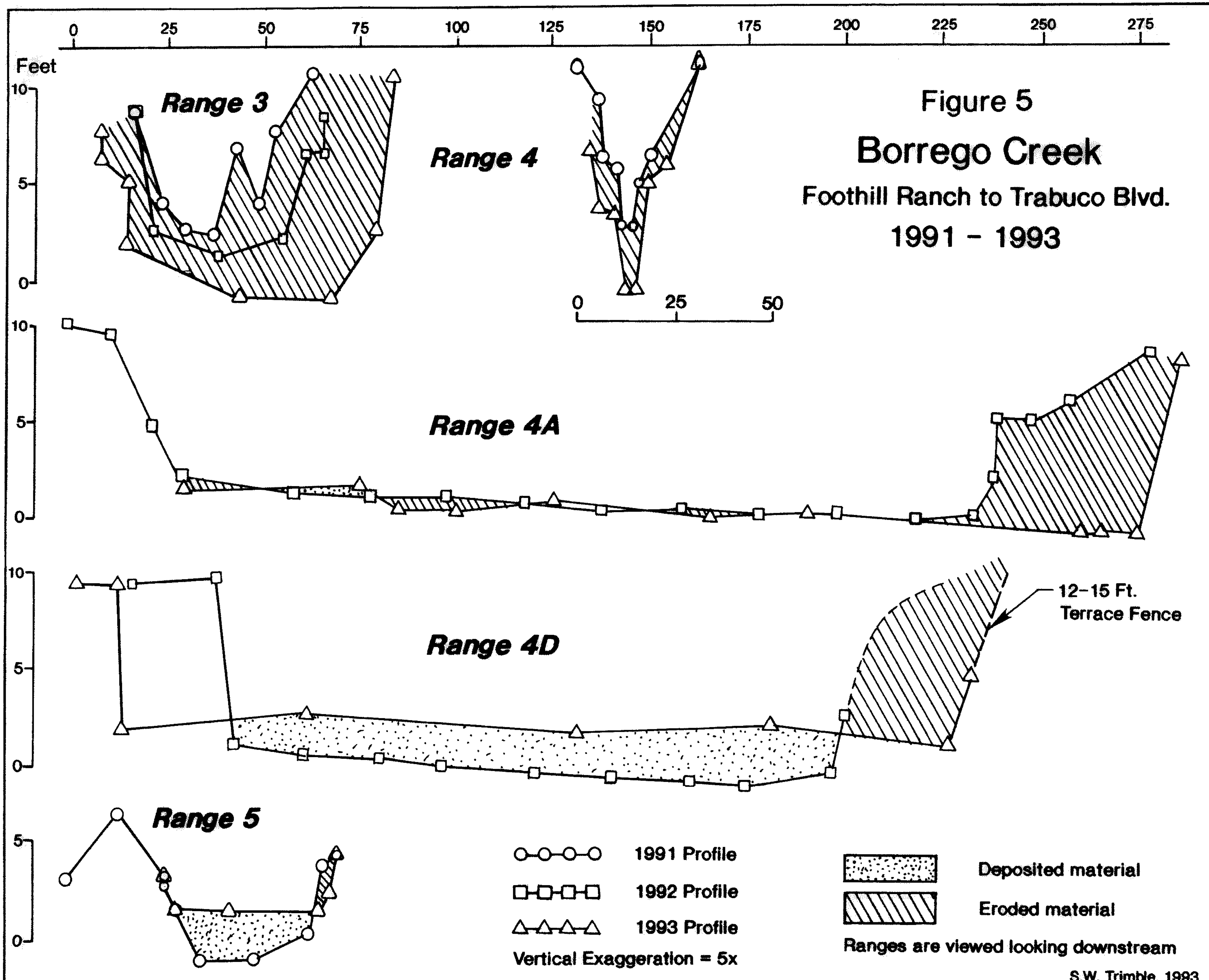


Figure 5
Borrego Creek
Foothill Ranch to Trabuco Blvd.
1991 - 1993
Feet
Range 3
Range 4
Range 4A
Range 4D
Range 5
12-15 Ft.
Terrace Fence
1991 Profile
1992 Profile
1993 Profile
Vertical Exaggeration = 5x
Deposited material
Eroded material
Ranges are viewed looking downstream
S.W. Trimble, 1993

originals return to Trimble

A

B

**Plate 3.** Severe Bank Erosion in Borrego Creek. A: 1992. Farm road in direct foreground recently went straight across the floodplain. Stormflows of water year 1991-1992 eroded away 50-100 feet of the floodplain. Note new farm road to left. Range 4A begins near tree to left. B: 1993. Bank has eroded another 50-75 feet and has almost undermined the tree.

erosion on Borrego Creek is out of control and is furnishing vast amounts of sediment downstream. Amelioration should start as soon as possible.

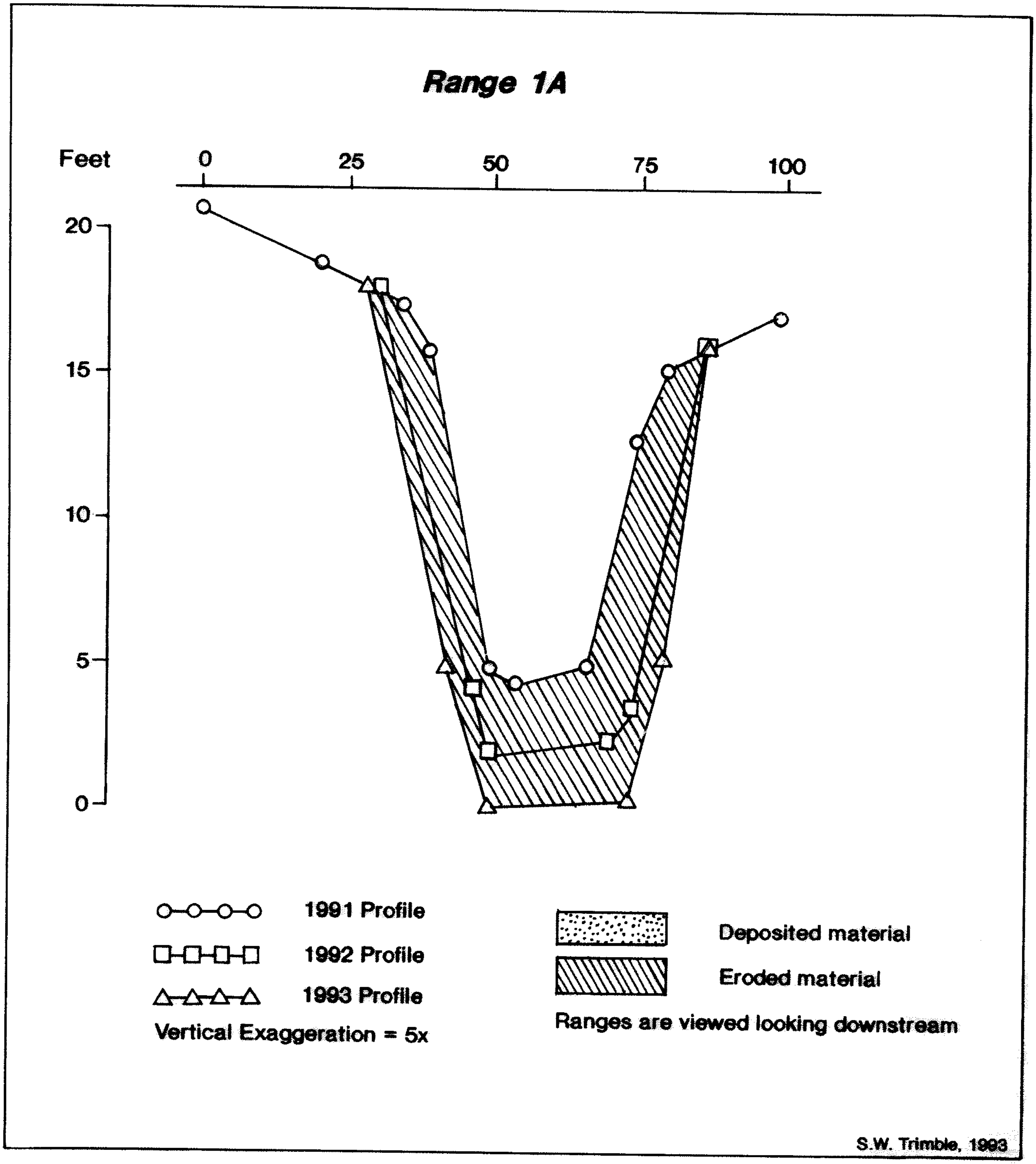
3.3.2. Serrano Creek (I9, Fig. 1), while eroding rapidly, has not been affected like Borrego Creek. First, the urbanized drainage area is smaller. Secondly, the channel downstream to Trabucco Road is naturally protected by narrow bedrock constrictions, and heavy vegetation on the banks. This same reach has had various artificial control features installed, primarily drop structures, rip-rap, and gunite banks. Below Trabucco Road, however, the channel has had significant erosion (Ranges 1A and B, Table 1). The channel size at Range 1A, directly below Trabucco Road, has more than doubled since 1991 (Figure 6). There are two reasons for this rapid erosion. First, the channel is less protected in this reach and secondly, high runoff from the urbanized Lake Forest area enters the channel in this area.

