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South San Francisco Bay Shoreline Study

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Field Assessment of Selected South San Francisco Bay Streams

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Abstract: Riverine sediment transport studies require knowledge of existing river conditions, including stream-flow characteristics, in-stream controls such as dams or weirs, channel geometry and plan form, general channel stability, bed sediment type and gradation, and extent and degree of vegetation or other encroachments in the channel. The stability of a stream channel is directly related to flow, bed slope, sediment size, and inflowing sediment load. Field observations can provide important clues to how well a stream is adjusting to changes in these variables over time due to factors such as urbanization and changes in watershed land use. Relatively stable channels may indicate localized instabilities, but overall they retain a relatively consistent channel plan form and crossection in response to system hydraulics.

A stream channel field assessment is necessary before any sediment transport or channel morphology change studies are conducted. Five South San Francisco Bay streams were evaluated in support of the riverine sediment transport component of the South San Francisco Bay Shoreline Study (Coyote Creek, Guadalupe River, Calabazas Creek, Stevens Creek, and Permanente Creek). The evaluation consisted of observing the lower reaches of the streams, with general reach boundaries extending from Highway 101 to the bay sloughs. Sediment samples were taken along each stream reach where feasible, particularly in areas where the bed slope or bed sediment composition was changing. Observations of channel crossections were made, along with in-steam controls (bridges), vegetation, or stream corridor controls such as levees. Markings on vegetation defined the influence of Bay tides in the lower channels. Base flows were noted within the channels and sediment deposits in floodplains were examined.

This report summarizes observations and general assessment of the lower channels. Generally, the channels above Highway 101 are gravel and cobble bed steep gradient channels for which sand, silt, and clay behave as wash load during intermediate to large flow events. Just below Highway 101, a number of factors make the lower channels a depositional area for sand sized sediments. A decrease in channel slope combined with the influence of Bay tides and backwater elevations due to the bridges spanning the steams results in deposition of sand-sized sediments between Highway 101 and the lower Highway 237 Bridge. Below Highway 237, sediment transport consists primarily of silts and clays, along with some very fine and fine sand.

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Preface

The research presented in this paper was sponsored by the U.S. Army San Francisco District Army Corps of Engineers. This work was conducted in the Coastal and Hydraulics Laboratory (CHL) of the U.S. Army Engineer Research and Development Center (ERDC) during the period of May 2007 – June 2009 under the direction of Thomas J. Richardson, Director, CHL; Bruce Ebersole, Chief of the Flood and Storm Protection Division, CHL; and Dr. Lisa Hubbard, Chief of the River Engineering Branch, CHL.

This stream channel assessment was conducted by Dr. Steve Scott of the River Engineering Branch, CHL. Acknowledgements are made to Dr. Rob McAdory, Chief of the Estuarine Engineering Branch, CHL, Dr. Joe Letter, Estuarine Engineering Branch, CHL, and Terry Marks, San Francisco District, for their guidance and assistance during this study.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	.02831685	cubic meters
feet	.3048	meters
inches	.0254	meters
mile	0.621212	kilometer

1 Introduction

A channel assessment was conducted on five South San Francisco Bay streams in support of the South San Francisco Bay Shoreline study. The channel assessment was conducted to provide both qualitative and quantitative information to support riverine sediment transport modeling activities associated with the shoreline study. The existing channel morphology, bed sediment composition, and bed sediment distribution was documented through photography and bed sampling activities.

Five streams were evaluated; Coyote Creek, Guadalupe River, Calabazas Creek, Stevens Creek, and Permanente Creek. Only the lower stream segments were evaluated from just above the head of tide (upstream boundary) to the beginning of the South Bay sloughs (downstream boundary).

A number of channel characteristics were of interest during the assessment including:

- Channel plan form – width, depth, sinuosity
- Channel over bank characteristics (bank composition, vegetation, confinement, etc)
- Channel stability including bank and bed erosion and depositional areas
- Flood control or bank / bed protection structures
- Degree and type of channel vegetation
- General bed sediment composition and spatial distribution
- Transition from riverine flow (run of river conditions) to tidally influenced flow

2 Background

The South San Francisco Bay shoreline study was proposed to evaluate the impact of South Bay shoreline alterations on the flood risk of adjacent urban infrastructure and the related change in bay morphology due to altered sediment pathways. A number of salt ponds are located within the bay bordered by the lower reaches of the selected streams. It has been proposed that the salt ponds be altered to create wetlands through a number of activities such as breaching or removal of levees. The salt pond levees provide an existing degree of tide and wind driven wave protection for the infrastructure along the South Bay shoreline. Additionally, the existing salt pond levees bordering the streams prevent inflowing fluvial sediments from entering the ponds. The breaching or removal or these levees will potentially result in a higher flood risk due to tidal and storm effects and alter the fluvial sediment supply and distribution to the bay and adjacent areas.

Both riverine and coastal studies have been proposed to evaluate the future flood risk in the area and changes in riverine and bay morphology after the salt ponds are altered. The coastal study will use two-dimensional hydrodynamic models developed by the US Army Corps of Engineers, RMA2 and ADH, to simulate the impact of the bay tide, wind, and wave effects as well as estimate changes in bay morphology. Riverine flood risk will be evaluated by simulating concurrent fluvial flood events using existing US Army Corps of

Engineers HECRAS models of the Bay area streams. The change in fluvial sediment transport in the lower stream reaches will be evaluated with the US Army Corps of Engineers one-dimensional sediment transport model, HECRAS. The channel assessment described in this report was conducted in support of the HECRAS sediment transport study. During the channel assessment field trip, bed sediment samples were collected along each stream where accessible.

3 General Stream Morphology

The streams of concern to this study flow from headwaters located in the eastern Santa Cruz mountains. The upper reaches of the streams are characterized by steep slopes and broadly graded sand / gravel bed material. Base flow in the streams is primarily provided by upstream reservoir releases or water treatment discharge. The significant flow events which move sediment occur from approximately November to April of each year.

Changes in land use have significantly altered stream morphology in this area. Farming operations in the upstream watershed contributed to erosion and increased sediment loads into the streams. Urbanization has led to increased runoff and peak flows which in turn leads to channel adjustments. Flood control levees confine the flow that would otherwise be spread out over the flood plains.

The plan form of a channel is directly related to the hydrology, inflowing sediment discharge, sediment size, and bed slope. A simple proportionality relationship describes channel response when any of these variables are altered:

$$Q_w S_o \ \alpha \ Q_s D_{50} \qquad (1)$$

with Q_w the water discharge, S_o the bed slope, Q_s the sediment discharge, and D_{50} the median bed sediment grain size. Changes in any of these variables in a fluvial system will result in a channel response. A stream is said to be in equilibrium when these variables are proportionally balanced. However, a natural fluvial system is always in a state of flux to some degree, always striving to maintain equilibrium conditions.

