V* AS AN INDEX OF SEDIMENT IMPAIRMENT TO STREAM HABITAT IN THE ARROYO CORTE MADERA DEL PRESIDIO WATERSHED MARIN COUNTY, CALIFORNIA SEPTEMBER 2005

PREPARED FOR

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INTRODUCTION

Aquatic habitat in the Arroyo Corte Madera del Presidio watershed may be impaired by high supply of sediment from erosion processes. The non-profit Mill Valley StreamKeepers (MVSK, http://www.millvalleystreamkeepers.org) is interested in determining the degree and trends of such impairment so that they can most effectively support policies and actions that will lead to the protection and restoration of aquatic habitat. One important goal of the MVSK is the recovery of steelhead trout and coho salmon populations, which are particularly sensitive to excessive supply of fine sediment.

Quantitative procedures for determining sediment impairment such as bed composition studies and suspended sediment monitoring demand extensive commitments of time and money. Less quantitative procedures such as visual assessments of gravel embeddedness (CDFG 1998) provide very limited ability to detect changes over time due to variability among observers. MVSK decided to use V* as an index of sediment impairment because it can be applied inexpensively, provides the ability to detect changes over time, and directly relates to a critical feature of fish habitat.

V* (pronounced "V-star") is defined as the fraction of residual pool volume filled with fine sediment (i.e. bed particles mobilized during a frequent storm event). The V* index is becoming widely used as an unbiased estimator of sediment supply in Pacific coastal gravel-bed streams (Lisle and Hilton 1999) and has been effectively used to detect changes in channel conditions as a result of decreased sediment delivery. Decreased supply of fine sediment causes less pool filling. In watersheds with very high sediment supply, coho salmon and steelhead trout populations are often limited by a lack of pools deep enough to provide protection from predation and to support over-winter rearing (Spence et al. 1996).

The purpose of the 2005 monitoring (including benthic macroinvertebrate sampling reported separately) is to document baseline conditions for tracking changes or trends in stream condition which may be associated with changing land use policies or watershed restoration activities. A substantial investment in watershed restoration projects by the Marin Municipal Water District and other agencies is currently underway. This report summarizes V* sampling results from 2005 and provides baseline information for repeated surveys in the future.

