# Arana Gulch Watershed Enhancement Plan Phase 1: Steelhead and Sediment Assessments, Santa Cruz County, California

Prepared for:

Arana Gulch Watershed Alliance

Funded by:

The Coastal Conservancy

California Department of Fish and Game

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*in association with*

D.W. Alley and Associates, Coastal Watershed Council and Toni Danzig

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A report prepared for:

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Balance Project Assignment 99005.08

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# ACKNOWLEDGMENTS

This watershed assessment and enhancement plan has been prepared for the Arana Gulch Watershed Alliance. The Coastal Conservancy and the California Department of Fish and Game funded the project and the watershed coordinator position. The technical and planning aspects of the project were conducted with oversight from a Technical Advisory Committee (TAC). TAC members include representatives from the City and County of Santa Cruz, Santa Cruz Port District, Santa Cruz City Public Schools, Santa Cruz County Resource Conservation District, Coastal Conservancy and environmental consultants.

The assessment and enhancement plan was written by Shawn Chartrand, Barry Hecht, Don Alley, with Tamara Clinard and support from Toni Danzig. Data utilized in this report was collected by Shawn Chartrand, Barry Hecht, Don Alley, Jason Parke, Roberta Haver, Toni Danzig and Darcy Wells. Shawn Chartrand and Barry Hecht conducted the sediment assessment, prepared the conceptual enhancement projects and the implementation plan and compiled this report. Don Alley conducted the steelhead assessment. Donna Meyers and Jason Parke, both formerly with the Coastal Watershed Council, conducted the water quality investigation. Jason Parke and Roberta Haver conducted the baseflow investigation. Toni Danzig provided field and technical drawing support for our point source repair recommendations. Brian Foss and Ron Duncan from the Santa Cruz Port District compiled the dredging records for the north harbor. Jim Keller and Jim Wherle from the Santa Cruz County Geographic Information Systems Division assisted us by providing key layers from the County's GIS database (EMIS). Finally, Roberta Haver, AGWA Coordinator, has invested countless hours, ideas and a penetrating optimism that has kept this project on tract and alive.

# 1. EXECUTIVE SUMMARY

## 1.1 Project Overview and Major Findings

Hidden away in valleys beneath the benchlands of eastern Santa Cruz, and extending two miles into the first range of hills, Arana Gulch flows to Monterey Bay. Its residents and the broader community of central Santa Cruz County have the opportunity to restore and enhance this waterway and its watershed:

- To restore the run of steelhead, allowing it to stabilize and grow
- To protect homes, parks, businesses, schools, a harbor and public works along the stream
- To sustain and expand the nearly-continuous streamside woodland valued by wildlife and residents alike
- To slow filling of Santa Cruz's vital small-craft harbor
- To allow flooding, debris flows, and logjams to form along the stream and to serve their natural functions without unduly endangering residents, roads, or other facilities, and
- To help naturally renovate and clean flows from Arana Gulch into Monterey Bay, and the marine habitat it supports

This project is an initial assessment of current stream and habitat conditions in the Arana Gulch watershed, and our recommendations for restoring it (**Figure ES-1**). The plan provides a basis for suggesting projects at specific problem sites (**Figure ES-3**), and identifies what each might achieve. Balance Hydrologics, Inc. (Balance), D.W. ALLEY &