For the South Bay streams, a number of conditions can result in channel response (instability). Trapping coarse sediments behind dams in the upstream reaches can result in channel bed degradation downstream. The sediment supply, $Q_{s,}$ is not available to the downstream stream, thus the right side of the proportionality relationship in equation 1 has been reduced. Thus the left side of the relationship must be reduced accordingly. With a constant water discharge, this requires that the bed slope must be reduced. The system adjusts by lowering the bed through erosion. Trapping or removing coarse sediment deposits from the streams can have the same impact on bed stability. Confining the streams between flood control levees can also result in channel bed degradation. For unconfined streams, high flows are distributed across flood plains, whereas streams confined by levees contain all the flow. Thus the left side of equation 1 has increased. With a constant slope and particle size, the sediment discharge must increase accordingly.

Thus bed lowering (erosion) occurs. Increased urban runoff due to the increase in impervious areas also can have the same impact. Before urbanization, the channel has adjusted its plan form to the hydrology of the natural area. After urbanization, peak flows are higher due to higher runoff rates, thus the channel adjusts to accommodate the flows. Bank instability often is the result of bed erosion and lowering. Banks become too steep and fail, thus widening the channel and adding more sediment into the system.

Sediment transport in the lower stream reaches is influenced by tidal effects. Figure 1 indicates that the head-of-tide for all the study streams is below Highway 101.

The distribution of sediment deposits that results from riverine flooding events can be influenced by varying tidal water levels. Riverine floods that occur during low tide have the potential to deliver and deposit sediments further downstream, whereas flood events that occur at high tide will be influenced by the backwater effect of the tide, resulting in reduced flow velocities and subsequently reduced sediment transport capacity further upstream.

4 Stream Channel Assessments

The lower reaches of five South Bay streams were evaluated. The tidal reaches of these streams are in close proximity to the salt ponds which are under consideration for alteration or removal.

Many of the channel locations that were accessed during the trip were too deep to wade, therefore, sampling was accomplished using a tethered steel pipe that was thrown into the stream, allowed to bite into the substrate, and was then slowly pulled in. This method only samples the top few inches of material in the substrate. The finer materials (silts, clays, and organics) were frequently washed out of the container during the sampling.

Coyote Creek

The selected reach of Coyote Creek spans from Montague Bridge downstream to just above Dixon Landing (approximately 4.1 miles). During the reconnaissance trip, the channels were conveying base flow. For the most part, levees were used as access points for the channels.

At the Montague Expressway bridge, the channel was relatively narrow (6 ft), with a predominately gravel bed (Figure 2). The relatively narrow levied channel corridor was highly vegetated with trees, shrubs, and grass (Figure 3). Flow velocities were relatively high (approximately 2 -3 feet per second) with a depth of 1 – 2 ft, indicating a high gradient. In the vicinity of the bridge, the levee banks and channel toe were stabilized with large 10 – 12 inch rock) (Figure 4).

Just downstream of the bridge, the channel was wider (6-10 ft), with lower velocities (0.5 ft/s) and greater depth (2 – 3 feet). Bed sediments sampled in this area indicated a sand / fine gravel mix. No bed or bank erosion was observed.

The Tasman Road Bridge is approximately 1.1 miles downstream of Montague Bridge. Between Montague Bridge and Tasman Road Bridge, the channel corridor contains a relatively wide by pass channel (Figure 5). The main channel at Tasman Road was approximately 10-15 ft wide, with steep banks consisting of silts and clays (Figure 6). The flow velocity was relatively low (0.1 - 0.3 ft/s), with deeper channel depths (3 – 4 feet). The bypass channel was dry with low lying vegetation. The soil in the by pass channel appears to consist primarily of a silt loam (Figure 7). The over bank area adjacent to the main channel was highly vegetated with trees and low lying vegetation (Figure 8). No bank protection works or indications of channel instability were observed. The bed sample indicated a fine to medium sand.

The Highway 237 Bridge is approximately 2.2 miles below the Montague Bridge. The wide by pass corridor continues between the Tasman and Highway 237 bridge locations. The channel just upstream of this location is approximately 10-15 ft wide, with banks consisting of silt and clay (Figure 9). The over bank areas adjacent to the main channel are heavily vegetated with low lying shrubs and grasses, as well as trees (Figure 10). Low flow was observed (.3 ft/s), with a water depth of 2 – 3 feet. The bed sample indicated a fine to medium sand. No evidence of bank or bed instability was observed. The by pass channel ends just below the 237 bridge. The channel approaching the bridge becomes more narrow (6 – 8 feet wide) with a higher flow velocity (Figure 11).

Approximately 0.5 miles downstream of the 237 bridge the channel is somewhat wider (~20 ft), with low flow velocity (.3 ft/s) with greater water depth (approximately 5 – 6 ft deep). At this location, tidal influence was noted by water marks on adjacent channel vegetation (Figure 12). The banks were steep and consisted of primarily silts. The bed sample indicated sand and fine gravel. The over banks adjacent to the main channel were heavily vegetated with low lying shrubs and grasses as well as mature trees (Figure 13). No evidence of channel instability was noted.

The channel width increases to approximately 20 – 30 ft about 1.0 mile downstream of the 237 bridge, with little to no flow velocity and a water depth of approximately 5 – 6 ft deep (Figure 14). The location of the tidal influence was noted by water marks on adjacent channel vegetation (Figure 15). The banks were steep and consisted of primarily silts. The bed sample indicated sand and fine gravel. The over banks adjacent to the main channel were heavily vegetated with low lying shrubs and grasses as well as mature trees. No evidence of channel instability was noted.

The Dixon Landing Road location is approximately 4.1 miles below the Montague Expressway Bridge. The channel was approximately 30 ft wide, bounded by low lying reedy vegetation common to the tidally dominated areas (Figure 16). The water appeared to be approximately 6 ft deep, with no flow velocity noted. The bed sample indicated primarily sand and fine gravel.

The field observations indicate a distinct break in bed slope at the Montague Expressway Bridge. Bed sediments change from coarse gravel just upstream of the bridge to a sand

and fine gravel mix just below the bridge. The channel bank and toe areas upstream and downstream of the bridge are armored for protection. The flow velocity was observed to drop from approximately 2.0 ft/s to 0.5 ft /s over a relatively short distance. Channel depth and width also increased just downstream of the bridge.

The Coyote Creek channel gradually widens as it approaches the bay. Observations indicate tidal influence occurs approximately 0.5 miles below the Highway 237 Bridge. There were no signs of significant channel instability (excessive erosion or deposition) in the main channel or channel corridor. However, some localized erosion or bank sloughing was observed (Figure 17). Bed sediments remained somewhat consistent (sand and fine gravel) over the length of the channel. The channel over banks adjacent to the main channel were heavily vegetated with low lying shrubs and grasses, as well as trees for most of the channel between Montague Bridge and the final location upstream of Dixon Landing. At the lowermost location only low lying reeds were evident, indicating dominant tidal conditions (low flow and higher salinity).