METHODS

Following the procedures of Hilton and Lisle (1993), V* was measured by taking detailed measurements of pool dimensions and depths, including riffle crest depth and residual pool volume (see Figure 1). The depth of fine sediment was determined by pushing a calibrated stainless steel rod forcibly through the pool bottom sediment until contacting an armor layer of less mobile sediment. Four to seven transects were systematically assigned in each pool and a minimum of forty probe points were sampled. Up to 100 probe points were sampled in larger pools. V* for each pool and a weighted-mean value of V* for each reach was then calculated using a custom Excel template.
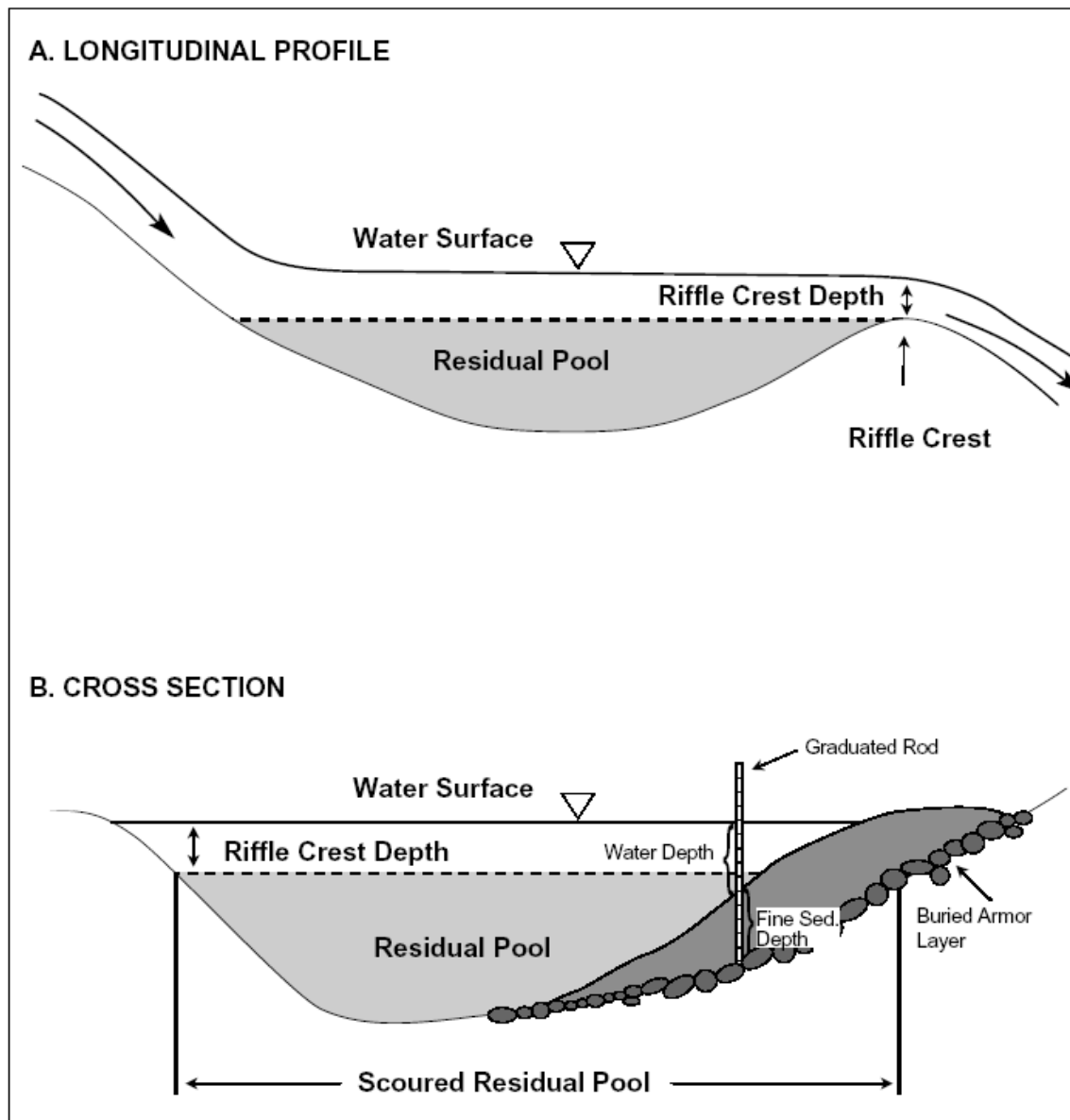
Figure 1: From Hilton and Lisle 1993 – "(A) Longitudinal profile of a pool, showing the riffle crest and the area included in the residual pool volume. (B) Cross section of a pool, showing measurement of water and fine sediment depth and volume of water and fine sediment in the scoured residual pool." Note the depiction of how the rod measures fine sediment to the depth of an armor layer.

V* was measured in twelve pools representing three reaches of the Arroyo Corte Madera del Presidio watershed. In each reach, a reconnaissance generated a list of candidate pools to meet the following criteria: large enough to persist in channel-changing events; unlikely to be changed by bank modification or restoration projects; and composed of a natural bed. From this list, a randomization procedure was used to select four pools dispersed across the reach. These pools were mapped on the back of datasheets with descriptions to enable their relocation (Table 1).

RESULTS

The three reaches of the Arroyo Corte Madera del Presidio watershed were identified as Old Mill Creek, Arroyo Corte Madera Creek above Mill Valley[1] (Upper ACM) and Arroyo Corte Madera Creek below Mill Valley (Lower ACM). The lower reach was located above the influence of tidewater, estimated to be the County streamgage site at 401 Miller Ave. The upper extent of Old Mill Creek was defined by the increased gradient at the Inkwells, and the upper extent of Arroyo Corte Madera Creek was limited by channel size reduction at Blithedale Park.

Pools in the Old Mill Creek reach were measured on September 23, 2005. Pools in Lower ACM and Upper ACM were measured on September 30, 2005. The residual pool volume of the twelve sampled pools ranged from 0.5 m^3 to 14.5 m^3. Pool size was not evenly represented among the three reaches. All four pools from Upper ACM were below the median of 5 m^3. Three of the Old Mill Creek pools ranked in the top four for size (Table 1).

Table 1: Description of twelve pools, including metric length and volume, measured for V* in Arroyo Corte Madera and Old Mill Creek.