Serrano Creek then flows through concrete channels until it emerges about 1/2 mile upstream from Interstate 5. From here, this channel has eroded significantly all the way to the confluence with San Diego Creek. Before this study began, the streambed and lower part of the channel walls were lined with concrete. When the water flowed above the concrete liner, the earthen wall above the concrete eroded, the concrete was undermined, and the channel eroded severely, a series of events predicted by Trimble (1986). In summary, reaches of Serrano Creek are also eroding rapidly and this condition should grow worse as urbanization continues.

## Figure 6

# Serrano Creek

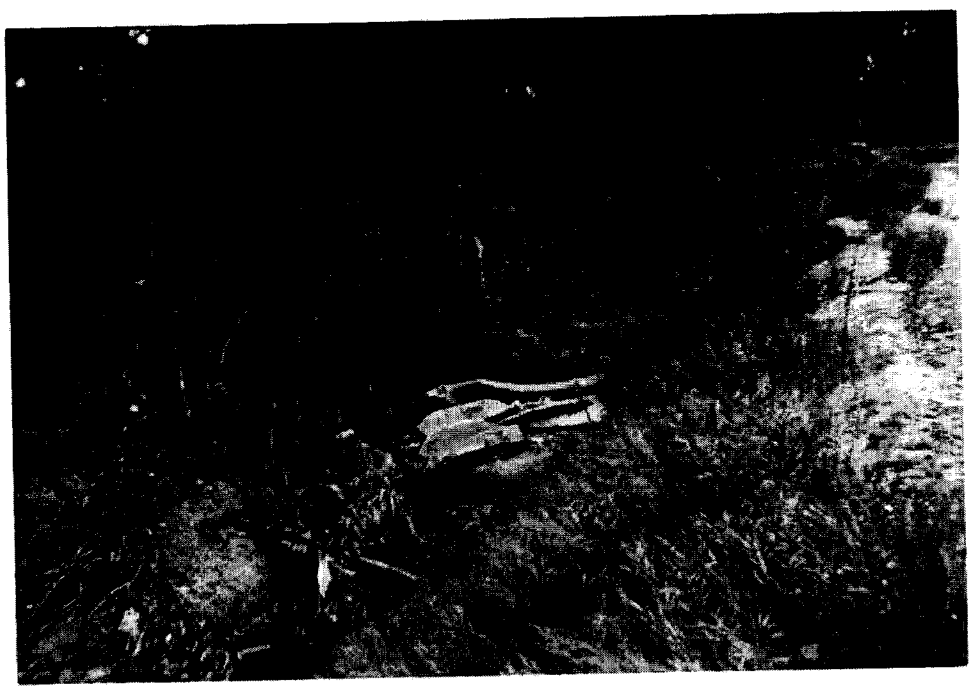
### 1991 - 1993



3.3.3. Peters Canyon Wash (PCW) from Tustin Ranch to Interstate 5 (Santa Ana Freeway, E-4, Fig. 1) is another case of urban-induced channel erosion, but there is an important difference from the examples at Borrego and Serrano Creeks; peak flows from above the Tustin Ranch development are contained or at least moderated by a large flood control structure. Thus, the major portion of the stormflow comes from the flatter area of Tustin Ranch rather than the steeper areas upstream. This should create a more suppressed hydrograph which will result in lower velocities and consequently less erosion.

The stream emerges from the urban area and flows through the golf course. Because of a good design with well-sloped banks and a low gradient created with drop structures, there has been no channel erosion in the golf course. Downstream of Jamboree Road to Interstate 5, however, channel erosion has been severe (Plate 4, Figure 7). Erosion in this reach is characterized by 1-6 feet of bed scour (Plate 4B-4D, Figure 7). One drop structure above Range 4 was undermined and destroyed (Plate 4B). Erosion below Bryan Avenue was perhaps more severe because the invert under Interstate 5 had been lowered (Dale Dillon, OCEMA personal communication). Note, however, that scour depths below Bryan Avenue average no more than those above.

A

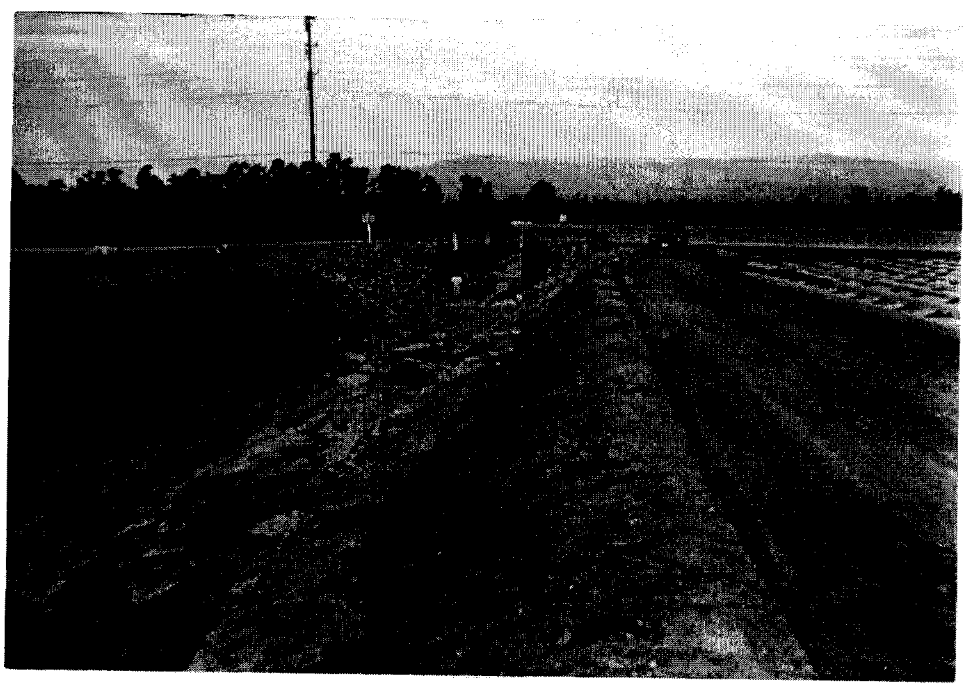


B

**Plate 4.** Channel Erosion from Urban Stormflow. Peters Canyon Wash 400 feet below Jamboree Road (F-3, Fig. 1). A: Looking downstream from road crossing and grade control structure. Undermining of this structure was prevented by reinforcement with rip-rap and concrete. B: About 400 feet downstream of photo A looking upstream. Note collapsed drop structure in channel and undermined bank. Range 4 is about 500' downstream.

Original returned to Trimble

C



D

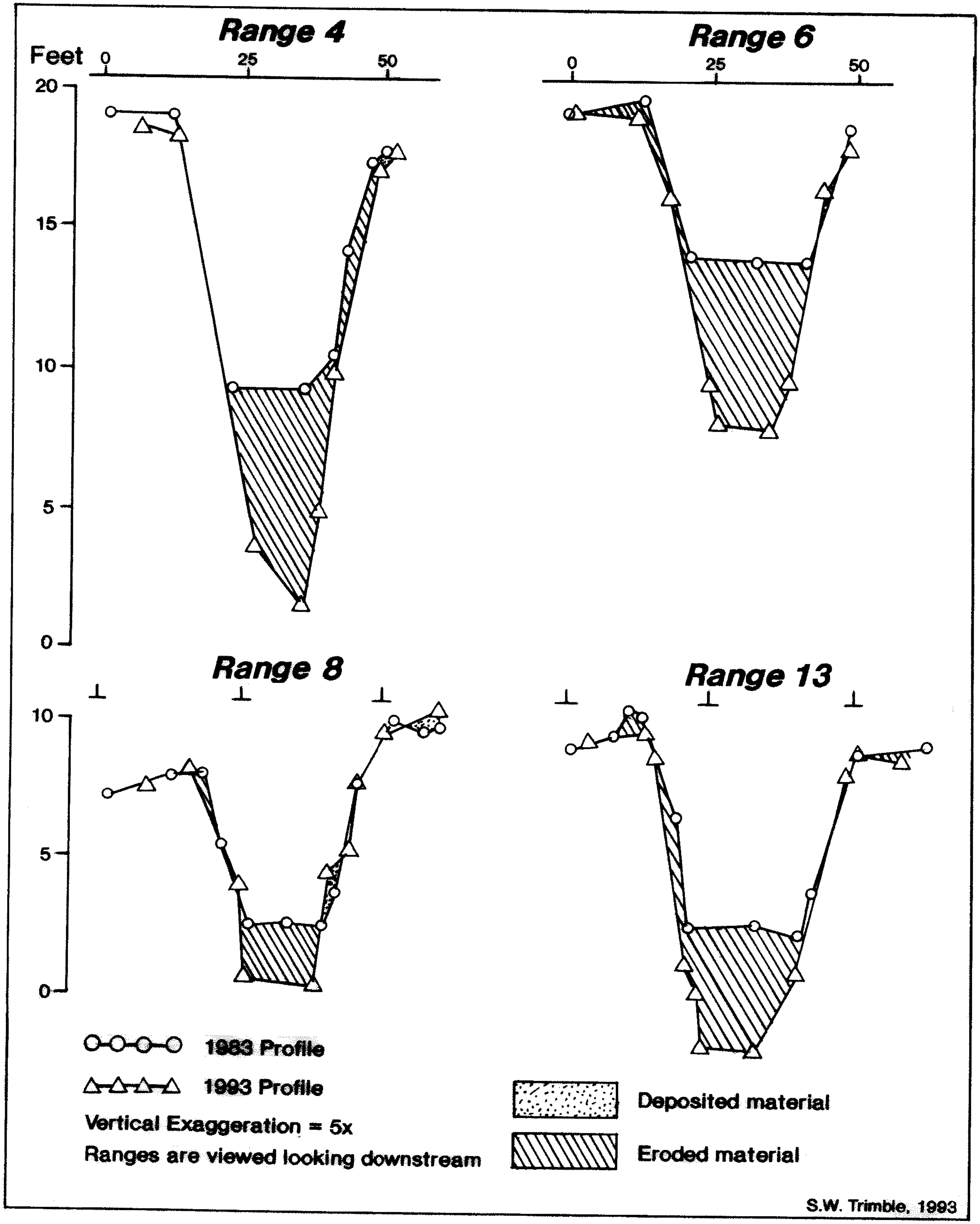
**Plate 4.** C: Peters Canyon Wash (PCW) looking upstream at the confluence of Diversion Canal (F-4, Fig. 1). The stream bed here has been scoured about six feet, but the scour was reduced to zero at a drop structure 600 feet downstream at Irvine Boulevard. Range 8 is 200 feet downstream. Undermining of the concrete structure here was prevented by emergency treatment with rip-rap and concrete. D: Looking upstream at Bryan Avenue. Range 13 is about 200 feet downstream. There was about 4-6 feet of scour this winter along this reach between Bryan Road and Interstate 5.