Guadalupe River

The selected reach of the Guadalupe River was bounded by the West Trimble Road Bridge and the Highway 237 Bridge (approximately 3.5 miles).

Trimble Bridge is located approximately 0.5 miles downstream of the Highway 101 Bridge. The channel at Trimble Bridge was relatively narrow and shallow (approximately 10 feet wide and 1 to 2 feet deep). The base flow velocity was approximately 2 – 2.5 ft /s (Figure 18). Thick vegetation lined the channel. No channel instability was noted. The channel characteristics along with the channel corridor were relatively constant for approximately 0.5 miles downstream. At this point the main channel appeared to transition to a depositional zone with narrow channels on each side (10 ft width, 3 – 4 ft depth). No flow was noted in the channels. The depositional zone between the channels appeared elevated and was highly vegetated (Figure 19). Bed samples indicate predominantly fine sediments and organic material mixed with sand and gravel in the side channels. The depositional zone between the channels was not sampled. This same general channel configuration extended down to the lowermost reach boundary (Highway 237, approximately 2.4 miles below Trimble Bridge). Water marks on vegetation indicate the tidal range extends to between Tasman Road and the Montague Expressway Bridge (Figure 20).

The Guadalupe River transitions from a relatively narrow fast flowing gravel bed stream to a branched low energy channel (depositional in nature) about halfway between Trimble Bridge and Montague Bridge (approximately 1.0 mile below Highway 101). Tidal influence occurs just upstream of the Montague Highway Bridge. The channel corridor from Montague Bridge to Highway 237 is characterized by narrow side channels (10 ft width) with thickly vegetated and elevated depositional areas between the channels. Bed sediments in these side channels contained more fine sediments as well as some vegetation.

Calabasas Creek

The reach of Calabasas Creek included in the channel assessment ranged from the Highway 101 Bridge to the Highway 237 Bridge. Just upstream of the 101 bridge, the creek is contained by a concrete channel. Large deposits of sand and gravel sediments along with thick vegetation were found just below the 101 bridge, with a narrow, shallow channel running along one side of the deposits (Figure 21). Historically, sediment is removed from this area. It was apparent that sediment removal operations had not been conducted in quite some time. The sediments consisted of widely graded sand and gravel (Figure 22). From Highway 101 to the Highway 237 Bridge, the channel was highly vegetated, with no coherent channel visible (Figure 23). At the 237 bridge, the channel was approximately 15 – 20 ft in width, with no flow. Vegetation consisted of low lying reeds characteristic of a tidally influenced channel (Figure 24).

The reach of Calabasas Creek from the Highway 101 Bridge to the Highway 237 Bridge is depositional, with recent sediment deposits found just below the 101 bridge and historical deposits with a thick cap of vegetation occurring between the bridges. The channel is tidally influenced up to a point just below the Highway 101 Bridge. Sediments located in the recent depositional zone below Highway 101 were primarily sand and gravel.

Stevens Creek

The Stevens Creek channel assessment ranged from just below the Highway 101 Bridge to Crittenden Lane (approximately 1.1 miles). Above Highway 101, Stephens Creek is contained by a concrete channel (Figure 25). A drop structure is located just below the 101 bridge (0.3 miles below the 101 bridge). Associated with the drop structure are artificial features built into the channel (Figure 26). Approximately 200 feet below the structure, the channel is approximately 10 – 15 feet in width, with bed sediments consisting of widely-graded gravel, with a large gravel surface armored layer (Figure 27). The median sediment size for this area was estimated to be 30 mm (Figure 28). The flow velocity was approximately 2.0 ft/s.

Approximately 1000 ft below this area, two distinct channels form around a central vegetated ridge. These channels are approximately 10 ft wide (Figure 29). The bed sediments consist of gravel and sand, with a maximum gravel size of about 15 – 25 mm. At this location, water marks indicate the uppermost tidal boundary. Vegetation growing on top of the middle ridge consists of low lying shrubs and grasses as well as mature trees, indicating older sediment deposits (Figure 30). The side channels cross over and merge downstream (Figure 31). Further downstream, the channel plan form remains somewhat the same, with the bed sediments consisting of a higher percentage of sand and low flow velocities. At the lowermost location (Crittenden bridge), the channel is tidally dominated with bed sediments consisting of fine sand, silts and clays, and organic debris (Figure 32).

A concrete lined channel contains Stevens Creek upstream of the Highway 101 Bridge. A grade control structure is located just below the intersection of the concrete and natural channel, indicating that channel instability (channel incision) was addressed at some point in the past. The channel between the Highway 101 Bridge and the grade control structure consisted of steep, highly vegetated banks.

The channel rapidly transitions from a transport reach to a depositional reach just downstream of the structure. From this point until the Highway 237 Bridge, the plan form consists of two separate side channels bounding a high vegetated ridge of historical deposits. The side channels may or may not be man-made. Below the Highway 237 Bridge, the channel is tidally dominated, containing fine sediments and low-lying vegetation common to the tidal areas.

Permanente Creek

The channel assessment reach for Permanente Creek ranged from the Highway 101 Bridge to a public park just upstream from the Bay (approximately 1.0 mile). Just above the Highway 101 Bridge Permanente Creek is confined to a concrete channel (Figure 33). Approximately 200 feet downstream of the 101 bridge, the concrete channel transitions into the natural alluvial channel (Figure 34). From this point to the Charleston Road Bridge (approximately 1200 feet), the channel is approximately 20 feet wide, 1 – 2 feet deep, with very little vegetation. The toe of the channel bank was undercut, along with evidence of channel meandering (Figure 35). The bed sediments are widely graded consisting of silt deposits along with sand and fine gravel. Bank instability was evidence by an undercut tree that was leaning over the channel (Figure 36).

From Charleston Road downstream to the Amphitheater Parkway, the channel was approximately 3 feet in width, with a highly vegetated channel corridor (Figure 37). The creek corridor is narrow for this reach (50 ft), bounded by steep levees. Some bank sloughing was noted where the creek cut into the levee base (Figure 38). No other channel instability was noted in this reach.

The channel reach from the Amphitheater Parkway to the public park / golf course (approximately 3000 ft) was tidally dominated, with a larger stream corridor (Figure 39). Bed sediments collected at the golf course bridge indicated the presence of fine sediments (silts and clays) with a high organic content. Vegetation was low-lying and common to the tidally dominated areas (Figure 40).

5 Bed Sediment Particle Size Analysis Results

Summary data plots for each stream are presented in Figures 41 – 45. The plots present indicators of the coarse, median, and fine sediment fractions in the sample (D_{90}, D_{50}, and D_{10} size classes) Bed sediment data were provided by the Santa Clara Water District for the upstream reaches of Coyote Creek, Guadalupe River, and Calabasas Creek. These samples were representative of a gravel bed, and had very similar size distributions. As expected, the stream bed sediments became less coarse in the vicinity of the head-of-tide

(Figure 1). The transition of the median bed sediment class from gravel to sand was in the vicinity of the Highway 101 bridge for all of the streams except Coyote Creek. The median sediment composition in the lower channels adjacent to San Francisco Bay was representative of very fine to fine sand.