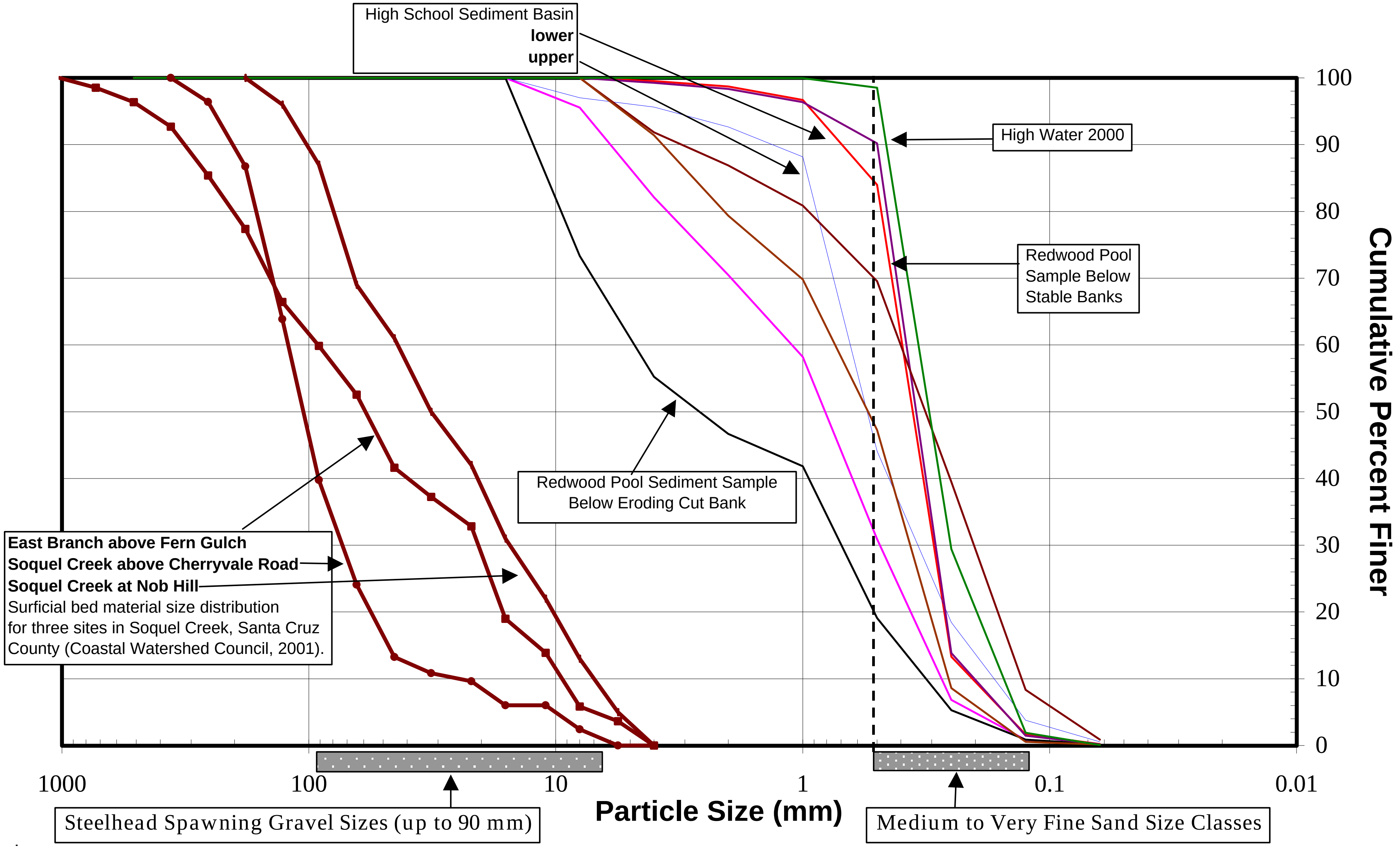

**Figure ES-2**: **Particle-size distribution of sediment samples from the channel and high water marks of Arana Gulch**. Note that the 50 percentile for 6 our of 8 samples falls within or near the medium to fine sand class sizes and that sizes needed for steelhead spawning were found in only three samples, one being situated below an eroding road bank. Three samples collected from nearby Soquel Creek are shown for comparison. The size distribution curves . illustrate that the coarsest material found in Arana corresponds to the finest size fractions sampled in Soquel Creek

Balance Hydrologics, Inc.

99005 Sediment Samples Plot.xls, Figure ES-2

Associates (Alley), the Coastal Watershed Council (CWC) and Toni Danzig worked together to prepare the phase 1 assessment and enhancement plan for the Arana Gulch Watershed Alliance (AGWA). Field work for this plan was conducted from late 1998 through mid-2001. Balance carried out the sediment source analysis, synthesis and preparation of this document. Alley completed the steelhead assessment. CWC completed the baseline water quality and low-flow program, and Toni Danzig assisted with the development of point source repair concepts and illustrations.[1] The California Coastal Conservancy (CC) and the California Department of Fish and Game (DFG) funded this project.

Sand-sized sediment fills almost all pools, holes, and other resting places in Arana Gulch from the headwaters to the mouth at the Santa Cruz Small Craft Harbor (**Figure ES-2**). Further, riffles throughout the creek are mantled with sand. In part, the sand is intrinsic to the stream, since Arana Gulch has evolved in a sandy geologic environment; however, the extent to which sand overwhelms pools and riffles in this stream system is probably much greater than usually prevailed under natural conditions. The underlying sandstones and siltstones (Purisima Formation), as well as unconsolidated terrace deposits tend to weather to sand and silt, with very little gravel- or cobble-sized debris. Silts and clays tend to wash rapidly through this relatively short, steep watershed, leaving significant volumes of sand for the stream either to (a) transport to Monterey Bay or (b) store in its channel or floodplain.[2] Channel reaches situated below logjams and culverts on the eastern, central and western branches of Arana Gulch do contain gravel and cobbles, often buried beneath a foot or more of sandy sediments. For these coarser materials to provide spawning or rearing habitat, the volume of sand in the stream will need to be curtailed. The volumes of sand in the channel have been growing since the watershed has been settled, grazed, farmed, and cleared, and as the networks of roads, paths, and gullies expand. As long as the sandstone canyons are occupied, well-planned stewardship of the streams can help offset the effects of these uses.

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[1] This plan is perhaps more action-oriented than many first-generation watershed assessments in the region, as much of the original environmental analysis had been compiled in an earlier assessment of sedimentation in the watershed (Hecht and others, 1982), which is included as Appendix C to this report.

[2] Most of the samples we collected of the banks of the stream, high-water marks left by recent storms, or the material filling pools and glides throughout the watershed were primarily medium or fine sand (0.125 to 0.5 millimeters) (c.f., **Figure ES-2** ). Very small proportions of gravel or pebbles, and no cobble-sized sediment, were observed in any of these samples.

Most of the projects proposed in this report are intended to reduce delivery of sand and other sediments to Arana Gulch, its tributaries, and to the harbor (**Figure ES-3**). The majority of the remaining projects are directed at providing passage for upmigrating adult steelhead to the eastern and central branches, where low flows in late summer are greatest, and where the best steelhead habitat was identified. Even the best habitat in Arana Gulch, at least at present, is rated as substandard relative to other streams in Santa Cruz County canvassed by fisheries biologist Don Alley. With less sand in the channel, the number of young fish rearing in Arana Gulch – the basis of Alley's rating – is expected to increase, but is likely to remain small relative to other streams in the Santa Cruz Mountains. Nonetheless, the relatively large number of yearling fish he observed in the east and central branches suggest that Arana Gulch can sustain a run worth enhancing.

In earlier drafts of this plan, small-scale sedimentation basins were proposed for Arana Gulch at four to five locations, when and where willing owners are prepared to incorporate them in future plans. One such basin, originally constructed in the 1970s, has been put back into operation through a cooperative effort of AGWA, the School District, Department of Fish and Game, and the Public Works Departments of both the County and City of Santa Cruz. The basin has already been cleaned out once of its capacity of about 400 cubic yards of material that has been recycled to projects of these two agencies where sand fill is needed. Up to three or four basins of approximately the same size are recommended on the west branch, the Chaminade tributary, and the main stem. Modification of an existing borrow pit to create an off-line basin just south of Highway 1 is also under consideration. Use of sedimentation basins is both suitable and necessary in Arana Gulch because of (a) the excessive volumes of sand presently in the channel and which are beyond the capability of upslope measures to control with the restoration efforts planned for the next 10 years, (b) the virtual absence of gravels in the materials trapped in the existing basin, such that spawning-size material is not selectively removed, and (c) steelhead do not appear to use most of these reaches for spawning. The basins illustrate twin concepts which underlie much of this plan – use of innovative measures appropriate to a wholly sand-bed channel and of working with willing owners and cooperating agencies.

Late summer baseflows in 1999 were quite low, sometimes as low as 5 gallons per minute (0.01 cfs), approximately the flow of one garden hose. The lowest flows were observed in the main stem from the mouth of the west branch to the Brookwood Drive crossing (**Figure ES-1**). All surface flow from the upper watershed originated in the eastern and central branches, with the eastern branch accounting for 89% of the total flow. Flow was slightly higher at the high school fish ladder with measurements slightly exceeding those for total flow originating in the upper watershed. At the mid-greenbelt flow was observed to be less than that which was measured at the fish ladders. However, these were visually estimates of flow and it is unclear if flow was actually lost between the fish ladders and the mid-greenbelt. Given the possibility that flow may become discontinuous or subsurface in the main stem from the western branch to Highway 1, efforts to restore this are important, with particular attention warranted to diminishing the volume of sand on the bed (now sufficient to allow all flow to go subsurface in some years) and shading this reach to mitigate elevated temperatures during extremely dry conditions.