# Figure 7

## Peters Canyon Wash

### Jamboree Road to Interstate 5

### 1983 - 1993



The disparity in erosion rates between Peters Canyon Wash and Borrego-Serrano Creeks is very significant (Table 4, A, B & C). Because measurements for Borrego and Serrano Creeks were made mainly during the recent wet period, the erosion rates for these two streams of 24,000 tons/mile/year should be considered as short term and exceptional (Table 4A & 4C). Their inclusion would probably exaggerate the long-term average so that the ten-year record for Peters Canyon Wash of 1,390 tons/mile/year may be a more reasonable long-term value (Table 4B). In light of the much higher channel erosion rates from Borrego-Serrano Creeks, the rates of Peters Canyon Wash might be considered as minimum values. Hence, the Peters Canyon Wash values are used for this channel category in the compilation of the long-term sediment contribution of the San Diego Creek channel system.

3.4. **Trunk Channels.** (Tables 1 & 5, Figures 1 & 3) These are the wide, regular channels excavated for Peters Canyon Wash (F06) from Interstate 5 to the junction with San Diego Creek (F05), and San Diego Creek from the confluence with Agua Chinon to the Sediment Trap Reach below Interstate 405 (C-8, Fig. 3). The trunk streams are, or will be over time, characterized by both erosion and sedimentation. That is, scour and fill may alternate both in space and time. For example, the reach of San Diego Creek from just above Irvine Center Drive (H-9, Fig. 1) downstream past Sand Canyon Avenue (3.1 miles), has been a big sediment sink for the past two or so years (Figures 1 and 8A, Table 5). Based on an average accumulation of 36.8 $ft^2$/year, or 8740 tons/mile/year, the total annual accumulation for this 3.1 miles of San Diego Creek would be 27,100 tons.

As upstream channels and other critically eroding areas are stabilized so that the sediment supply is curtailed, one may expect much of this stored sediment in San Diego Creek to eventually move downstream. The channel is so wide, however, that only a linear portion of the sediment probably will be eroded. That is, the stream will tend to erode a narrow channel or trench into the accumulated sediment. The deposits to either side will probably become established in woody plants.

In contrast to San Diego Creek, the 2.6 miles of Peters Canyon Wash apparently has been a sediment source for at least the past year or so (Table 5). Both Range 15 (Figure 8B) and Range 16 have lost 112 $ft^2$ of cross-section in the past year. This would be about 26,600 tons/mile or a total of 69,200 tons/year of sediment, much of which is fine and

# Figure 8
# Recent Changes in Trunk Channels
## 1991 - 1993

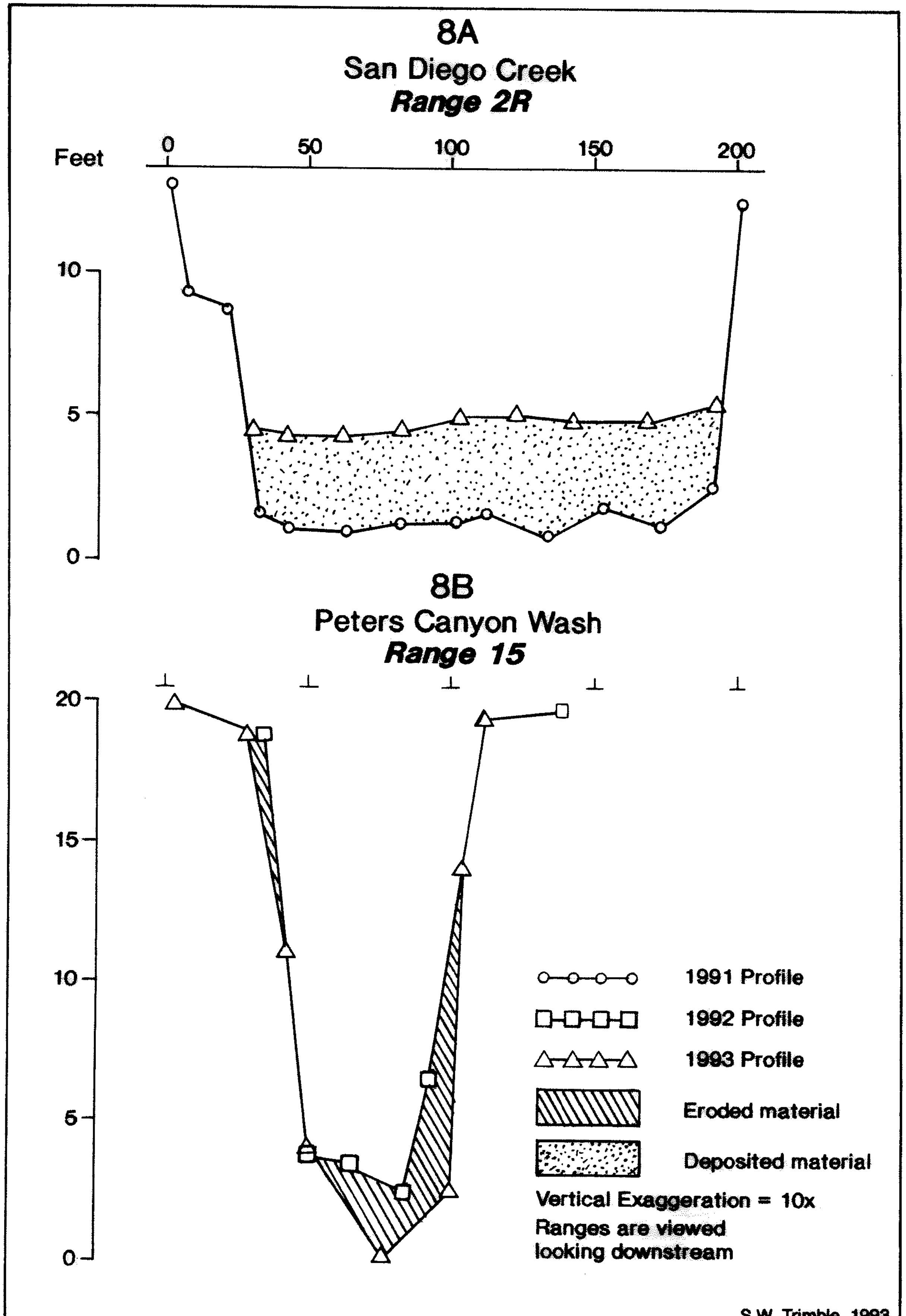


**Table 5**

Average Annual Channel Changes, Trunk Channels (5.7 miles)

| Range | | Change, $ft^2$/year |
|---|---|---|
| San Diego Creek | C | +9.8 |
| | B(R) | + 24 |
| | 2R | +135 |
| | 3R | + 39 |
| | 5A | + 15 |
| | 6 | -1.8 |

No. of Ranges = 6 Average Change = +36.8 $ft^2$/year

= +8,740 tons/mile/year @ 90 $lbs/ft^3$

Total Annual Change for 3.1 miles of channel = +27,100 tons

| | | |
|---|---|---|
| Peters Canyon Wash | 15 | -112 |
| | 16 | -112 |

Average Change = -112.0 $ft^2$/year = -26,600 tons/mile/year @ 90 $lbs/ft^3$

No. of Ranges = 2

Total Annual Erosion for 2.6 miles of channel = 69,200 tons for 1992-1993 (not counted in this study, subject to revision by OCEMA long-term Scour Studies).

See Appendix 1 for conversion factors.

would be more likely transported to Newport Bay. Both F06 and lower F05 are measured by OCEMA Scour Studies and a more correct approximation of long-term changes will await those measurements.

3.5. **Sediment Trap Reaches.** The lower reach of San Diego Creek between Interstate 405 and upper Newport Bay (C-8, Fig. 1) is configured into basins which trap the coarser part of the sediment load. These basins are being measured and excavated under the direction of OCEMA and I will use those values for the sediment budget to be calculated next year.