6 Summary

As expected, the lower stream reaches of Guadalupe, Stevens, and Calabasas Creeks were depositional in nature, primarily due to a decrease in bed slope and energy gradient as the streams approach the bay. Significant depositional areas were found in the Guadalupe River (approximately 0.5 miles below the Highway 101 Bridge), Calabasas Creek (just below the Highway 101 Bridge), and Stevens Creek (approximately 0.5 miles below the Highway 101 Bridge). These depositional areas were characterized by branched channels with low flow velocities and elevated and highly vegetated depositional areas between the channels. Generally, a narrow gravel bed channel (6 – 10 feet) was found upstream of the depositional areas exhibiting relatively high flow velocities (approximately 2.0 ft/s). The branched channels contained sand and fine gravel with some fine sediment.

The Coyote Creek plan form was consistent throughout the reach in question. The upper reach adjacent to the Montague Expressway Bridge consisted of a narrow, fast flowing gravel bed stream with a highly vegetated corridor. The downstream reaches were characterized by a gradual widening of the creek (approximately 10 – 30 ft) with a sand or sand and gravel mix bed. The stream corridor was highly vegetated throughout the 4.1 mile reach, with no evidence of stream instability. No significant depositional areas were found along the length of the reach.

Of the five streams, only Permanente Creek exhibited any significant bed and bank degradation. The channel reach between the Highway 101 Bridge and the Charleston Road Bridge showed evidence of channel instability including widening of the channel, undercut banks, and bank failures. This reach of the creek is directly below a concrete lined section of the channel. A similar situation exists in Stevens Creek for which a grade control structure was constructed to mitigate stream degradation.

Flood flows in the upper Permanente Creek watershed are diverted to Stevens Creek. The diversion is designed to divert all flood flows over 1500 cfs. The additional flow added to Stevens creek during flood events is potentially responsible for the channel degradation and subsequent addition of grade control structures in Stevens Creek below Highway 101. The diversion of sediment laden flows from Permanente may also have detrimental impacts to the lower Permanente channel. If significant amounts of sediment are diverted from the upstream reach of the channel, the sediment depleted flow has the potential to initiate bed and bank erosion downstream.