Results for water quality measurements made in Arana Gulch from 1997 to 1999 indicate that, for the constituents test, the water quality meets standards for domestic consumption and fell within acceptable ranges for salmonid survival (**Appendix D**). Water quality parameters measured include water temperature, dissolved oxygen, pH, specific conductance and turbidity. It is important to note, however, that the potential for excessive summer water temperatures does exist in Arana Gulch due to (a) the very low baseflows that were measured and (b) the potential for the riparian corridor to be compromised in this urban corridor within multiple jurisdictions.

Working meetings between the project consultants and the Arana Gulch Technical Advisory Committee has resulted in a list of 21 major sediment sources and steelhead migrational barriers currently located in the Arana Gulch watershed (**Table ES-1**). Mapped sources of sediment in the watershed range in total volumes lost from 8 to 9000 cubic yards (**Table ES-2**) and steelhead migrational barriers were found on the main stem, the central branch and the eastern branch. Conceptual repair plans and priority ranking of these 21 sites has been developed by the project consultants and the TAC

## Table ES-1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **East Branch Arana Gulch** | | | | | | |
| 1 | **Right Bank below the Blue Trail Dam** | Would avoid an extremely large volume of sediment in the event of dam failure | Right bank below the Blue Trail Dam is experiencing accelerated erosion and could compromise dam structure | Treated sandbag spillway to protect further bank erosion and dam failure | $10,000-$20,000 | Chaminade, Fines Funds (county and State), Community groups | NMFS, CDFG, County of Santa Cruz, RWCQB |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Repairs must be done without vehicular access, large volunteer crew will be needed, wheelbarrels etc. | | | | | |
| 2 | **Right Bank Meanders below Blue Trail Dam** | Would avoid direct addition of moderate volumes of sand to the channel and protect the existing Blue Trail | Numerous right bank failures in conjunction with meander bends: downstream of the Blue Trail Dam and upstream of the Blue Trail foot bridge | Protect eroding face with log cribbing , suitably keyed into the banks, plant alders or other vegetation behind cribbing | $5,000-$10,000 | **Small grant**: CAB / NREP, CCC's (labor force) | NMFS, CDFG, County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Repairs must be done without vehicular access, large volunteer crew will be needed, wheelbarrels etc. | | | | | |
| 3 | **Blue Trail Gullies** | Would restabilize the hillslope, part of the Blue Trail, the Citiy's water line and dramatically reduce sediment input through the reach | Several very large gullies are contributing large amounts of sediment to the channel and have compromised a City water line | Drain the bottom of the gullies with perforated piping, add structured support, backfill the gullies with appropriate material and plant | $50,000 + | **Large Grant:** City and Chaminade supervision, RCD / NRCS tech assist, Done by contractor | County of Santa Cruz Grading Permit |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | We should seek Jen Hyman's involvement; could run a shoot down the trail to transport soil for filling | | | | | |
| 4 | **Steelhead Migrational Barrier (B5) roughly 40 feet upstream of site 5** | Allow for fish passage to the upstream reaches on the eastern branch and stabilize downstream banks | Two four-foot diamter culverts placed in the middle of the channel are jammed with LWD at the upstream end. Barrier is impassable. | A) Manual clearing of debris and culverts from stream recommended. Use of large volunteer team suitable (5-6 people) | 500 + permit fees | County of Santa Cruz Fish and Game Commission, California Youth Authority Crews | CDFG, County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Manual removal of jam could be conducted with a chain saw and supervision by a Fisheries Biologist | | | | | |

## Table ES-1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **East Branch Arana Gulch** | | | | | | |
| 5 | **Steelhead Migrational Barrier (B4) roughly 90 feet upstream of site 6** | Allow for fish passage to the upstream reaches on the eastern branch and stabilize downstream banks | Redwood log jam roughly seven feet in height at time of stream survey. Barrier is probably impassable. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Manual removal of jam could be conducted with a chain saw and supervision by a Fisheries Biologist | | | | | |
| 6 | **Steelhead Migrational Barrier (B3) roughly 0.37 miles upstream of Paul Sweet Road** | Allow for fish passage to the upstream reaches on the eastern branch and stabilize downstream banks | Log jam anchored by large redwood rootwad and concrete structure in left bank. Barrier might be passable at 20-30 cfs. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Manual removal of jam and culverts is recommended with the help from a volunteer team of 5-6 people. Fisheries Biologist should be present | | | | | |
| 7 | **Culvert Beneath Paul Sweet Road** | Allow for fish passage to the upstream reaches on the eastern branch, reduce local flooding potential and stabilize downstream banks | Culvert has downcut roughly 6 feet. Downcutting has accelerated erosion of banks downstream of culvert and impedes fish passage at all flows | A) build channel elevation up to the current culvert mouth elevation using step-pools<br>B) (optional) construct settling pond and trash rack roughly 50-yards upstream of redwood cathedrals | $100000 + | Prop 13, County Public Works, DFG (partial), Road Association supervision, Done by contractor | NMFS,<br>CDFG,<br>County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Local observers report repeated blockages of culvert by woody debris; Don Alley suggest new bridge; need some mechanism to slow water upstream of culvert | | | | | |

## Table ES-1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County (continued)

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **Central Branch Arana Gulch** | | | | | | |
| **8** | **Steelhead Migrational Barrier (B9) roughly 0.39 miles upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | A current series of 3 woody debris jams that is likely impassable. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | | | | | | |
| **9** | **Steelhead Migrational Barrier (B8) roughly 0.37 miles upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | A six-foot high log jam that is likely impassable. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | | | | | | |
| **10** | **Steelhead Migrational Barrier (B7) roughly 0.27 miles upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | Rip-rap piled instream has created a partial dam and destabilized banks by forcing flow around the rip-rap into the banks. | A) Remove rip-rap manually with supervision by a Fisheries Biologist | $500-$1,000 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG, County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | | | | | | |
| **11** | **Rebedding of Maybee Lane from roughly 0.05 miles upstream of the confluence with the eastern branch to mile 0.5** | Would avoid massive bank destabilization and increased localized flooding potential along the central branch of Arana Gulch. | Stretch of old road roughly one-quarter mile long is showing signs of gullying and concentrating runoff from the drainages above. Concentrated runoff is leading to bank destabilization along the central branch upstream of the Bone property. | Restore original cross slope along road, repair gullies and restore vegetation where needed with appropriate material | $20,000-$50,000 | **Large grant (useful as a demonstration grant)** | NMFS, CDFG, County of Santa Cruz Grading Permit |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Will require cooperation and interest of owners; county riparian permitting could prove difficult | | | | | |
| **12** | **Steelhead Migrational Barrier (B6) roughly 112 feet upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | Perched driveway culvert which is likely impassable under most flow conditions and contributing to bank destabilization downstream. | Construct new crossing | $20,000-$50,000 | **Large grant** | NMFS, CDFG, County |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | At the time this report was prepared, it was understood that this project had been awarded funding and was slated to begin in the next year | | | | | |

