A Sediment Budget for Two Reaches of Alameda Creek:
support for flood control channel management

WATERSHEDS SCIENCE PROGRAM

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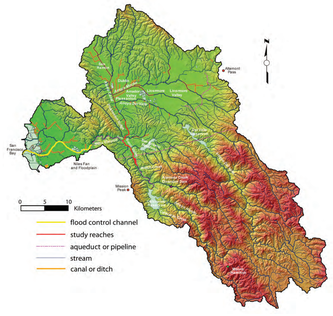
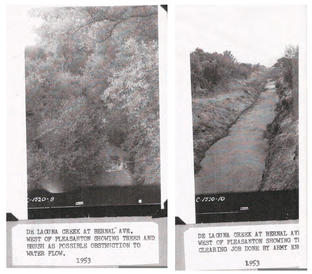
1 Alameda Creek Flood Control Channel: a sediment sink near the Bay margin

Sediment deposition in flood control channels is a chronic problem for managers tasked with dual objectives to maintain both flood protection and aquatic or riparian habitat. Since construction of the Flood Control Channel on lower Alameda Creek, the Alameda County Flood Control and Water Conservation District (the District) has periodically dredged sediment from the creek to maintain channel flood capacity. Because dredging is costly and disrupts habitat, and because obtaining permits is becoming more difficult, the District is seeking to minimize dredging frequency. Conceptually this can be achieved by reducing sediment supply from upstream, or modifying the channel for more efficient sediment transport. A sediment budget was constructed to provide data to support District decisions about future channel and watershed management.

2 Alameda Creek Watershed

The Alameda Creek Watershed (1,662 km² or 642 mi²) is the largest local watershed draining to the San Francisco Bay. It has a history of extensive land management and use, water use, and channel modification, all of which affect present-day water and sediment transport through the channel network. Notably, the early connection of tributaries in the Livermore-Amador Valley, the draining of Tulare Lake in 1900 (which provided a dampening effect upon flow and sediment transport), the construction of three large reservoirs (trapping sediment from 44% of the total watershed area), extensive urbanization, and construction and maintenance of the Flood Control Channel all contribute to the current sediment regime of the watershed and the chronic sediment deposition within Lower Alameda Creek

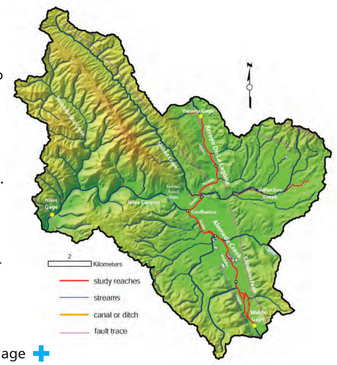




Dramatic example of channel modification that occurred on Arroyo De La Laguna at Bernal Avenue in 1953. The photo on the left shows the reach before riparian vegetation clearing, while the photo on the right shows the same reach after clearing by the Army Corps of Engineers (Source: Alameda County Resource Conservation District).

3 Sediment Budget Methods

To address upstream sediment supply, we evaluated two reaches identified by others as probable sources of sediment to the flood control channel: a highly incised reach of Arroyo De La Laguna and upper Alameda Creek in Sunol Valley. The budget was constructed from field and air photo bank erosion surveys, current and historical bed elevation surveys, cross section analysis, tree coring to estimate floodplain age, and interpretation of USGS suspended sediment and bed load data. Only a subset of these methods were used in the Alameda Creek reach because its morphology suggested that it was not a major source of sediment. By interpreting this data, we identified the dominant processes and quantified rates of sediment supply and storage over time (1901 to 2006 over four decadal time periods).



The sediment budget followed the equation:

Sediment input at Verona gage + sediment input at Welch gage + sediment derived from study reaches + sediment input from ungaged tributaries = sediment passing through Niles gage +/- balance

Arroyo De La Laguna study reach

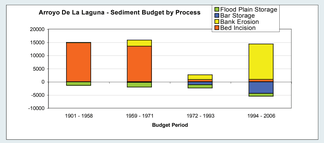
Alameda Creek study reach

4 Sediment Budget

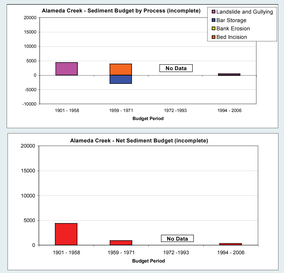
Take home message: During the most recent period (1994-2006), roughly 6% of the sediment mass passing through the Niles gage was derived from net channel erosion of the study reaches, mostly from the Arroyo De La Laguna reach. While not the major source hypothesized by others, it remains substantial given the reach only comprises 0.25% of the watershed stream network length.