LIST OF FIGURES

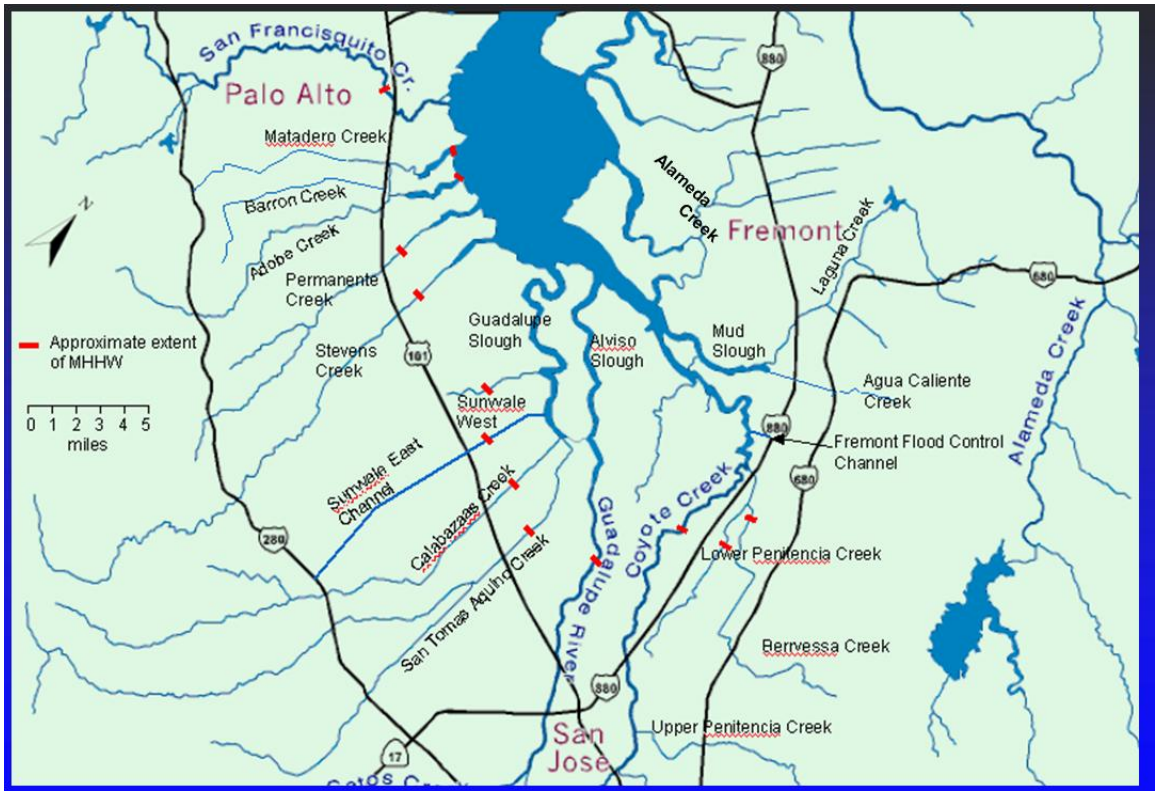

Figure 1. Approximate location of the head-of-tide for South Bay streams

Figure 2. Coyote Creek at the Montague Expressway Bridge

Figure 3. Vegetation along Coyote Creek at the Montague Expressway Bridge

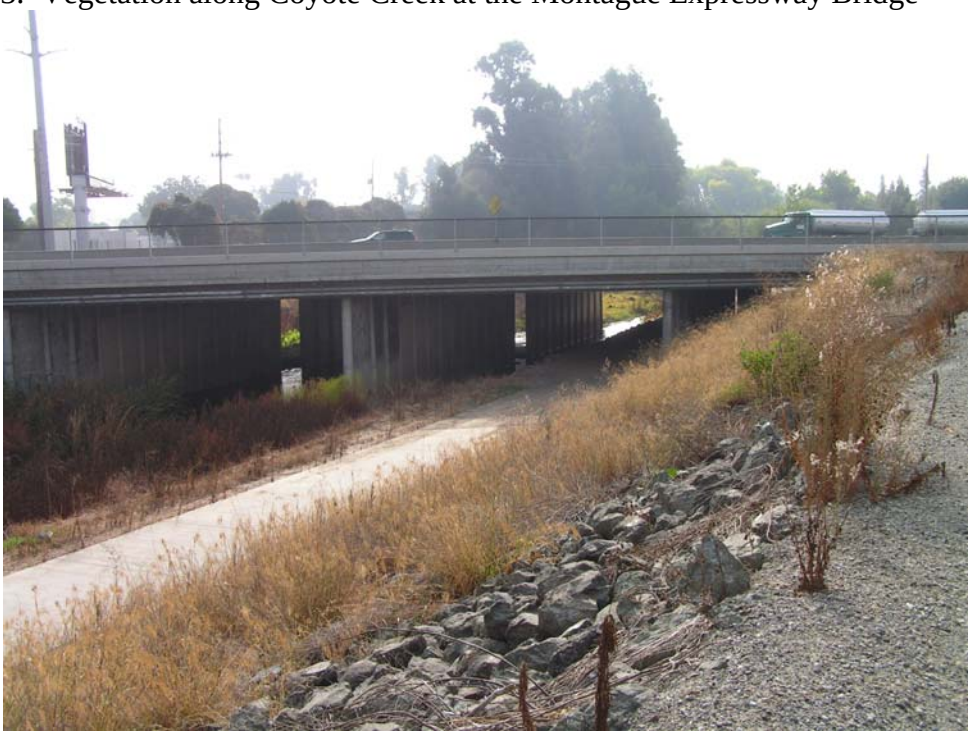

Figure 4. Levee bank protection along Coyote Creek at the Montague Expressway Bridge

Figure 5. Vegetated floodway channel below Montague Expressway Bridge

Figure 6. Coyote Creek channel under the Tasman Road Bridge

Figure 7. Bank soils along Coyote Creek in the vicinity of the Tasman Road bridge

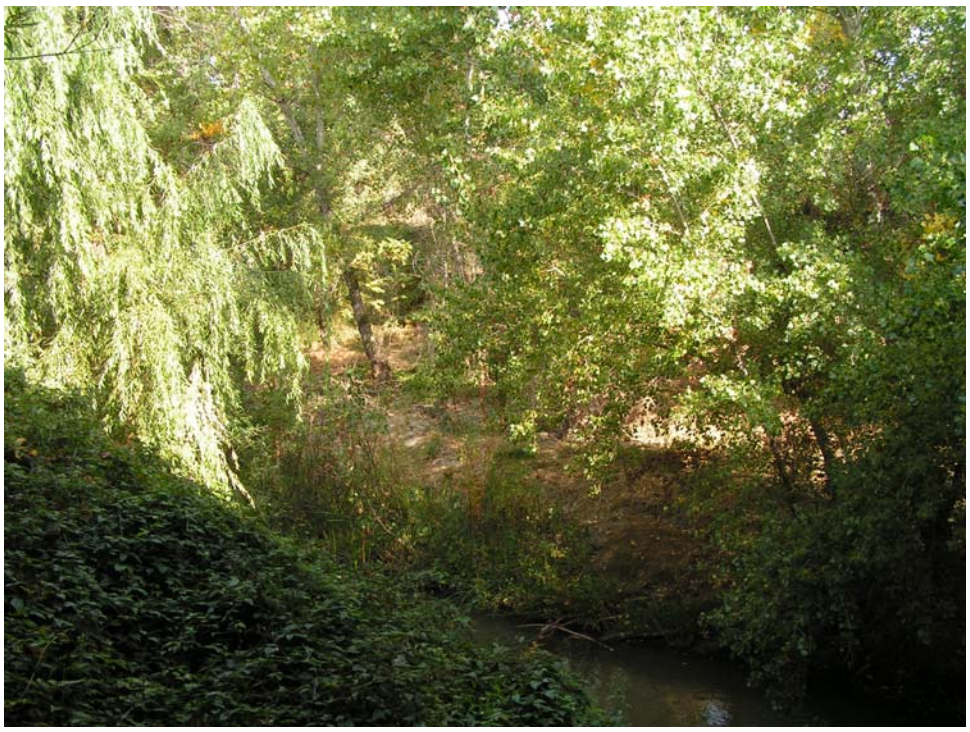

Figure 8. Over bank vegetation along Coyote Creek

Figure 9. Coyote Creek just above the Highway 237 bridge

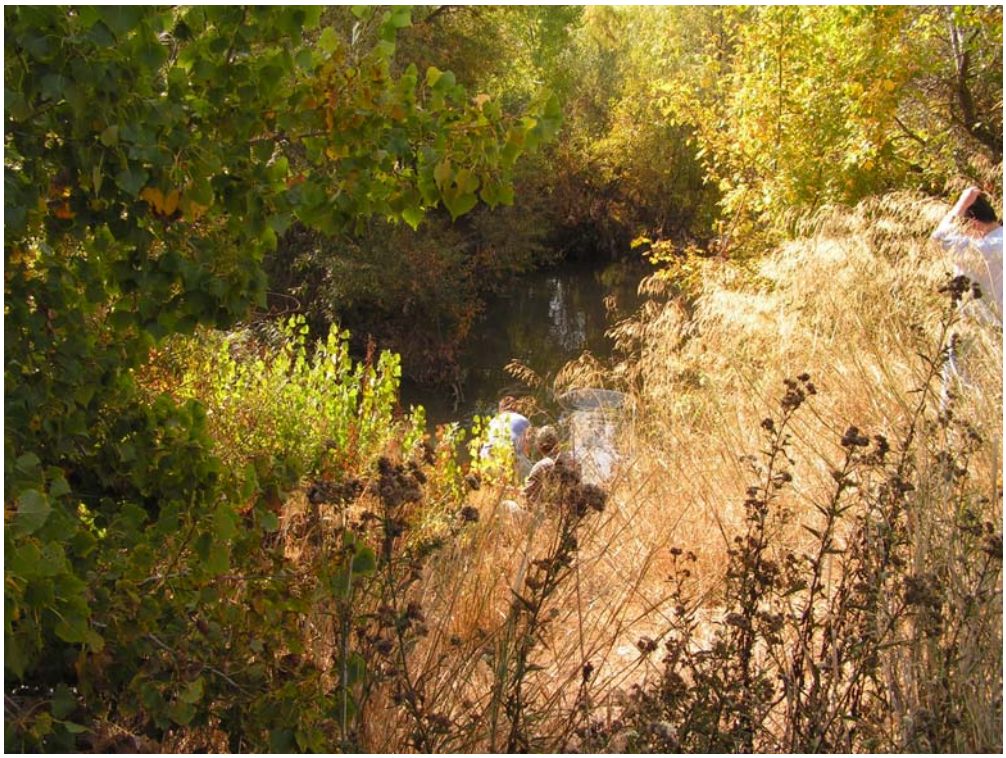

Figure 10. Vegetation along Coyote Creek just above the Highway 237 bridge

Figure 11. Coyote Creek approaching the Highway 237 bridge

Figure 12. Coyote Creek approximately 1.0 mile below the Highway 237 bridge

Figure 13. Bank vegetation along lower Coyote Creek

Figure 14. Bank vegetation along lower Coyote Creek

Figure 15. Water mark on vegetation indicating tidal effects

Figure 16. Coyote Creek channel just above Dixon Landing road

Figure 17. Bank sloughing around a drainage pipe

Figure 18. Guadalupe River just above the Trimble Road bridge

Figure 19. Guadalupe River between Trimble Road and the Highway 237 bridge

Figure 20. Water marks on vegetation indicating tidal effects between Tasman Road and Montague Expressway