## Table ES-1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County (continued)

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **West Branch Arana Gulch** | | | | | | |
| 13 | **Pilkington Road Drainage** | Reduce potential for massive landsliding on the eastern hillslope and direct input of large volumes of sediment to the system. Protect property owners near the site (equestrian center) and downstream. | Concentrated runoff from hillslope above Pilkington Road is causing increased gullying in slope adjacent to existing landslide at head of the west branch. Could cause extensive landsliding and massive input of sediment to the system. | Stabilize banks near culvert outlet, general drainage repairs above road | > $20,000 | Grant to Road Association and Community groups | Santa Cruz County Grading Permit |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Need access and participation from homeowners | | | | | |
| 14 | **Disc Golf Course** | Restore natural capacity of soils to absorb water thus reducing the volume of runoff during storm events. Restoration of grasses and 'top soil' on these holes will help reduce the rate of growth in the gully draining to the west branch. | Disc Golf Course holes 1-5, 25 and 27 have lost large amounts of soil1 and currently is by and large devoid of grasses. Increased runoff through the area has resulted in accelerated growth of the gully which follows holes 20 and 21 and drains to the west | Moderate re-grading, major re-soiling and planting of resilient golf course related turf | > $100,000 | City of Santa Cruz | Santa Cruz County Grading Permit |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Roughly 9 acres need 6 inches or more of soil for planting-to prevent further erosion and to slow bank erosion seen in the associated gully due to high runoff rates. 1: Steve Singer (June, 1999) has estimated that most areas near these holes have lost at | | | | | |
| 15 | **Large Gully below Disc Golf Course** | Reduce volume of sediment input to the west branch and protect the adjacent holes of the disc golf course. | This site is directly linked to site 8 above. Gully contributes large volumes of sediment to the west branch and is growing. | To be closely monitored and considered for active repair if re-establishment of golf course groundcover does not halt bank erosion seen in the gully | ? | City of Santa Cruz | |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Roughly 300 yards long, completely overgrown with poison oak | | | | | |
| 16 | **Tributary from West at Lower Service Road** | Reduce volume of sediment input to west branch, reduce flooding potential for residents of the former Paul Sweet House and protect service road. | Increased rate of tirbutary growth due to concentrated runoff. Tributary contributes moderate volumes of sediment to west branch. | Step-pool ladder similar to site 4 above | $5,000-$10,000 | City of Santa Cruz | |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Roughly 40 yards long, material used to build step-pools needs to considered | | | | | |

## Table ES-1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County (continued)

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **Main Stem Arana Ck.** | | | | | | |
| 17 | **Capitola Road Crossing** | - | Monitor site for future incision and bank instability downstream of the existing culvert. Site has the potential to become a fish passage barrier. | - | - | - | - |
| | **Property Ownership** | private property | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Monitoring should be taken very seriously. Upstream projects are limited in effectiveness if this project is not taken seriously | | | | | |
| 18 | **Greenbelt Gully** | Increase removal of sand and sediment from Tidal reach and Harbor | Accelerated erosion of hillslope below the corner of Agnes Street and Park Way South has resulted in a gully which directly delivers sediment to the Tidal reach. | Reconstruct stormwater outlet and consider new drainage plans. Backfill gully and plant. | $20,000-$50,000 | City of Santa Cruz, Port District and/or other AGWA participants | ???? |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Need access clearance from homeowners and cooperation from the City of Santa Cruz | | | | | |
| 19 | **Tidal Reach** | Stabilize Tidal reach, dramatically decrease sediment loading to the Harbor. Maintain current marsh habitat that is unlike any other in Santa Cruz County and perhaps the central coast of California. | Accelerated channel headcutting and channel bank failure through the tidal reach resulting in increased loading of sandy sediment to the harbor and the tidal reach | ??? | $100,000+ | City of Santa Cruz, Port District and/or other AGWA participants | NMFS, CDFG |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Could be a cooperative project between the Port District and the City of Santa Cruz. | | | | | |

## Table ES-2. Total Volume of Sediment Lost for Mapped Sediment Sources in Arana Gulch, September and October 2000

| Site | Site | Dimensions[1] | Volume | Volume |
|---|---|---|---|---|
| # | *name* | *(ft x ft x ft)* | *(cucic ft)* | *(cubic yard)* |
| | | | | |
| 1 | Blue Trail dam: right bank below dam | 20x40x12 | 9600 | 350 |
| 2 | Right Bank Meanders below blue trail dam | 49x18x8 | 7056 | 261 |
| 2 | Right Bank Meanders below blue trail dam | 35x15x6 | 2520 | 93 |
| 2 | Right Bank Meanders below blue trail dam | 25x6x5 | 750 | 28 |
| 3 | Blue Trail Gullies | 200x135x9 | 243,000 | 9000 |
| 13 | Pilkington Road drainage | 48x12x75 | 40300 | 1492 |
| 14 | Disc Golf Course (see Singer 1999) | ~ 1 acre | - | ~ 1700 to 3300 |
| 15 | Large Gully beneath Disc Golf Course | 8x6x1000 | 48000 | 1778 |
| 16 | Tributary from west at lower service road | 11x11x75 | 9000 | 333 |

*Notes:*

1. Source dimensions, except for site 14, were measured by Balance Hydrologics staff in the fall of 2000
2. Sites 18 and 19 were excluded from this table because source dimensions were not measured