## 4.0. CONCLUSIONS

Based on 1 to 10 years of data at over 100 ranges throughout the Basin, a minimum of about 97,000 tons of sediment per year is being eroded from stream channels upstream of the OCEMA scour study areas (Table 6). At the same time, about 27,000 tons/year is being stored in upper San Diego Creek (Range C to Range 6) upstream of Jeffery Road. This leaves a minimum net value of about 70,000 tons/year, which is being transported into the OCEMA scour study areas. The OCEMA Scour Study covers Peters Canyon Wash from Interstate 5 to San Diego Creek and includes San Diego Creek from Jeffery Road to the Sediment Trap Reach ending at MacArthur Boulevard. The results of the OCEMA scour study may change appreciably the channel erosion values calculated for the Basin in this study. In any case, it seems clear that channel erosion furnishes a significant proportion of the sediment transported towards Newport Bay, but a more exact estimate of the proportion furnished will be part of the forthcoming sediment budget study.

**Table 6**

Summary, Long-Term Annual Channel Changes (see Tables 2-5)

| | Channel Category | Total Annual Change, Tons |
|---|---|---|
| 1. | Minor Tributaries and Roadside Ditches (Table 2) | - 4,800 |
| 2. | Non-Urbanized Channels and Urbanized Channels with Low Gradients (Table 3) | - 74,100 |
| 3. | Urbanized Channels with Steeper Gradients Long-Term Average (Table 4B) | - 16,000 |
| | Sub-Total, Gross Loss | - 96,800 |
| 4. | Trunk Channel, San Diego, Range C to Range 6 (Gross Gain) Note: PCW Ranges 15 & 16 not included here, see text | + 27,100 |
| Total Net Annual Erosion from Channels in the San Diego Creek Basin (excluding reaches covered by OCEMA Scour Studies) | | - 69,700 |

## References

Hoag, B.L., 1983. Channel Erosion as a Source of Sediment in Newport Bay, California. Unpublished MA thesis. Department of Geograpny, University of California, Los Angeles.

Schumm, S.A., 1974. Geomorphic Thresholds and Complex Response of Drainage Systems in M. Morisawa (ed.) Fluvial Gormophology SUNY Binghamton.

Trimble, S.W., 1986. Field Research Report for San Diego Creek Channel Study, Fall 1986, in Annual Report 1986-1987, San Diego Creek Monitoring Program, Santa Ana, California: Orange County Environmental Management Agency.

Trimble, S.W., 1991. Field Research Report for San Diego Creek Channel Study, Spring 1991, in Annual Report, 1990-1991, San Diego Creek Sediment Monitoring Program, Santa Ana, CA: Orange County Environmental Management Agency.

Trimble, S.W., 1992. Field Research Report for San Diego Creek Channel Study, Spring 1992, in Annual Report, 1991-1992, San Diego Creek Sediment Monitoring Program, Santa Ana, CA: Orange County Environmental Management Agency.

APPENDIX 1

Volumetric and Mass Conversion Factors

One $ft^2$ of change at a profile means one $ft^3$ per foot of channel or 5280 $ft^3$/mile. Assuming an average density of 90 pounds per cubic foot (PCF) one $ft^2$ of change, over a mile of channel would be the equivalent of 5280 $ft^3$/mile (90 PCF) = 475,200 lbs/mile or 237.6 short tons/mile or 195.6 cubic yards/mile (1.215 tons/cubic yard).

As an example, the average change for the 6 profiles on Minor Tributaries and Roadside Ditches is -0.4 $ft^2$/year (Table 2). Thus -0.4 $ft^2$/year (237.6 tons/mile/$ft^2$ change) = -95 tons/mile/year. For the estimated total of 50 miles of these channels, about -95 tons/mile (50 miles) = about 4800 tons/year of channel erosion occurs. This is equal to about 3,950 cubic yards/year.

# FIELD RESEARCH REPORT FOR SAN DIEGO CREEK CHANNEL STUDY

SPRING 1992

Stanley W. Trimble, Ph.D.

Geomorphologist/Hydrologist

Professor of Geography

UCLA

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# EXECUTIVE SUMMARY

The Winter rains of water year 1991-1992 did not generally cause significant channel erosion. The major exception was on Borrego Creek directly downstream from a large urbanizing area where extensive areas are being paved. This channel was enlarged up to a factor of two and the eroded material was transported further downstream, aggrading the channel. Other significant erosion was in Hines Channel directly downstream from Hines Nursery. While there were short reaches of severe channel erosion elsewhere, most channels had little channel erosion this year. This was especially true of channels draining wild lands like upper Hicks Canyon. Some reaches of channels partially filled rather than eroded. The generally moderate channel erosion this Winter is due to the nature of the rains. Intense, but short-duration storms caused considerable hillside erosion but generally resulted in inadequate volumes of runoff to cause significant channel erosion.

Field Research Report for San Diego Creek Channel Study

Spring 1992

1. Introduction. The Winter of 1991-92 was the wettest since 1982-83. As a result it was deemed necessary to investigate the effects of these storms on channel processes (see map of study area, Enclosure 1). Field research was conducted during April and May, 1992. Twenty-seven previously surveyed channel profiles were resurveyed but one, Peters Canyon Wash Range 14, had apparently been altered by construction and was not usable. One new range was installed on Rattlesnake Canyon Channel downstream of Range 15 because the new location appears better than the present location of Range 15. Additionally a reconnaissance of the basin was made and relevant photographs were taken.

2. Preliminary Observations. A reconnaissance of the basin suggested that the greatest channel erosion was in Upper Borrego Creek, Upper Hines Channel, and to a much lesser degree, in Rattlesnake Canyon. Some channel filling was observed in McCoy Channel and the lower reaches of Borrego Creek. Otherwise, channels appeared to have eroded somewhat, but not in the dramatic manner of 1983 when large sections of bank were removed. Channels draining more-or-less wildlands like Upper Hicks Channel showed little change.

Plate 1. Eroded orchard slopes. Round Canyon looking downstream.

My general impression was that upland erosion was much more remarkable than channel erosion. Rills and small gullies on steep orchard slopes were common (Plate 1) whereas severe channel erosion was not common. This phenomenon probably relates to the intense but short duration of the rainfall received this Winter. It was severe enough to erode hillsides but the volume of runoff was just not adequate to generate high channel discharge and consequent erosion. Additionally, conditions may not have been wet enough to cause channel banks to be at their weakest and therefore most erosive condition.

3. Other Observations. An artificial channel system is being created to route runoff water around and over the Bee Canyon landfill. Below the landfill, construction of concrete channels is underway to replace the formerly eroding earth channels. This construction has removed Bee Range A2. The supervising engineer told me that channels will be constructed around each side of the landfill to conduct the runoff water generated above the landfill.

Material is still being dumped into channels. This is generally to rebuild eroded banks, but in some cases it appears that land is being developed at the expense of channel capacity (Plate 2). One last observation is that the channel of Kim Creek has been recently modified and reinforced with rip-rap. This improvement should assist in stabilizing this potentially erodible (Class 4) channel.

Plate 2. Dumping of loose soil along channel margins. Such material is easily entrained by floodwaters. Serrano Creek at Range 1A just downstream of Trabuco Road.

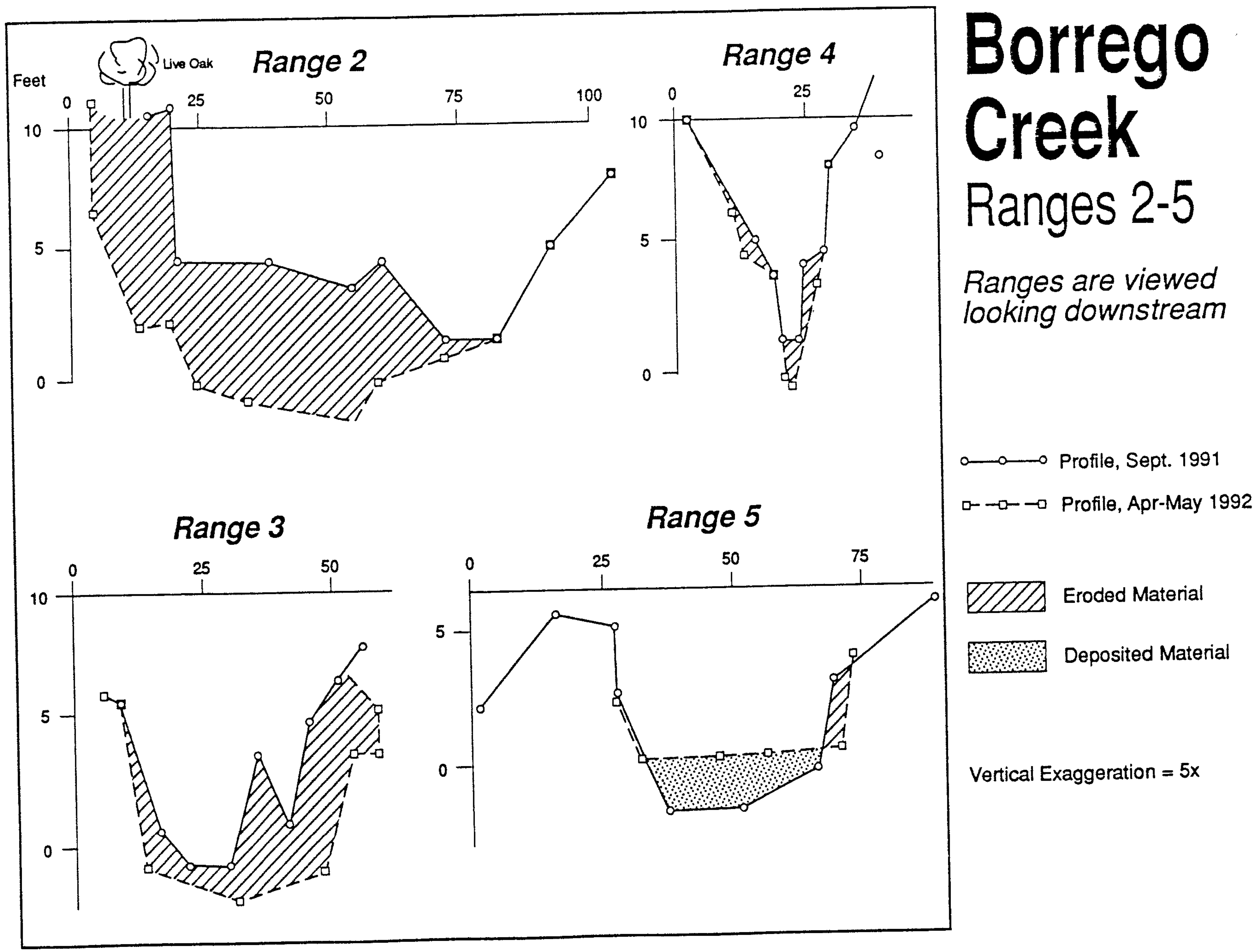
Table 1
Resurveyed Profiles, Net Change, Spring 1992