Net Budget for the Study Reaches - Patterns of Erosion over Time

Combining the various estimates of sediment supply and storage over the four time periods reveals patterns of erosion and storage by process. In Arroyo De La Laguna, we see that 1901-1958 was dominated by channel incision triggered by the ditching of Tulare Lake, 1959-1971 saw another phase of incision in response to the aggradation caused by the extreme flood events in the 1950s, and 1994-2006 was dominated by bank erosion as the channel adjusted through widening. In Alameda Creek we see much lower rates of erosion, primarily because the channel is well connected to its floodplain, and because 70% of its drainage area is upstream of reservoirs, impounding both flow and sediment. Based upon the partial budget, we see that landslides and gullies dominate the sediment supply.



(upper) Arroyo De La Laguna study reach sediment budget by process over the four time frames. (lower) Net sediment budget over the four periods.



(upper) Alameda Creek study reach sediment budget by process over the four time frames. (lower) Net sediment budget over the four periods. Y axis is same scale as Arroyo De La Laguna plots for visual comparison.

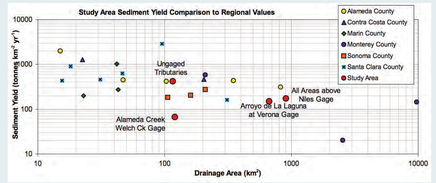
Relative Sediment Supply- Comparison of Yields within the Watershed

To evaluate the significance of net sediment supplied from the study reaches, the field-based estimates were compared to sediment supply from upstream, as measured at USGS gage stations at Verona and Welch Creek, and sediment supply transported from the study reach, as measured on Alameda Creek at Niles. Based upon rating curves developed for each gage, we estimate that an average of 156,000 metric t/yr of sediment (suspended plus bed sediment) passed through the Niles gage. Comparing USGS measured yields with the yields derived from the interpretation of our field measurements along with comparisons to yields in other Bay Area watersheds provided us with confidence in our results. In the budget, the estimate for sediment supply from the ungaged area (116 km2) has the most associated uncertainty; the sediment budget would benefit from additional study in these areas.

Comparison of the total sediment budget for the most recent budget period 1994 - 2006.

Area	Sediment Yield (metric t/year)	Percent of Total measured at Niles
Arroyo De La Laguna at Verona Gage	104,000	63
Alameda Creek at Welch Creek Gage	3,400	2
Arroyo De La Laguna Study Reach	8,400	5
Alameda Creek Study Reach	320	0.2
Ungaged areas	47,908	29
All Areas upstream from Niles Gage	164,000	
Alameda Creek at Niles Gage (estimated from rating curves)	156,000	

Comparison of sediment yield rates (on a per area basis) between the Alameda Creek watershed and yields for other watersheds in the region.



Sediment Supply to the Flood Control Channel Through Time

To better understand how sediment supply has varied through time, we compared the estimated sediment yield at the Niles gage to that from the study reaches for three budget periods. The higher contribution from the study reaches during 1959-1971 reflects a period of rapid incision migrating through the reach after the major disturbance of the 1950s floods. As channel incision migrated upstream, and channel adjustment in Arroyo De La Laguna transitioned to bank erosion and sediment storage increased, sediment contributions decreased.

Time Period	Niles Gage (metric t/yr)	Study Reaches Combined (metric t/yr)	% of Niles
1959-1971	74,000	19,300	26
1972-1993	90,000	320	0.4
1994-2006	156,000	8,700	6

5 Recommendations and Next Steps

Our findings indicate that although the sediment supply from the study reaches is high relative to the channel length, other much larger sources of sediment to the Flood Control Channel exist in the watershed. To work towards the goal of reducing or eliminating downstream dredging requirements, we recommend:

- quantifying sediment sources and rates from ungaged watersheds and areas upstream of the Verona gage, to improve understanding of the primary processes supplying the majority of sediment to the Flood Control Channel, and to allow identification of potentially controllable sources of sediment.
- enacting restoration approaches that encourage upstream sediment storage
- studying solutions to increase sediment transmission through the flood control channel

Towards this goal, our current and future work includes:

- providing science support for the Alameda County Resource Conservation District restoration projects within the Arroyo De La Laguna reach
- a reconnaissance level sediment source assessment for the Dry Creek tributary, which inputs coarse sediment directly to the Flood Control Channel
- analysis of reconfiguration of the Flood Control Channel to increase sediment transport, possibly via construction of a bankfull channel and inset floodplain

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For More Information: Download the full report at http://www.sfei.org/sfeireports.htm

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