Figure 21. Large area of deposition in Calabasas Creek at the Highway 101 bridge

Figure 22. Sediment gradation on the Calabasas Creek bar at the Highway 101 bridge

Figure 23. Calabasas Creek between Highway 101 and 237

Figure 24. Calabasas Creek at the Highway 237 bridge

Figure 25. Concrete lined channel in Stevens Creek just below Highway 101

Figure 26. Grade control structure below concrete lined channel in Stevens Creek

Figure 27. Stephens Creek channel 200 feet below the grade control structure

Figure 28. Bed sediment composition 200 feet below the grade control structure

Figure 29. One side of branched channel with central vegetated bar in Stevens Creek

Figure 30. Vegetated central ridge between Stevens Creek side channels

Figure 31. Stevens Creek channel crossing over to other side of central bar

Figure 32. Stevens Creek channel at Crittenden Lane with water marks on vegetation

Figure 33. Concrete lined channel in Permanente Creek above Highway 101

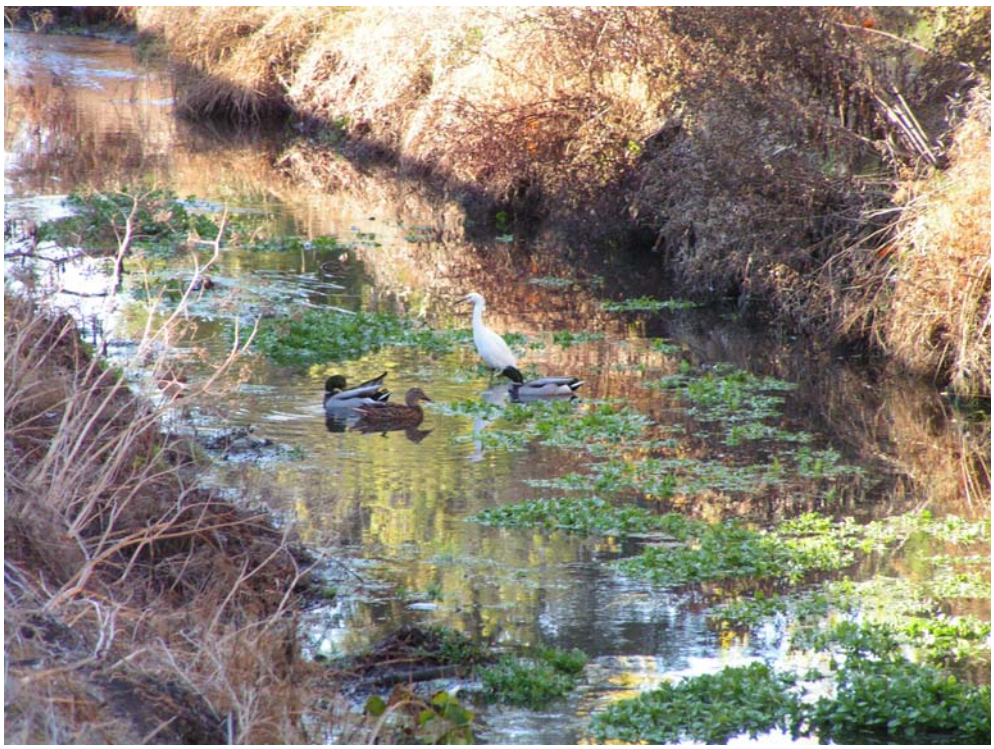

Figure 34. Permanente Creek channel Just below Highway 101

Figure 35. Permanente Creek channel between Highway 101 and Charleston Road

Figure 36. Undercut bank and tree sloughing in Permanente Creek between Highway 101 and Charleston Road