| | Name of Range (Profile) | | Year last surveyed | Net change of cross-sectional area, $ft^2/yr$ | Net Rate of Change, Tons/yr/mi |
|---|---|---|---|---|---|
| 1 | Borrego | 2 | 1991 | -322 | -76,640 |
| 2 | | 3 | 1991 | -127 | -30,230 |
| 3 | | 4 | 1991 | - 15 | - 3,500 |
| 4 | | 5 | 1991 | + 37 | + 8,810 |
| 5 | Hicks | A2 | 1986 | + 3 | + 710 |
| 6 | | A4 | 1986 | - 1 | - 240 |
| 7 | | C | 1986 | - 10 | - 2,380 |
| 8 | | 5 | 1983 | - 1 | - 240 |
| 9 | | 6 | 1983 | - 21 | - 5,000 |
| 10 | Hines | A | 1991 | - 5 | - 1,200 |
| 11 | | B | 1991 | - 64 | -15,100 |
| 12 | | 4 | 1991 | 0 | 0 |
| 13 | Kim Creek | 3 | 1988 | 0 | 0 |
| 14 | McCoy | 1 | 1986 | + 15 | + 3,570 |
| 15 | Marshburn (F16) | 1 | 1991 | - 12 | - 5,950 |
| 16 | | 2 | 1991 | - 5 | - 1,200 |
| 17 | Rattle-snake | 1 | 1991 | - 10 | - 2,380 |
| 18 | | 2 | 1991 | - 10 | - 2,380 |
| 19 | | 6 | 1983 | - 3 | - 710 |
| 20 | | 10 | 1983 | - 3 | - 710 |
| 21 | | 11 | 1983 | - 1 | - 240 |
| 22 | | 13 | 1983 | - 6 | - 1,420 |
| 23 | | 14 | 1986 | - 11 | - 2,600 |
| 24 | | 15 | 1983 | - 10 | - 2,380 |
| 25 | San Diego Creek B (R) | | 1991 | - 5 | - 1,200 |
| 26 | Serrano | 1A | 1991 | -204 | -48,550 |
| Average of 26 profiles | | | | | - 7,350 |
| Average (delete Borrego 2 & 3, and Serrano 1A) | | | | | - 1,550 |

4. <u>Measurements</u>. Twenty-six usable channel profiles were resurveyed to measure channel changes since the last survey (Table 1). Measurements of Ranges 1-3 in Upper Borrego Canyon showed severe erosion. This channel reach is immediately downstream from a huge urbanizing area in the foothills where much of the area has been paved during the past three or so years. The large proportion of waterproof area combined with the very steep slopes gives a very rapid and large runoff discharge so that channel erosion may be expected (Refer to my earlier reports of 1989-91). The greatest damage was within a mile or so of the urban area where Borrego Ranges 2-4 are located (Figure 1). At range 2, a huge portion of the left bank was eroded away, toppling a large live oak into the stream channel (Figure 1, Plate 3). Range 3 also had significant damage while erosion at Range 4 was limited by bedrock control. Directly downstream from range 4, however, a large section of the left bank (approximately 2000 tons) was eroded. (Plate 4). This is the sort of bank erosion that was common during water year 1982-83.

Downstream from the severe erosion on Borrego Creek was channel filling (Figure 1, Range 5). This is because there was inadequate stream energy downstream to transport the sand through the channel this year. Similar channel aggradation also occurred in part of McCoy Channel (Plate 5). This sand is only in temporary storage and will be transported farther downstream in wet years.

Figure 1


Borrego Creek
Ranges 2-5
Ranges are viewed looking downstream
Profile, Sept. 1991
Profile, Apr-May 1992
Eroded Material
Deposited Material
Vertical Exaggeration = 5x
Range 2
Live Oak
Feet
0
25
50
75
100
10
5
0
Range 4
0
25
10
5
0
Range 3
0
25
50
10
5
0
Range 5
0
25
50
75
5
0

original returned to Trimble

Plate 3. Severe bank erosion in Borrego Creek, looking downstream from urbanizing area. Note severe scouring in foreground. The toppled live oak lying in the channel bed marks Range 2 in the background.

A.

original returned to Trimble

B.

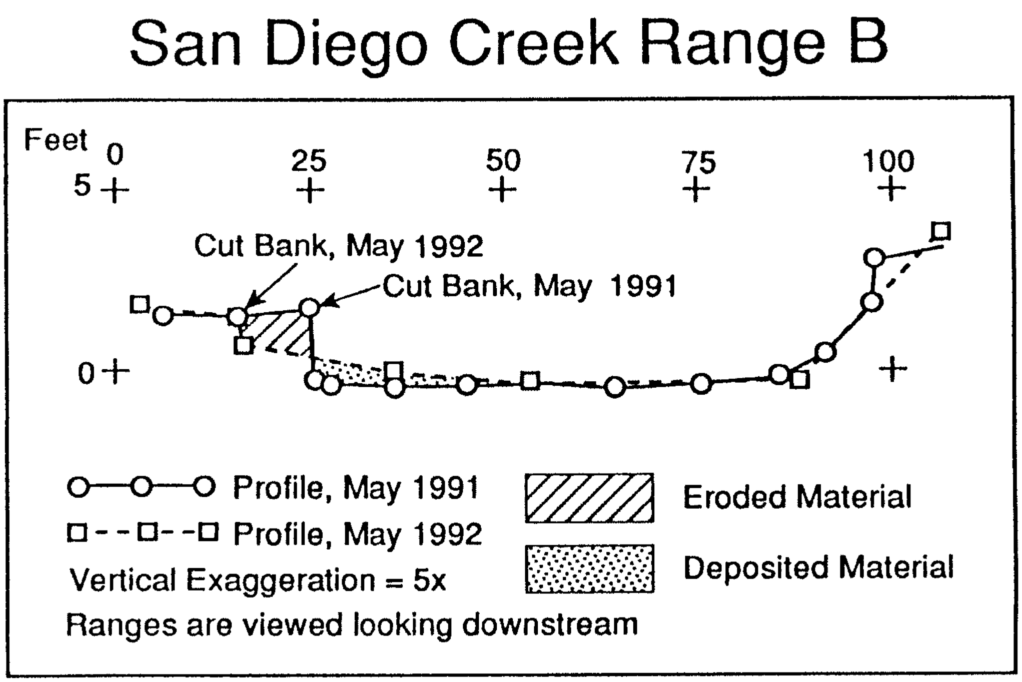
Plate 4. Severe bank erosion on Borrego Creek downstream of Range 4. (A) Photo made Sept. 1991. (B) Photo made April, 1992, Note that the entire farm road has been removed and the orchard trees severely threatened. For scale, the student in the background is 68" tall. The removed area is about 25' wide by 300' long by 6' deep.

Plate 5. Channel filling in McCoy Channel at Range 1. The fill in the foreground is about 5 feet deep.

As explained in my Spring 1991 report, migrating coarse sediment such as sand can itself cause channel widening with attendant bank erosion. In Figure 1, Range 5, note that about 4 feet of bank has been eroded away. This is similar to San Diego Creek Range B (1991 Spring report, p. 7) where about 10 feet of bank was removed. At that location this Winter, another 10 feet of bank was removed, but because of channel filling the bank was only about 1 foot high (Figure 2). The other area of significant channel erosion was on Hines Channel directly downstream from the nursery. Because so much of the nursery area is hard-packed and stays wet most of the time, there is much runoff, but inasmuch as the rainfall was relatively moderate this year, severe channel damage was localized. In a very wet year, however, it is anticipated that Hines Channel will be severely eroded to Irvine Boulevard and perhaps to Jeffrey Road. Although Serrano Creek Range 1A showed significant erosion, it appeared to be very localized.