# Table ES-3: Recommended Implementation of Repair Projects in the Arana Gulch Watershed

| Site # | Site-Specific Projects | Priority | Project Iniation Phase | Comments |
|---|---|---|---|---|
| | | | | |
| 1 | Blue Trail Dam: right-side of dam structure bank failure | High | Phase 1 | Repair here avoids massive pulse of sediment |
| 3 | Blue Trail Gullies | High | Phase 1 | |
| 4 | Fish Barrier #5 - 4' drop, in-channel culverts | High | Phase 1 | Eastern branch below the Blue Trail crossing |
| 5 | Fish Barrier #4 -7' drop, log jam | High | Phase 1 | Eastern branch below the Blue Trail crossing |
| 6 | Fish Barrier #3 -log jam, root wad | High | Phase 1 | Eastern branch below the Blue Trail crossing |
| 7 | Culvert Beneath Paul Sweet Rd, ID barrier #2 | High | Phase 1 | |
| 12 | Fish Barrier #6 - perched culvert | High | Phase 1 | Lance Bone's driveway crossing: project has been initiated |
| 14 | Disc Golf Course: west of parking area | High | Phase 1 | |
| - | Grade control at fish ladder | High | Phase 1 | Project is roughly 80% complete |
| | | | | |
| 2 | Right Bank Meanders below Blue Trail Dam | Medium | Phase 2 | |
| 13 | Pilkington Road Drainage | Medium | Phase 2 | Repair here avoids potential landsliding |
| 15 | Large Gully below Disc G.C. | Medium | Phase 2 | Try to stabilize gully profile with repair of site 8 |
| 16 | Trib. From West at Lower Service Rd. | Medium | Phase 2 | |
| 18 | Greenbelt Gully | Medium-High | Phase 2 | Gully delivers sediment directly to the greenbelt |
| - | 1-bank erosion sites at Harbor High | Low | Phase 2 | |
| | | | | |
| 8 | Fish Barrier #9 - 3 log jams in succession | Low | Phase 3 | Central branch above Lance Bone's property |
| 9 | Fish Barrier #8 - 3' drop log jam | Low | Phase 3 | Central branch above Lance Bone's property |
| 10 | Fish Barrier #7 - rip-rap dam | Low | Phase 3 | Central branch above Lance Bone's property |
| 11 | Rebedding of Maybee Lane | Low | Phase 4 | Central branch above Lance Bone's property |

*Notes:*

1. Site # refers to notation in Figure ES-3 as well as Table ES-1
2. Priority Categories: High, Medium and Low
3. Initiation Phases: Phase 1: 1-3 years, Phase 2: 3-5 years, Phase 3: 5+ years
4. Implementation order is based on consensus among AGWA TAC memebers
5. Site 17 (Capitola Road) is to be monitored for rate of incision and right bank stability downstream of existing culvert

with suggested implementation phases of 1 to 3 years, 3 to 5 years and 5 to 10 years (**Table ES-3**). Monitoring plans have also been suggested to observe the success and failure of implemented repairs and to aid further tracking of changes in the watershed.

## 1.2 Enhancement Planning: Suggested Conceptual Repairs, Monitoring Plan and Implementation Plan

Enhancement planning for Arana Gulch means, to a large extent, learning to live compatibly with sandy soils and a sandy watershed. By limiting the amount of sand entering the stream, many of the existing issues and constraints can be minimized. By diminishing erosion in the hillsides, the streambanks will become more stable, the pools deeper and the creek more diverse and productive. With less sand in the stream, the streamside ecosystem will have the essential basis for self-restoration and will benefit from enhancement efforts. In this respect, the Arana Gulch watershed serves as a bellwether, offering a useful test of potential long-term stream enhancement in small, sandy watersheds. As such, restoration efforts in Arana Gulch can also pioneer ways that will have importance far beyond the narrow confines of its watershed.

Attempts to decrease the delivery of sandy sediment to Arana Gulch from hillslopes and in-channel sources needs to be both comprehensive and visionary. We suggest repair and monitoring plans to comprehensively span the next 10 years. We also discuss some opportunities and challenges likely to arise during the next 10 to 50 years, including the expected episodic events (such as fires or blights) and issues or management steps which might constructively be pursued as opportunities arise during the next five decades.

The suggested repair and monitoring programs include:

- Site specific repair and stabilization of point and non-point sources of sediment,
- Removal of steelhead migrational barriers with coordinated efforts to leave important LWD in the channel,

- Re-vegetation plans for areas where riparian communities have been lost,

- Enhanced removal of sandy sediment from the sedimented channels through small-scale sediment basins and off-channel storage surfaces,

- Monitoring of identified areas prone to gullying, landscaping and other erosional problems, and

- Monitoring of summer baseflows and their water quality to establish a stronger understanding of long-term baseflow characteristics.

Suggested, conceptual repairs have estimated costs that range from $500 for removal of logjams to $200,000+ for culvert replacement at bridge or driveway crossings (**Table ES-3**). The conceptual repairs were designed to be site specific and, where appropriate, to reflect commonly used erosion control practices. The implementation of conceptual repair plans have been built around logical prioritization of repair sites in terms of potential benefits gained from project implementation and consensus priority rating of each project by the Arana Gulch Technical Advisory Committee (**Table ES-3**).

Suggested implementation of conceptual repairs include three implementation phases of 1 to 3 years (Phase 1), 3 to 5 years (Phase 2) and 5 to 10 years (Phase 3) coupled with priority ranking of repairs in each phase. For example, repair sites 3, 7, and 14 were given phase one initiation status and were all ranked as high priority repair projects (**Table ES-1 and ES-3, Figure ES-3**). Once repair plans have been implemented, the suggested monitoring program will provide a means to measure relative success or failure and will provide valuable data about the changing conditions in the watershed. This systematic and comprehensive plan for implementing and monitoring repairs will provide a science-based rationale to use when applying for funds, will increase the opportunity for funding of future repairs because of forward momentum, and can build support among residents of the watershed and among others interested in or charged with its repair.

## 1.3 Need for Future Work

Future investigations should focus on filling in data gaps. Arana Gulch lacks historic streamflow and sediment-transport records. These data are important, basic pieces of information, which help in characterizing basin hydrology and the sediment sizes and volumes that are transported by the stream. For the purposes of the sediment assessment presented in this report, simulated estimates of streamflow and sediment transport were modeled from (a) streamflow records for Soquel Creek and (b) sediment discharge records collected on Zayante Creek and three other Santa Cruz Mountains streams. These estimates can be updated when relationships for Arana Gulch are established by direct measurement.[3] Results of the direct measurements can not only be used to evaluate our simulations, but can also serve as a baseline, against which future reductions in sediment transport effected by the projects proposed above (among others) can be evaluated.