Figure 37. Permanente Creek below Charleston Road

Figure 38. Bank sloughing below Charleston Road

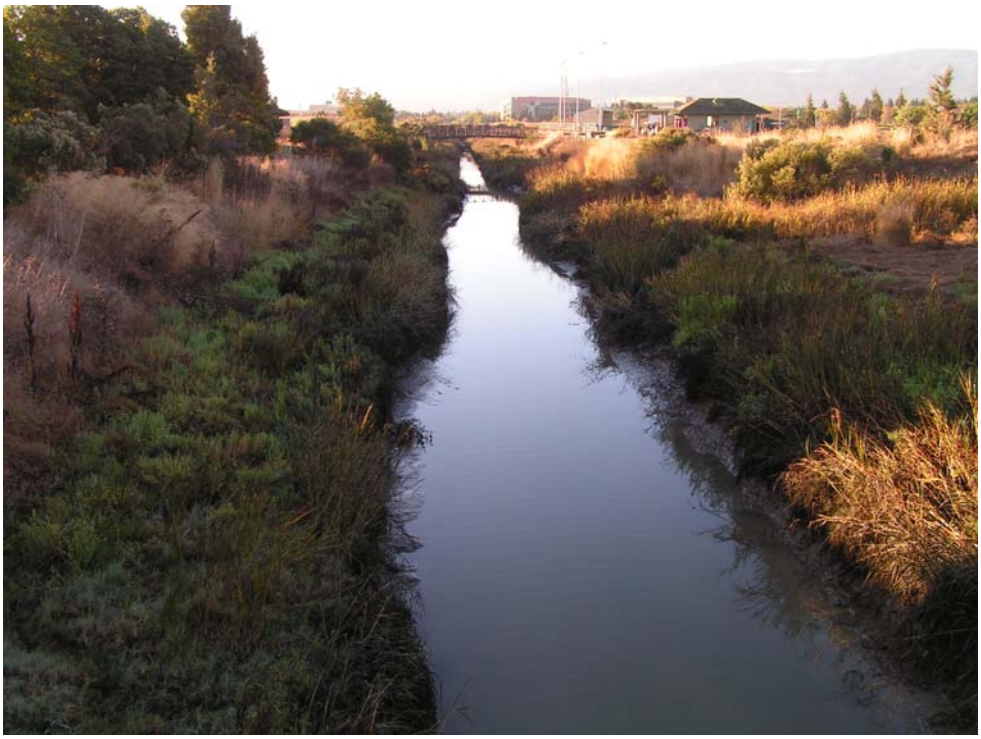

Figure 39. Permanente Creek between Charleston Road and the golf course

Figure 40. Permanente Creek at the golf course bridge

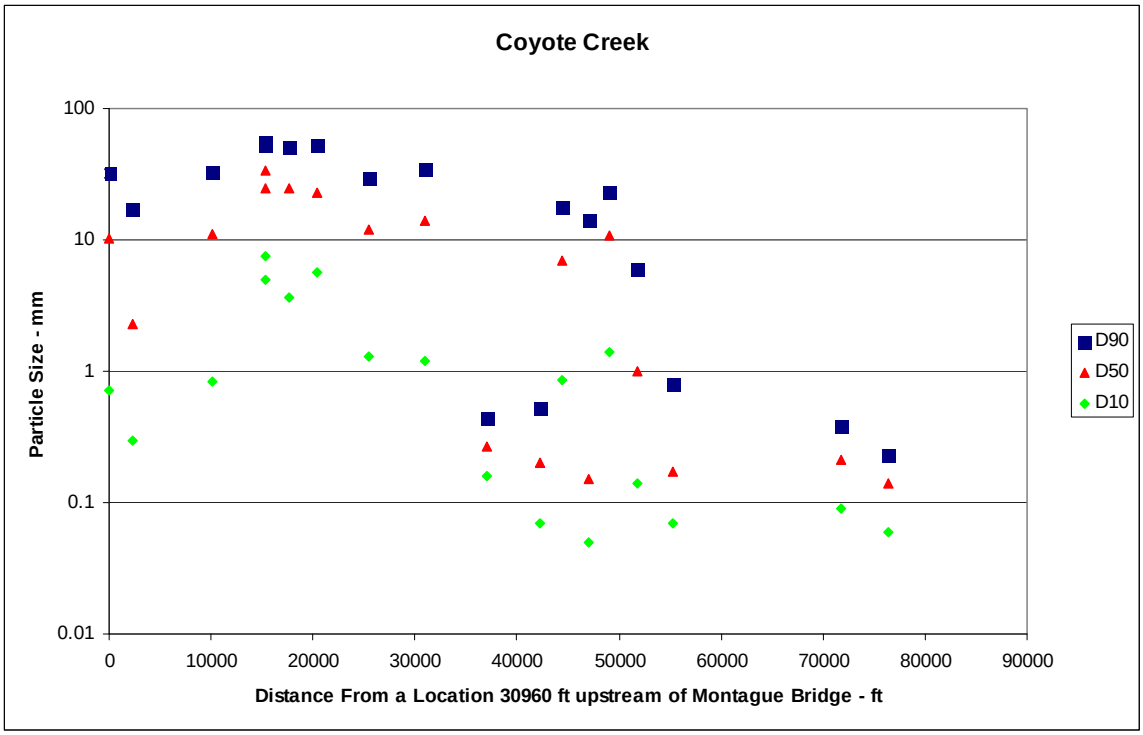

Figure 41. Bed sediment size distribution for Coyote Creek

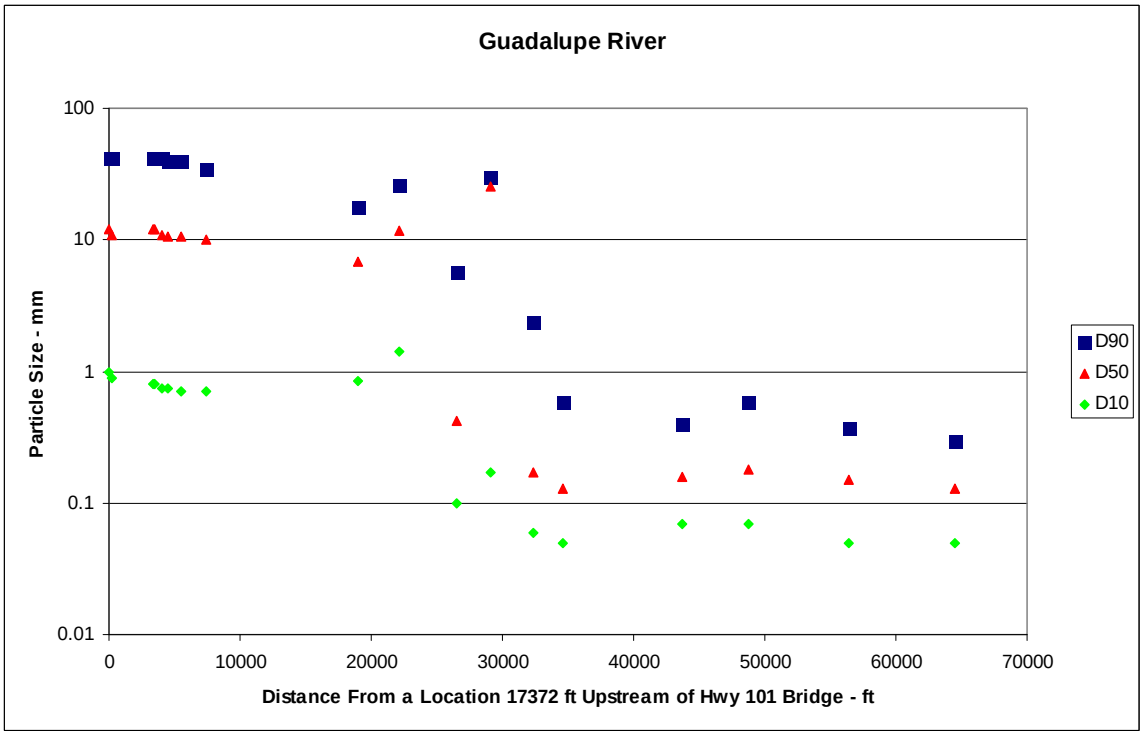