Because only 26 of the 107 total ranges were resurveyed, it is not possible to make conclusive statements about the average rate of channel change. However, a very rough estimate for the entire basin might be obtained by simply averaging the Net Rate of channel Change (Table 1), a figure of 7,350 tons/year/mile of channel. Applying this to the approximately 60 miles of erodible channel left in the San Diego Creek basin not controlled by a reservoir, we see that a highly provisional estimate of total channel erosion is 441,100 tons per year, assuming 90 pounds per cubic foot (PCF). Note that this figure is influenced by this moderately wet year (13 of 26

Figure 2


San Diego Creek Range B
Feet
0
25
50
75
100
5
0
Cut Bank, May 1992
Cut Bank, May 1991
Profile, May 1991
Profile, May 1992
Vertical Exaggeration = 5x
Ranges are viewed looking downstream
Eroded Material
Deposited Material

profiles are for the 1991-1992 season.) Moreover, 3 of the profiles are the most severely eroded this year, thus probably greatly inflating the average. This potential inflation may be demonstrated by deleting the 3 profiles showing the greatest erosion (Borrego 2 & 3, and Serrano 1A). This reduces the overall estimate of channel erosion to 93,200 tons/year, a more realistic figure. However, none of the calculations includes an extremely wet year. Nevertheless, these provisional calculations do suggest that channel erosion has an important role in contributing sediment to Newport Bay.

5. Recommendations. The channel erosion in Borrego Creek, even in this moderately wet year, shows how banks can be undercut, dropping large trees and other vegetative debris into the stream. In an extremely wet year, much of this debris would be washed downstream perhaps to the inlet for the subterranean channel under El Toro Air Station. Such debris could easily clog that opening and force flood waters across Trabuco Road and the air base. It is imperative that a grate system be installed upstream to catch such debris before it can plug the channel. This is true for most earth channels upstream from any subterranean channel such as Serrano Creek at Range 1B just upstream of Bake Avenue.

# FIELD RESEARCH REPORT FOR SAN DIEGO CREEK CHANNEL STUDY

Fall 1991

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## EXECUTIVE SUMMARY

Field Research on channel erosion was conducted in the San Diego Creek Watershed from September 27, 1991 to October 1, 1991. Eleven new profiles were installed. These were targeted to the most potentially active channels. A potentially unstable area, in particular, is the headwater area of Serrano and Borrego Creeks where a large area has been denuded and destablized in the course of urban construction. The erosion potential is extremely high there and the resulting sediment could seriously impact downstream channels. Additionally, urbanization is completed there for a large area and the consequently higher streamflow peaks have already caused channel erosion. Large organic debris is a problem throughout the foothill areas of the basin because it can constrict channels during streamflow. I recommend that such debris be removed.

FIELD RESEARCH REPORT FOR SAN DIEGO CREEK CHANNEL STUDY

Fall 1991

1. **Introduction.** Field research was conducted in the San Diego Creek Watershed from September 27 to October 1, 1991. All accessible areas of the basin were inspected. A field orientation concerning the channel system was given to Len Narel of OCEMA on October 1, 1991.

2. **Recovery of Old Profiles.** Simonek Creek, Range 5, has been destroyed by construction, but the remaining four ranges are adequate for this relatively short channel. Bonito Canyon Drive is still under construction so that it was still impossible to replace Ranges 1 and 2 which were lost in 1990. Hopefully, that can be done next Fall.

3. **New Profiles.** Eleven new profiles were installed this year. Since the drainage area of upper Borrego and Serrano Creeks was undergoing the most rapid development, three new profiles were installed on Serrano Creek and four were installed on Borrego Creek. Upper Hines Channel, noted in the Spring 1991 report as being unstable, received two additional profiles in the nursery area. A profile was installed on the short reach of Myford Channel near the Dow Business Center.

Finally, one more profile was installed on the new channel reach of upper San Diego Creek just upstream of the Laguna Canyon Road bridge. Although I do not expect this section to erode, it may be that sand eroded from upstream channels and erosion sites will be deposited in this reach.

4. **Construction in the Borrego-Serrano Headwater Area.** The rapid urban development (Lake Forest) in the headwaters of Borrego and Serrano Creek continues and several hundred acres of land are now denuded and unstable. The moderate rains of last winter caused extensive erosion, sending a sand plume down Serrano Creek with considerable loss of downstream channel capacity (see my Spring 1991 report). There is very little sediment detention storage capacity immediately downstream of the construction area in either Serrano or Borrego Creek and heavy rains this winter could cause significant downstream sedimentation damage in both streams. Inasmuch as both streams have some of their routes underground, a loss of channel capacity in those areas could be highly problematic. Additionally, much of the storm drainage in the headwaters of Serrano Creek is now complete and the resulting increase of storm discharge peak flows caused significant channel erosion in the vicinity of new Ranges 2-4, with several trees being undermined and falling into the channel. A big storm this winter would do much more damage and the resulting movement of sediment and large organic debris might plug downstream channels, especially where they enter underground conduits. These headwater areas (especially that of Serrano Creek) will be strongly

transformed, hydrologically speaking, by urbanization. The weakly-cemented porous sandstone of this area appears to be very permeable and its being covered by waterproof urban surfaces should greatly increase runoff. Profiles are needed for the entire length of Borrego Creek but there is no access to the El Toro Marine Base Reservation and for the Baker farm which lies just upstream of the Reservation. For next Fall, I would like to get access to those restricted areas.

5. **Bee Canyon Sanitary Landfill.** There is a large area of steep unvegetated slopes in the landfill area which is highly susceptible to erosion with consequent downstream sediment movement. There are two sediment basins directly downstream but the lower one is already full. A deep gully has formed on the east hillside below the landfill and this is highly susceptible to further expansion with consequent sediment movement. It is not yet clear to me how streamflow from upstream is to be routed either under or around the landfill.

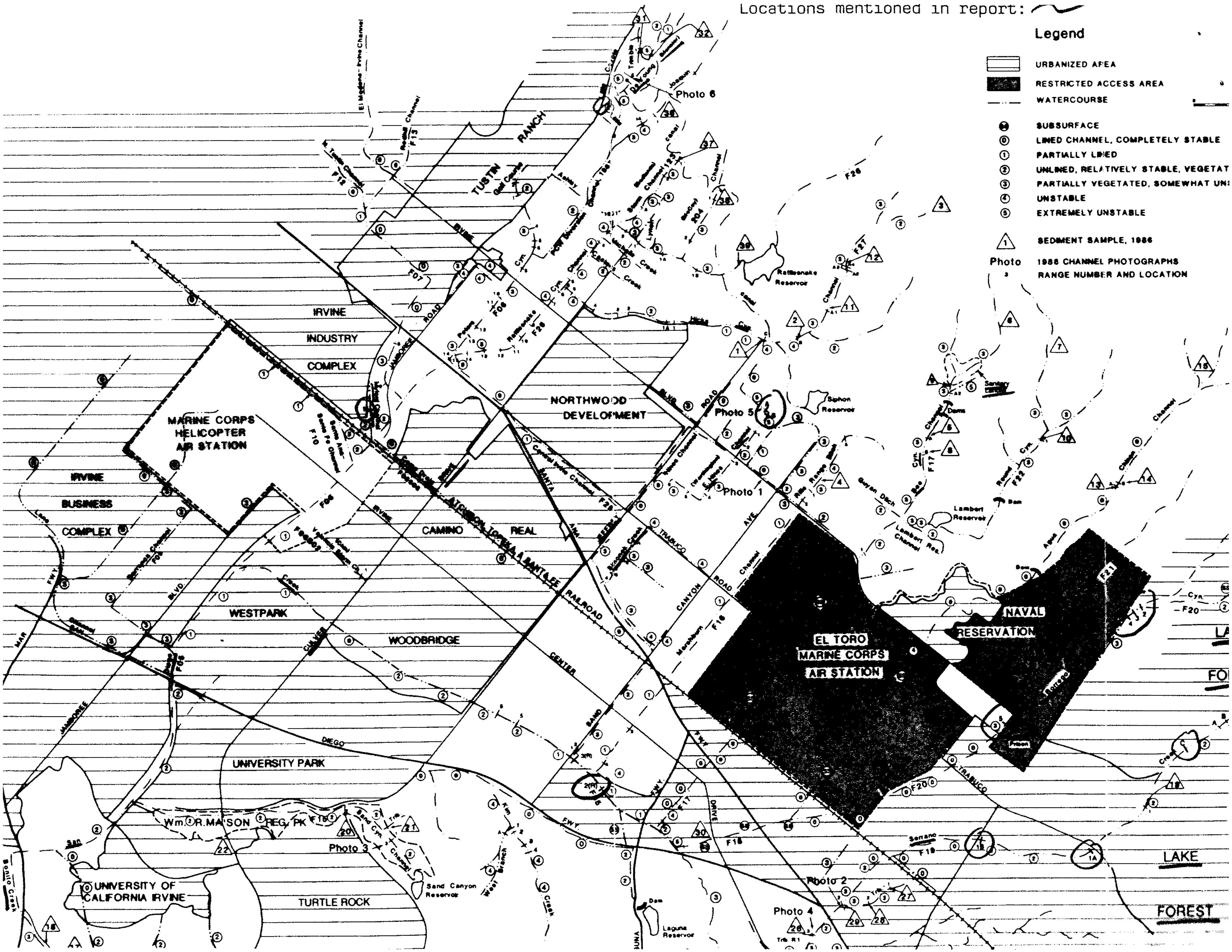
6. **New or Relocated Channels.** No new or relocated channels of any consequence were found this year. However, a deep gully has formed on the east hillside below Bee Canyon landfill (see Par. 5 above).