A complete assessment of the vegetation riparian corridor was not conducted as a part of this project, as it was not part of the scope proposed or funded. The riparian corridor and the status of vegetative cover are integrally connected to the steelhead populations through their amelioration of summer water temperatures and by the stability that the vegetation adds to stream banks. Where applicable, our suggested repair plans for channel-bank failures and hillslope gullies include the removal of non-native riparian species with planting of native species. We understand the importance of re-introducing native plant species to the riparian corridor and strongly suggest that a comprehensive riparian assessment be included in future watershed efforts.

A plan for the tidal reach of Arana Gulch was prepared by ecologist Prof. Tom Harvey in 1982, based largely on investigations presented in the 1982 geomorphic report. In 1999, CWC staff repeated many of the geomorphic measurements, including re-occupying the cross sections established in 1982. These efforts have confirmed the earlier understanding of the rates and mechanistic causes for bank collapse and channel head cutting observed in the tidal reach. Tidal action was identified as the cause of bank collapse, and restriction of tidal action (perhaps with flap gates) on the existing culverts

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[3] The Santa Cruz Port District has recently installed a gaging station near the fish ladder to begin to address many of these data needs.

would reduce bank instability. It is also possible that sustained and/or increasing high rates of sand transport from the upper watershed are contributing to the widening. However, recent discussion concerning the tidal reach has focused on the steelhead passage suitability of the four culverts that connect the lower tidal reach to the Santa Cruz Small Craft Harbor. Some agency staff wish the culverts either to be removed or reconstructed due to potential passage difficulties for steelhead, while the restoration team’s fishery biologist does not believe the culverts pose any passage difficulties. Resolution of future management of the tidal reach requires discussion that will extend beyond the time allotted for this effort into planning and implementation of the Greenbelt plan, and is likely to call for further investigation; however, any future decisions will benefit from the measures identified below.

# 2. BACKGROUND AND INTRODUCTION

*Chapter 2 will present background information and narrative setting the stage for this multi-disciplinary project. The project purposes will be discussed as will the project scope which basically describes the philosophy of long-term watershed planning. The chapter will end with a description of previous work in and about the watershed, as well as other accounts which have shaped this plan.*

## 2.1 Background: AGWA and Long-range Management[4]

In 1994, Friends of the Arana Greenbelt began to meet. The group focused on promoting open space and bio-diversity. In 1996, the Coastal Watershed Council initiated a Volunteer Water Monitoring Program in Arana Gulch. The joint efforts of these two groups led to the Coordinated Resources Management and Planning (CRMP) Program for the Arana Gulch Watershed. The Santa Cruz Port District, USDA Natural Resources Conservation Service, Santa Cruz County Resources Conservation District, and a number of dedicated individuals were instrumental in starting the CRMP Program in 1996. One of the individuals, Roberta J. ("Bobbie") Haver, wrote a UCSC senior thesis identifying values of the creek and its corridor, presenting a strategy to protect and augment these values. The Santa Cruz Port District provided seed funding. Bobbie Haver served as the volunteer convener of the CRMP through late 1998, when she became part-time watershed coordinator.

Through a series of public meetings from 1996 to 1998, a list of community issues and resource concerns were generated and a watershed steering committee established. The steering committee named the collection of peoples the Arana Gulch Watershed Alliance (AGWA) and subsequently developed AGWA's Mission Statement: "**To conserve, protect, restore and enhance the natural resources throughout the Arana Gulch Watershed.**" In order to realize this mission, AGWA has adopted a list of goals that include:

- To improve water quality and riparian habitat along the Arana Creek

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[4] Text adapted from written description by Bobbie Haver, 1996, DFG SB-271 Grant Application

for fish and wildlife,

- To enlist community support and involvement, both private and public, for the conservation of Arana's natural resources, and

- To provide for long-term management and viability of the project.

The collaborative efforts of technical professionals, landowners, residents, districts and agencies under the direction of Bobbie Haver have been the key to the current successes of the AGWA. The continued efforts of all parties, supported by both financial and in-kind assistance, will be central to refining and implementing a successful, long-term enhancement plan.

## 2.2 Project Purpose

Arana Gulch supports an important, highly-valued riparian community and creek corridor at the eastern edge of the City of Santa Cruz. It is one of the smaller streams on the Central Coast of California which has historically sustained, steelhead spawning and rearing (personnel communications, Jerry Smith). Currently, available salmonid habitat in the watershed is poor in quality due to a number of limiting factors (Alley 2000). If steelhead numbers are to increase in Arana Gulch, the limiting factors will need to be managed over the long term and assessed on a recurring basis.

As mentioned in the executive summary, the purposes of this project were to (a) conduct an assessment of current sediment and salmonid fisheries conditions and (b) to recommend restoration projects to repair individual sites or constraints in the Arana Gulch Watershed. Specific objectives linked to the project purpose include:

- Identifying problems in the watershed related to erosion and bed sedimentation and related effects on salmonid habitat,

- Developing an understanding of the causes of these and other current problems,

- Preparing conceptual plans to manage and repair identified problems, generally at specific sites,

- Providing strategies to implement conceptual repairs and management programs, and

- Suggesting a monitoring plan for use in long-term adaptive management.

The enhancement plan also aimed at anticipating and addressing conditions which could develop in the watershed as a result of episodic events or from the expansion of existing problems to new portions of the watershed. Finally, we hope to set a precedent for future watershed enhancement plans by carefully assessing the health of the watershed and by logically planning for a 30- to 50-year potential conditions.

## 2.3 Project Scope

Many watershed plans adopt a short- to mid-term perspective, typically with a 10- to 15-year anticipated lifetime, including a monitoring period following implementation of the action plan. We believe that a useful plan for Arana should be based on a longer vision, recognizing that:

- Since the watershed is small, resources to revisit the whole plan may not be as readily available as for larger watersheds undergoing rapid change.

- A large number of jurisdictions with land- and water-use authority[5] regularly take actions affecting this watershed, actions which merit both consistency and coordination. An expired or outdated plan may

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[5] Including, but not limited to, both the City and the County of Santa Cruz, Caltrans, Harbor High School and the Santa Cruz Unified School District, Coastal Commission, Natural Marine Fisheries Service, California Department of Fish and Game, US Fish and Wildlife Service, Monterey Bay National Marine Sanctuary, the National Guard, several special districts and the various agencies connected with ongoing dredging at the harbor, in addition to state, federal, and local government entities responsible for all watersheds in the region.

not effectively (or legally) guide these decisions or realize important opportunities that may arise.