Figure 42. Bed sediment size distribution for Guadalupe River

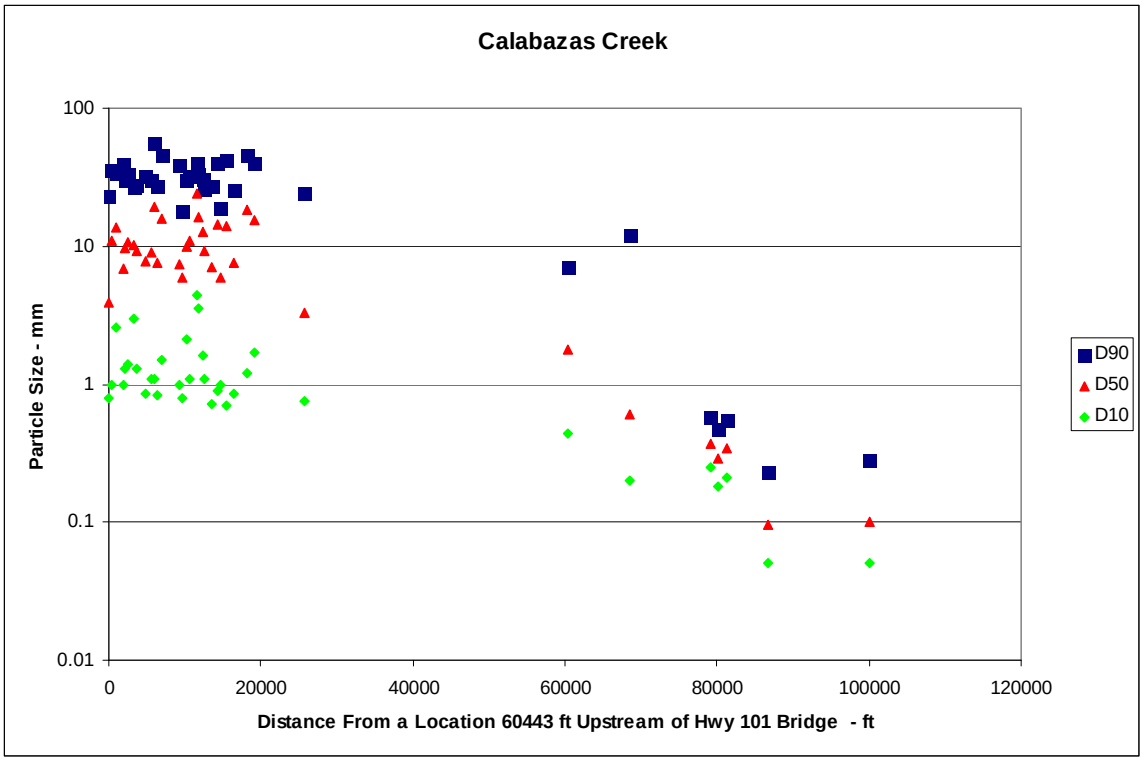

Figure 43. Bed sediment size distribution for Calabasas Creek

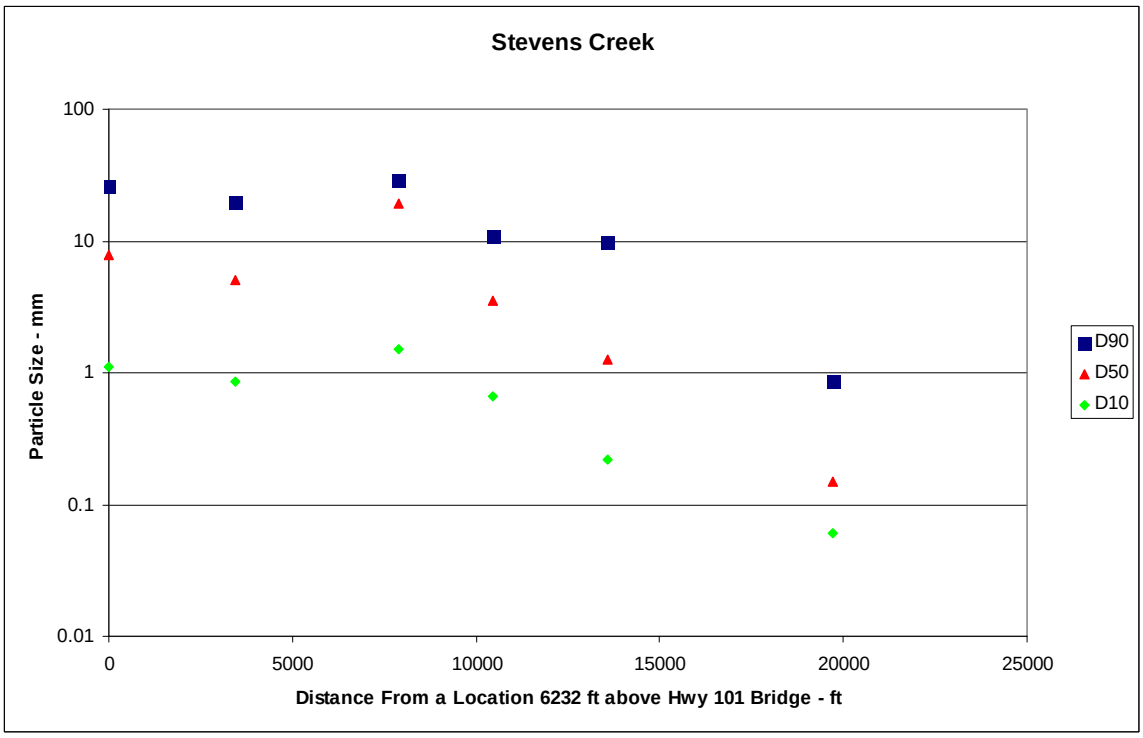

Figure 44. Bed sediment size distribution for Stevens Creek

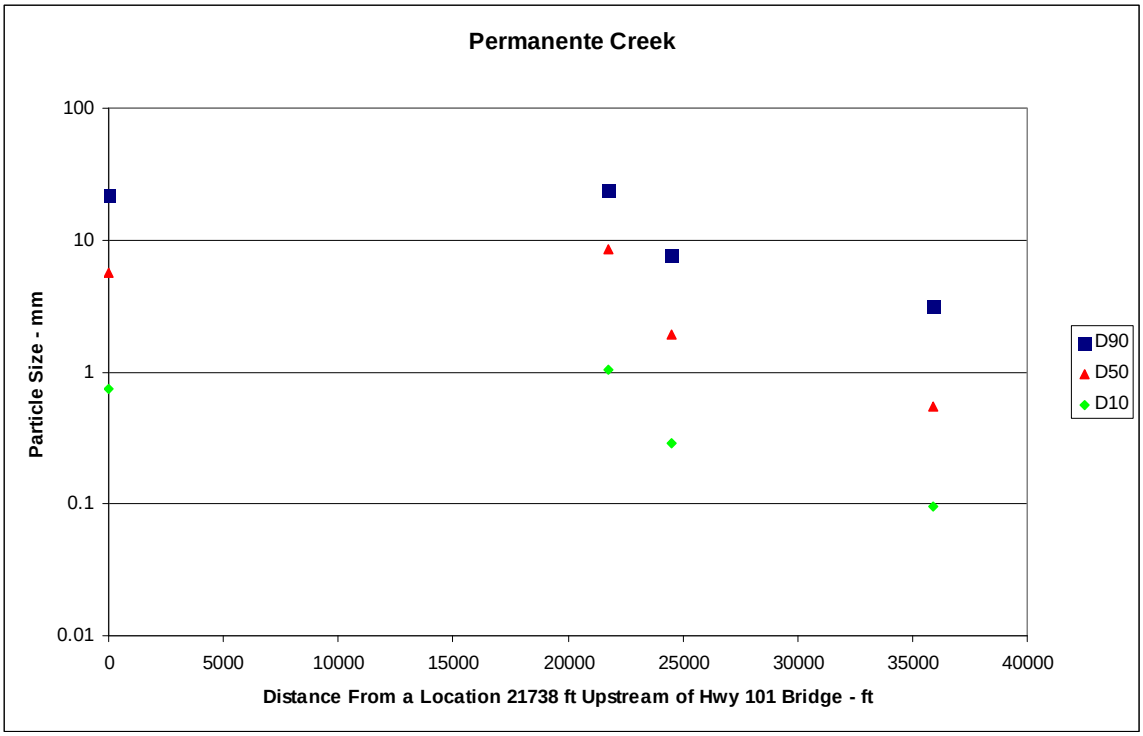

Figure 45. Bed sediment size distribution for Permanente Creek