7. **Large Organic Debris in Channels.** As noted in Section 4 (above), a major problem of channel erosion in headwater areas is the potential undercutting of

banks and the collapse of trees, stumps, and other large organic debris into the channel. Additionally, routine trimming and maintenance of trees along streams produces much organic debris, some of which is dumped into the streams. This problem is especially pronounced along Hicks Canyon Creek where the channel is small and constricted between Jeffrey Road and Culver Drive. Such organic debris can seriously restrict channel capacity and cause overback flooding. Especially susceptible are the intakes to underground channels which can be readily blocked. An example of this is where De Young (Monster) channel flows under Jamboree Road, entering the underground channel through Tustin Ranch. The capacity of this intake has been reduced by about twenty percent by vegetation and sediment. That occurred during the mid-winter of last year and a wet winter would have a more profound effect. Local governmental agencies should consider removal of large organic debris from channels before the occurrence of major storms.

8. **Further Investigation of Dry Period Sediment Dynamics.** In the Spring, 1991, Field Investigation Report, I showed that channel enlargement by erosional processes had been significant during the relatively dry period of 1983-1991. I recommend that the resurvey of 15-20 older profiles be added to the Fall, 1991, field work so that dry period channel erosion could better be segregated from that of wet periods. In this review of my report, Lane Waldner of OCEMA suggested that the needs of the overall channel erosion study might better be served by installing additional profiles rather than resurveying existing profiles, (letter to S.W. Trimble dated 18

June 1991). Given the finite time and resources available, I agree that priority should be given to additional profiles. Additionally, I believe that the Spring, 1991, resurveys already give a reasonable approximation of dry period channel erosion, particularly since the variance among the 12 resurveyed profiles was so small. However, 10 of the 11 new profiles installed this Fall can provide future data on dry period channel erosion.



Locations mentioned in report:
Legend
URBANIZED AREA
RESTRICTED ACCESS AREA
WATERCOURSE
SUBSURFACE
LINED CHANNEL, COMPLETELY STABLE
PARTIALLY LINED
UNLINED, RELATIVELY STABLE, VEGETAT
PARTIALLY VEGETATED, SOMEWHAT UN
UNSTABLE
EXTREMELY UNSTABLE
SEDIMENT SAMPLE, 1986
Photo
1986 CHANNEL PHOTOGRAPHS
RANGE NUMBER AND LOCATION
TUSTIN RANCH
IRVINE INDUSTRY COMPLEX
NORTHWOOD DEVELOPMENT
MARINE CORPS HELICOPTER AIR STATION
IRVINE BUSINESS COMPLEX
EL TORO MARINE CORPS AIR STATION
NAVAL RESERVATION
WESTPARK
WOODBRIDGE
UNIVERSITY PARK
Wm. R. MASON REG. PK
UNIVERSITY OF CALIFORNIA IRVINE
TURTLE ROCK
LAKE FOREST
CAMINO REAL
ATCHISON, TOPEKA & SANTA FE RAILROAD
TRABUCO ROAD
CANYON ROAD
SAND CANYON AVE
JAMBOREE ROAD
CULVER
DIEGO
Rattlesnake Reservoir
Siphon Reservoir
Lambert Reservoir
Sand Canyon Reservoir
Laguna Reservoir
Photo 1
Photo 2
Photo 3
Photo 4
Photo 5
Photo 6
Bonito Creek
El Modena - Irvine Channel
Peters Canyon Channel
Hicks Cyn
Borrego
Serrano
F13
F12
F07
F08
F10
F16
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F18
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# FIELD RESEARCH REPORT FOR SAN DIEGO CREEK CHANNEL STUDY
1990

Stanley W. Trimble, Geomorphologist/Hydrologist

Department of Geography
University of California, Los Angeles

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## LIST OF ENCLOSURES

## EXECUTIVE SUMMARY

Field research on channel erosion was conducted in the San Diego Creek Watershed during Fall of 1990. Only 3 channel profiles have been lost in the past year, a decided decrease in the rate of loss over the past 5 years. Two profiles were installed to replace losses in previous years and a new profile was installed in the rapidly-developing urban area in headwaters of Serrano and Borrego Creek. No new channels of any consequence were found this year. The extent of grass cover in the Peters Canyon Wash Diversion Channel has improved, but the color still appears to be unhealthy.

## FIELD RESEARCH REPORT FOR SAN DIEGO CREEK CHANNEL STUDY

### Fall 1990

1. **Introduction**. Field research was conducted in the San Diego Creek Watershed on 29-30 September, 13-14 October and 3 November, 1990. All areas were visited except the upper Rattlesnake Wash which was not made accessible to me by the Irvine Company. In addition, a field orientation concerning the channel system was given to Lane Waldner on 1 December, 1990.

2. **Recover of Profiles**. Only 3 profiles were lost since the Fall 1989 inspection. The widening of Bonito Canyon Drive (now under construction) destroyed Bonito Creek Ranges 1 and 2. Bee Creek Range C was lost due to earth-moving in the orchard area. For both locations, new profiles will be surveyed next Fall when present construction is presumably finished.

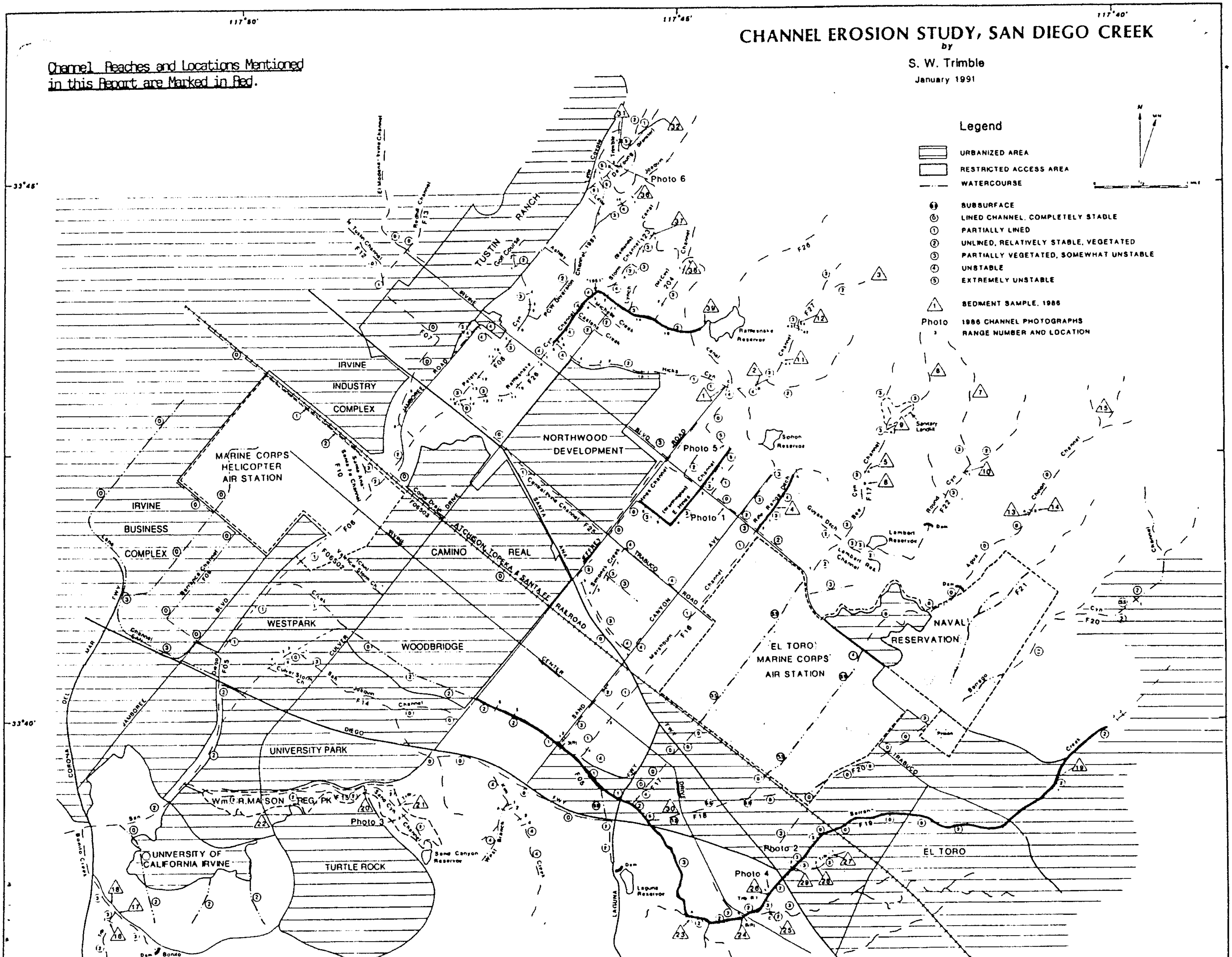
3. **Improvement of Upper Main Channel, San Diego Creek**. The channel of San Diego Creek (F05) from the Laguna Freeway to downstream of Sand Canyon Avenue now appears to be complete. Under construction for the past two years, the channel has been straightened, enlarged, and equipped with concrete banks and frequent masonry drop structures. This new channel appears to be well-designed. Although I surveyed a new profile (San Diego Creek Range 3

Relocated), I believe the County should include this new stretch in the scour studies (see the Review of the San Diego Creek Sediment Monitoring Program Annual Report, 1988-89). This would keep sediment reporting commensurate with similar channels in the lower stretches of F05 and F06.