Pool	Length (m)	Vol (m^3)	Scour Type	Description
Lower ACM 1	16	8	lateral	first natural pool above Locust St
Lower ACM 2	16	2.2	lateral	above lower footbridge at Willow Apts
Lower ACM 3	12	2.8	lateral	below upper footbridge at Willow Apts
Lower ACM 4	18	13.4	lateral	first natural pool below Park St outlet
Upper ACM 1	7	0.5	lateral	lowest pool before concrete wall channel
Upper ACM 2	11	1.1	lateral	single pool between adjacent pools sampled
Upper ACM 3	10	2.2	plunge	below 2' notched concrete weir
Upper ACM 4	22	5.9	lateral	near Blithedale park sign; scours left bank
Old Mill 1	10	14.5	plunge	outlet below Cascade Ave; Miller Park
Old Mill 2	19	10.1	lateral	400' above Cascade Ave
Old Mill 3	7.5	1.4	lateral	revetment bags on left bank
Old Mill 4	9.3	13.8	plunge	lower ink well pool below bedrock falls

The overall V* for twelve pools in the watershed was 0.15, and the V* for individual pools ranged from 0.08 to 0.27 (Table 2). As a weighted average, overall V* was strongly influenced by three particularly large pools: Lower 4, Old Mill 1, and Old Mill 4. The V* for these pools ranged from 0.09 to 0.16. V* correlated with residual pool volume (Coef. = -0.47). All pools with V* values greater than 0.21 were smaller in volume than the median pool size. The two smallest pools had V* values greater than 0.25 (Table 2).

The weighted average V* for each of the three reaches (Figure 2) was 0.16 (SE= 0.020) for Lower ACM, 0.21(SE= 0.076) for Upper ACM, and 0.14 (SE=0.024) Old Mill Creek. The apparently higher V* for Upper ACM was not statistically significant due to a small sample

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[1] Old Mill Creek joins Arroyo Corte Madera Creek in Mill Valley.

size (n=4). However, examination of individual pool V* by rank (Table 2) indicates that the pools in Upper ACM do have higher V* than the pools in Old Mill Creek.

Table 2: Final components of V* calculation, average weighted V*, and rank for pools of the Arroyo Corte Madera watershed, September 2005.

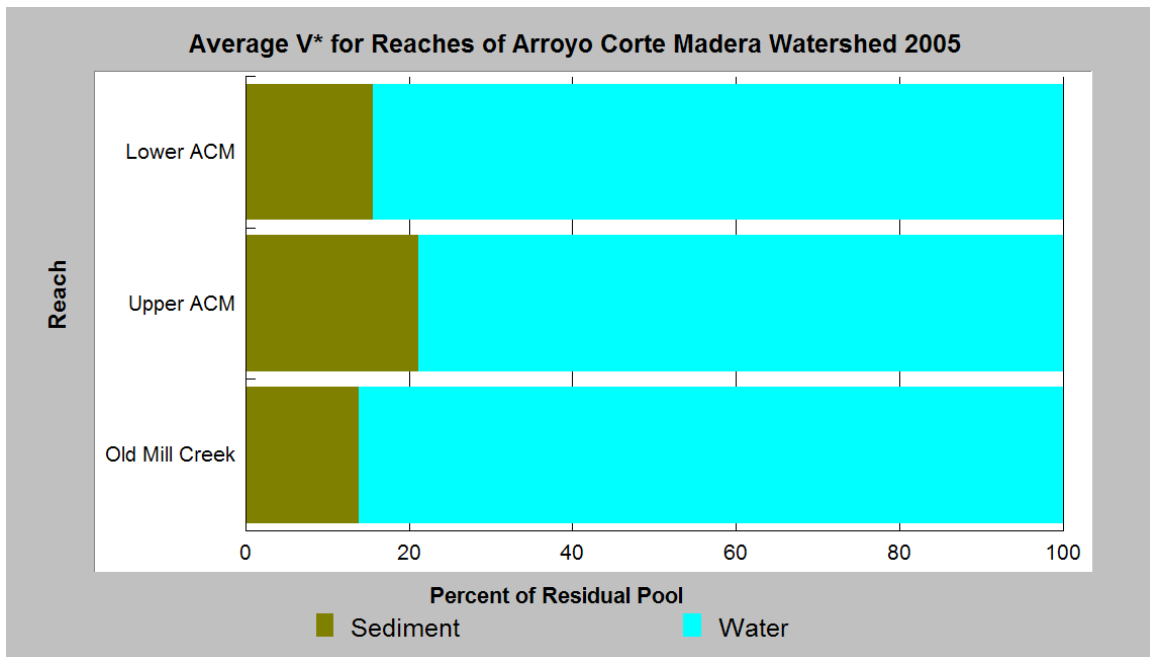| Pool	Water Vol (yd^3)	Fines Vol (yd^3)	V*	V* Rank
Lower ACM 1	10.53	1.16	0.10	3
Lower ACM 2	2.85	0.77	0.21	9
Lower ACM 3	3.61	1.06	0.23	10
Lower ACM 4	17.52	3.38	0.16	5
Upper ACM 1	0.55	0.19	0.26	11
Upper ACM 2	1.52	0.57	0.27	12
Upper ACM 3	2.92	0.67	0.19	7
Upper ACM 4	7.28	1.87	0.20	8
Old Mill Cr 1	19.00	2.69	0.12	4
Old Mill Cr 2	13.17	1.34	0.09	2
Old Mill Cr 3	1.82	0.16	0.08	1
Old Mill Cr 4	17.99	4.17	0.19	7
SUM TOTAL	98.76	18.03	**0.15**	