- Arana crosses the fringe of urban activity, with rapid change always a possibility. A sustained plan addressing potential issues which may well arise in the longer term has particular value in a small watershed.

A plan directed toward a 30- to 50-year period of effect may well be more appropriate to the needs and resources of this watershed. A plan with this longer view needs to recognize not only present conditions, but also cycles and episodes which may reasonably be expected during its lifetime. Going further, an effective long-range plan should also identify issues that may arise even beyond the anticipated life of the plan.

Our approach in planning for Arana Gulch recognizes three distinct areas of effort: implementation of repair and restoration plans, monitoring of implemented repairs and adapting management style to those repairs if negative conditions arise and preparing for issues which may arise in the next 50 years or beyond. Implementation of suggested repair plans is laid out over 10 years through 3 phases of implementation. Monitoring and adaptive management of repairs should continue indefinitely following implementation. Adaptive management should keep pace with evolving strategies or the discovery of new information. Although preparing for potential issues over the next 30 to 50 years or beyond may seem difficult or chancy, this duration is less than the expected life of homes, facilities, and public improvements which will be designed with the plan in mind. This span is also far shorter than the anticipated positive effects of habitat-restoration or sediment-reduction actions identified in the plan. And, it may take three to five decades for some measures to fully take effect, or to fill gaps in knowledge or resources needed to set the stage for the next plan.

Accordingly, this plan has been developed with the longer view in mind. In Chapters 4 and 5, we identify information needs and data gaps that seem to limit meaningful planning and allow interested individuals and entities the opportunity to understand what is needed. Chapter 9 includes a major section exploring issues which may well not arise during the anticipated life of the plan, but for which caretakers in the watershed should prepare with possible solutions arising due to foreshadowing.  Potential sponsors or guides for these long-range issues are also identified.  Finally, we recognize that looking well ahead often requires paying attention to the past.  The history of the watershed, its management, and views of its resources and issues are considered wherever feasible in this document, just as the basin's past has been repeatedly and knowledgeably discussed by many participants who have helped shape this plan.

## 2.4 Previous Work and Sources of Information

Several investigations pertinent to the current cause have been previously conducted in the Arana Gulch watershed.  During the late 1960s and early 1970s, a veteran team of soil scientists mapped the soils of Arana and adjoining watersheds as part of updating the maps of Santa Cruz County soils (National Cooperative Soil Survey, 1980), identifying that soils tend to be sandy.  In 1982, Barry Hecht and two then-graduate students (Matt Kondolf and Mark Reid) investigated the hydrology and geomorphology of lower Arana Gulch, including tidal reach bank-retreat rates and the nature of sediment deposited in the North Harbor of the Santa Cruz Small Craft Harbor.  They established that only about 10 percent of the sediment dredged from the upper harbor originated in the expanding tidal wetlands immediately upstream of the harbor, and that contributions from the San Lorenzo River and longshore drift (which then periodically closed the harbor) were negligible.  These findings clearly identified that the remaining 90 percent of the dredged material was transported from the watershed upstream of Capitola Road.  Harbormaster Brian Foss persisted in spreading this message, and integrating it into ongoing environmental analyses.  The Port District eventually partly sponsored a senior thesis by Roberta ("Bobbie") Haver, which resulted in a study and reference guide for the watershed, in which she laid out plans that – with the ideas and efforts of several dedicated residents -- have grown into the Arana Gulch Watershed Alliance.  In May 2000, D.W. Alley & Associates released an assessment of fishery habitat conditions as a part of this Arana Gulch enhancement planning effort.  The May 2000 report also included sampling of six different reaches of the stream for steelhead and other fish.

Steve Singer (1999) conducted soil erosion and vegetation management studies at De Laveaga Park in June and July of 1999. In the earlier investigation, Mr. Singer identified erosional problems in the De Laveaga Disc Golf Course and recommended management strategies to deal with these problems. In 1999, Robert Bixby, Arana Gulch watershed resident, presented a report to the Santa Cruz City Council and the California Department of Fish and Game. In the report, Mr. Bixby discusses contributing factors that he believes are directly related to increased sedimentation of Arana Gulch with 'silt'. Mr. Bixby's final conclusion is that the increase delivery of silt to Arana Gulch is directly related to recent growth and use of the De Laveaga Disc Golf Course. In 1981, Dr. Jerry Smith, San Jose State faculty member, assessed Arana Gulch for the presence of steelhead and the quality of habitat conditions. His visit to Arana Gulch was part of a larger, county-wide effort directed at planning for water supplies to be taken from some of the larger watersheds. His observations of Arana Gulch were not included in a report as his visit was one based on curiosity. During his visit he observed that Arana Gulch was a small, sand dominated stream with very little steelhead habitat or steelhead present.

Many other sources of information were compiled in this report. Numerous interviews with Arana residents by Roberta Haver and Jason Parke have provided general historical guidance for land-use change and storm activity. Aerial photographs from the Santa Cruz County archives, the Resource Conservation District and the University of California at Santa Cruz map library were valuable in our interpretation of historical changes within the watershed. Numerous GIS based layers from the County's database were used in representing basic information about the watershed, locations of monitoring sites, point-source locations, key landmarks and repair recommendation locations. A list of GIS layers used from the County's database can be found in the references chapter.

Other useful information is undoubtedly available, and should be included as soon as possible in future updates of this plan. Because watershed science and planning draws interested individuals from many fields and backgrounds, readers are encouraged to consider Chapter 10[6], in which we further discuss the objectives and the context within

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[6] Limitations of this report

which the work described in this report has been done, how the plan might best be used, and what additional efforts are anticipated to fill out and implement the plan

# 3. WATERSHED OVERVIEW

*Chapter 3 is intended to give the reader a detailed introduction to the Arana Gulch watershed. Topics covered include physiography, climate, hydrologic overview, geology, soils and results from baseflow and water quality monitoring. These pieces form the foundation for the sediment and fisheries assessments.*

## 3.1 Physiography

The Arana Gulch watershed drains a 3.5 square-mile area at the outer edge of the City of Santa Cruz (**Figure 3.1**). The basin is relatively long and narrow with elevations ranging from sea level at the harbor to over 600 feet at the northern boundary in the upper watershed.