4. **New Profiles**. As indicated above, one new profile was installed on San Diego Creek just upstream from Sand Canyon Avenue. Another was the replacement of San Diego Creek Range B just downstream from Irvine Center Drive. The channel there had been under modification over the past year or so. Finally, a profile was installed in a County wildlife protection area on upper Borrego Creek in the developing area in the headwaters of Borrego and Serrano Creeks (See Borrego Creek Range A on channel map). The graded slopes surrounding Range A are extremely steep and are presently unprotected by vegetation. Thus, if heavy rains come in the next year or so, I would expect Range A to be buried by sediment. However, should the rains come after a year or two when vegetation is well established, the slopes may hold, but the excess water coming from the storm drains should erode the channel at Range A. No new range was installed on Serrano Creek pending the completion of construction.

5. **New Channels**. No new channels of any consequence were found this year.

6. **Peters Canyon Wash Diversion Channel**. In my 1988 report, I noted that the diversion channel did not have a good stand of Bermuda grass. This year the extent of cover was improved, but the color of the grass does not look healthy. Perhaps it needs some nitrogen fertilizer. Keeping this channel well vegetated is important because it can be expected to carry a considerable flow in the event of heavy rains.


CHANNEL EROSION STUDY, SAN DIEGO CREEK
by
S. W. Trimble
January 1991
Channel Reaches and Locations Mentioned in this Report are Marked in Red.
Legend
URBANIZED AREA
RESTRICTED ACCESS AREA
WATERCOURSE
SUBSURFACE
LINED CHANNEL, COMPLETELY STABLE
PARTIALLY LINED
UNLINED, RELATIVELY STABLE, VEGETATED
PARTIALLY VEGETATED, SOMEWHAT UNSTABLE
UNSTABLE
EXTREMELY UNSTABLE
SEDIMENT SAMPLE, 1986
Photo
1986 CHANNEL PHOTOGRAPHS
RANGE NUMBER AND LOCATION
117°50'
117°45'
117°40'
33°45'
33°40'
TUSTIN RANCH
IRVINE INDUSTRY COMPLEX
NORTHWOOD DEVELOPMENT
MARINE CORPS HELICOPTER AIR STATION
IRVINE BUSINESS COMPLEX
CAMINO REAL
ATCHISON, TOPEKA & SANTA FE RAILROAD
WESTPARK
WOODBRIDGE
EL TORO MARINE CORPS AIR STATION
NAVAL RESERVATION
UNIVERSITY PARK
Wm. R. MASON REG. PK
TURTLE ROCK
UNIVERSITY OF CALIFORNIA IRVINE
EL TORO
Photo 1
Photo 2
Photo 3
Photo 4
Photo 5
Photo 6
Rattlesnake Reservoir
Siphon Reservoir
Lambert Reservoir
Laguna Reservoir
Sand Canyon Reservoir
TRABUCO
JAMBOREE
CULVER
DIEGO
SAND CANYON
CENTER
LAGUNA
CORONA DEL MAR FWY
BLVD
ROAD
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# Field Research Report for San Diego Creek Channel Study

Fall 1989

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# EXECUTIVE SUMMARY

Field research was conducted in the San Diego Creek Watershed during the period September 30 - November 4, 1989. Emphasis was placed on mapping human modifications to channels since 1988 and remarking established channel cross-sectional profiles. Additionally, five new profiles were established. Several profiles were lost, most of them being on the main branch of San Diego Creek (F05) upstream of Jeffrey Road where the channel has been straightened and enlarged. San Diego Creek is also being modified in its lower reach by protecting it from bank erosion with large rip-rap. This is a notable improvement because erosion of the fine-textured stream banks contributes significant amounts of sediment to Newport Bay. To lessen the probability of channel bed scour and reduction of channel capacity in the lowest reach of F05, I propose that large woody plants there be cut and removed. The San Diego Creek watershed continues to be urbanized, a factor leading to accelerated channel erosion. For that reason, the present urbanized area is shown on the 1989 channel map. A tributary on the south side of the basin, Kim Creek, is the last stream in the basin not connected to the present drainage system.

# FIELD RESEARCH REPORT FOR THE SAN DIEGO CREEK CHANNEL STUDY

## FALL 1989

1. **Introduction.** Field research was conducted in the San Diego Creek Watershed during the period September 30-November 4, 1989. Because of insufficient rainfall during the period 1988-1989, there appeared to be no need to resurvey any previously established channel cross-sections. Emphasis was placed on mapping human modifications to channels since 1988 and re-marking established channel cross-sectional profiles. Additionally, several new profiles were surveyed and recent urban expansion was mapped. The work is discussed by topic.

2. **Recovery of Profiles.** All cross-sectional profiles previously surveyed were checked. Benchmarks and witness points were re-marked where necessary to facilitate future recovery.

3. **Lost Profiles.** Because of channel modifications, the following profiles have been lost within the last year:

   A. San Diego Creek Ranges 1-4 and B.

   B. Marshburn (Hoag, F16) Channel Range 4

   C. Bee Channel (F17) Ranges 2-4

   Since the areas were still under construction, it was impossible to replace these ranges.

4. **New Profiles.** The following profiles were added this year (see attached survey notes):

**A.** Kim Creek Range A

**B.** Upper Serranno Creek Ranges 2 & 3

**C.** Peters Canyon Wash Golf Course Ranges 1 & 2

5. **Channel Modification and Problems with San Diego Creek (F05).** This main channel is undergoing significant changes. First, F05 is being lined bank-to-bank with large rip-rap from Culver Drive downstream to about Alton Avenue. Peters Canyon Wash (F06) is also being lined with rip-rap for a short distance upstream of the confluence with F05. This protection of channels is excellent because these previously-unlined banks have suffered significant erosion in the past. Because the natural bank materials are fine-textured, they are easily transported once entrained and have been shown to be a significant source of sediment load to Newport Bay. Without the rip-rap, increased stormflow from expanding upstream urbanization would have made this bank erosion even more serious.

Another important modification of F05 is the excavation of a new and straightened channel from Laguna freeway downstream to about 2000 feet below Sand Canyon Avenue. Also affected are the lower reaches of Marshburn (F16) and Bee (F17) channels. This enlargement was undertaken to accommodate the expected larger flows as a result of expanding urbanization. An unfortunate consequence of this channel modification is that 9 important profiles, all surveyed in 1983, were lost. New surveys cannot be undertaken until construction is finished. It would be highly desirable for the County to extend its Scour Study from Culver Drive upstream to Laguna Freeway. It would also be desirable for this channel reach to receive the same rip-rap treatment as the channel reach downstream from Culver Drive.

A problem, in my view, is the woody vegetation growing in the F05 channel bed in the vicinity of the 405 freeway. In large events, such vegetation would (based on my experience) cause additional turbulence inducing more channel scour. Additionally, these small trees and bushes can be entrained by flood waters and be snagged on downstream bridge piers, thus reducing their discharge capacity. I recommend that the larger plants be cut off at the root crown and removed. The resprouts would allow the root system to remain viable and help stabilize the channel bed without creating a hazard.

6. <u>**Continuing Urban Development.**</u> The San Diego Creek Watershed continues to be rapidly urbanized. As pointed out in this and earlier reports, urbanization (with its attendant waterproof surfaces) is a primary causal factor in increasing runoff

peaks. Increased erosion of vulnerable channels is the result. Based on ground reconnaissance, I have attempted to bring the urbanized area up to date on the 1989 channel map. Comparison of the western half of the map with the <u>Tustin</u> quadrangle (1965, photorevised 1981) will show the phenomenal urban growth there over the past quarter century.

A large and potentially significant urban area is now being developed in the headwaters of Serrano and Borrego Creeks. The area shown on the map can only be approximate until the project is completed.

The Tustin Ranch area, started in late 1987, continues to be developed. The golf course is virtually complete and two profiles were established across the new channel of Peters Canyon Wash. Elsewhere in the project, the surface channels are not yet established so it is not yet possible to place profiles. Much of the drainage of Tustin Ranch will be subsurface and discharges will be controlled to some degree by a floodwater detention structure now under construction which is located just downstream of the lower Peters Canyon Reservoir.

7. **<u>Kim Creek.</u>** Kim Creek is a tributary flowing from the San Joaquin Hills northward towards San Diego Creek. Channel erosion is quite active and five new profiles have been

established on this stream during the past two years. A particularly interesting feature about Kim Creek is that the channel disappears just south of the 405 freeway. Hence, Kim Creek may be the last remaining tributary not connected by channel to the drainage system of San Diego Creek. This was the original configuration of nearly all tributaries before European settlement. (Trimble, 1981, Figure 6).

## REFERENCE

Trimble, Stanley W. 1981. Geomorphic Analysis, Newport Bay Watershed, San Diego Creek Comprehensive Stormwater Sedimentation Control Plan. Part II, Task II-B, Water Resources Division, Boyle Engineering Corporation, San Diego.