Figure 2: Weighted average V* for three reaches the Arroyo Corte Madera Creek Watershed charted as relative proportions of residual pools occupied by sediment or water. The chart comes from a draft revision of KRIS East Marin-Sonoma.

DISCUSSION

The North Coast Regional Water Quality Control Board has established 0.21 as a target V* value for streams recovering from sediment impacts (Fitzgerald 2004). This assessment was made possible by a study which evaluated V* by applying it and other indices to more than fifty streams in northern coastal California (Knopp 1993). All of the watersheds were geologically composed of the Franciscan formation, as is the Arroyo Corte Madera. Knopp found that watersheds moderately and highly disturbed by logging activities had median V* values of 0.31 and 0.39, respectively. His control group of 12 undisturbed watersheds had a median V* of 0.17 with a minimum of 0.7 and a maximum of 0.27.

Measured V* values in this study do not support the hypothesis that sediment is a primary factor limiting aquatic habitat. Arroyo Corte Madera Creek V* values fall within the Knopp (1993) range for undisturbed watersheds. The reach average for Old Mill Creek is equivalent to the NCRWQCB target, and the other ACM reaches are below the target. However, the comparison may be inappropriate due to differences between the streams studied by Knopp (1993) and the Arroyo Corte Madera.

Knopp (1993) studied watersheds variously impacted by logging. He did not study urbanized watersheds. Impacts from urbanized watersheds would likely affect residual pool volume filling differently than impacts from logging. For example, urbanized watersheds have higher runoff coefficients and are typically influenced by artificial confinement. These conditions could potentially cause greater flushing of fine sediments. V* has not been evaluated for urbanized watersheds.

V* measures just one aspect of a complex and dynamic relationship between sediment yield and aquatic habitat. Salmonid biologists find V* interesting because of how it can measure filling of pool habitat that is important for rearing and holding. Pool filling has led, in some cases, to the reduction of pools to depths less than adequate for various life history stages of salmon and trout. This result of increased sediment yield is typically associated with decreased bed particle size, decreased gravel permeability and increased rates of suspended sediment.

Several alternative parameters are used by the San Francisco Bay Regional Water Quality Control Board and have established relationships between metrics and habitat condition. These include bed particle composition, spawning gravel permeability, and suspended sediment. Measuring any of these parameters would cost several times the budget for this project but would provide a quantitative means to assess sediment as a factor limiting aquatic habitat.

Upper ACM pools have higher V* values than Old Mill Creek pools when the data is examined as ranks. Parametric statistics (i.e. t-distribution) result in no significant difference because the sample sizes are low and variance for V* incorporates variability in residual pool volume. Higher levels of pool filling in Upper ACM may be an artifact of smaller pools or a consequence of higher sediment yield.

While V* values in Arroyo Corte Madera may not be easily evaluated for ratings of habitat condition, changes in V* values would be indicative of a change in the result of the sediment-habitat relationship. Repeated surveys of the same pools in the future will allow powerful detection of changes in V* through paired sample statistics. In the case of Upper ACM, V* may decrease either as a result of increased pool size or decreased sediment yield.

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ARROYO CORTE MADERA V* SAMPLING, SEPTEMBER 2005
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