Three steep-walled drainage systems, with sustained slopes of up to 70%, occupy the northern portion of the watershed: the eastern branch, the central branch and the western branch. These branches have carved valleys in the Purisima sandstone in the headwaters and come together upstream of the Oak Meadow Cemetery to form the main branch of Arana Gulch. The main stem flows along a flat-floored alluvial valley between steep walls cut into the staircase of marine terraces on which most of Santa Cruz has been built.

## 3.2 Climate

The climate of Arana Gulch Watershed is typical of coastal central California. Summers are usually warm and dry while winters are mild and humid. Winter months (December-March) may experience high temperatures of 60-65 degrees Fahrenheit and low temperatures of 35-40 degrees Fahrenheit. Summer months (July-September) may experience high temperatures of 75-80 degrees Fahrenheit or higher and low temperatures of 45-50 degrees Fahrenheit. Mean annual precipitation can range from approximately 26 inches per year along the coast to 34 inches per year near the headwaters of Arana Gulch. Most of the rain in Arana Gulch and Santa Cruz County falls during the months of November to March.

## 3.3 Land Use[7]

Principal land uses in the Arana watershed are urban, primarily residential, commercial and light industrial, plus institutional areas such as schools, hospitals and cemeteries. Much of the upper basin remains in large holdings, with sparse rural residential development; this part of the watershed is covered by forests and brushlands, with some grasslands and orchards. Land use within the watershed has changed significantly in recent years. Residential and institutional uses have increasingly displaced grasslands and orchards, especially in the lower watershed.

For a more detailed account of land use, land use history and land use effects on hydrology in Arana Gulch, please see **Appendix C** of this report, (Hecht and others, 1982).

## 3.4 Arana Gulch Watershed Vegetation Communities

The vegetation of the Arana Gulch watershed can be roughly arranged into four categories according to “Flora of the Santa Cruz Mountains of California” (Thomas, John Hunter; Stanford Univ. Press 1991): wetlands and freshwater marsh, streambank vegetation, mixed evergreen / mixed broadleaf forest, and a few patchy areas of chaparral habitat.

As in most of the coastal areas these are not distinct vegetative communities, but can be generally characterized by the dominant plant communities. It should also be noted that due to substantial human populations within the watershed, plant communities are frequently interrupted by other land uses such as roads, schools, housing, and other human development. Vegetative communities are also impacted by non-native invasives, some of which are listed below each of the plant communities described.

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[7] Text taken from Hecht and others, 1982

### 3.4.1 Freshwater marsh

The freshwater marsh begins at the upstream end of the north harbor and extends in a broad plain through the City's Greenbelt area to the Capitola Road crossing. There appears to be some saltwater intrusion during winter high tides and the downstream waters may be brackish for short intervals. The lower banks of the marsh are dominated by sedges (*Carex* ssp), low club rush (*Scirpus cernuus californicus*), and bog rush (*Juncus effusus*). Willow thickets comprised of arroyo willow (*S. lasiolepis*) and red willow (*S laevigata*), with an understory of California blackberry (*Rubus ursinus*) and pacific poison oak (*Rhus diversiloba*) characterize the mid-level banks. The upper banks are dominated by coast live oak (*Quercus agrifolia*) in distinctive sparse oak woodland habitat, with open grassy areas in the Greenbelt.

Non-native invasive blue gum eucalyptus trees (*E. globulus*) dominate the east bank of the harbor area. Other non-natives include Himalaya berry (*R. procerus*) and ornamental escapees.

### 3.4.2 Streambank

From the upstream end of the marsh area to approximately Highway 1, the streambanks rise in elevation to drier, but still frequently inundated soils. Dominant are a mix of coast live oak, red alder (*Alnus oregona*), California buckeye (*Aesculus californica*), and willow. There is also a sparse occurrence of big-leaved maple (*Acermacrophyllum*) and western creek dogwood (*Cornus occidentalis*). These trees afford abundant cover, insect and bird habitat, and shade to the stream throughout most of the mainstem and its tributaries. The understory is comprised of California blackberry and poison oak.

The mainstem streambank area from Harbor High School north into De Laveaga park is heavily populated with non-native invasive acacia (*Acacia longifolia*), French broom (*Cytisus monspessulanus*), and pampas grasses (*Cortaderia jubata* and *C. selloana*), with a robust understory invasion of English ivy (*Hedera helix*), periwinkle (*Vinca major*), poison hemlock (*Conium maculatum*), and Himalayan blackberry.

### 3.4.3 Mixed Evergreen/Mixed Broad-leaf

The upslope areas of the watershed are characterized by less water dependent plants, the dominant being coast live oak and tanbark oak (*Lithocarpus densiflorus*), Douglas fir (*Pseudotsuga menziesii*), with a shrub understory of evergreen huckleberry (*Vaccinium ovatum*), coyotebrush (*B. pilularis var. consanguinea*), and bush monkeyflower (*Mimulus aurantiacus*).

In disturbed areas and drainages from disturbed areas non-native invasives such as pampas grasses, brooms, vinca, English ivy and forget-me-not (*Myosotis latifolia*) are becoming abundant.

### 3.4.4 Chaparral

There are a few south-facing steep areas of the watershed that exhibit disjunct patches of chaparral. These areas are dominated by scrub oak (*Quercus berberidifolia*), bush monkey flower, California lilac (*Ceanothus integterrimus*), and buck brush (*C. cuneatus).*

Due to the relatively inhospitable terrain, few other plants thrive on these steep dry slopes other than the occasional pampas grass clumps.

## 3.5 Existing Habitats not Included in this Assessment

A freshwater wetland several acres in size occupies the wooded area immediately to the east of the existing Harbor High School sediment basin (**Figure 3.1**). The drainage basin contributing surface and ground water to the wetland has not been mapped nor has the wetland been delineated. However, from aerial photograph interpretation some hydrologic characteristics of the wetland can be observed. A northeasterly trending cluster of trees located where the wetland exists suggests that the wetland receives water from a surficial area which extends from the east side of the sediment basin to the northern side of Highway 1 (just west of the Soquel Avenue exit in Santa Cruz). We considered it likely that this wetland originated as a borrow pit for material used to build Highway 1.

## 3.6 Geology and Soils

### 3.6.1 Geology

The three types of sedimentary rocks and deposits (**Figure 3.2**), which outcrop in the Arana watershed, all weather to soils that tend to be sandy or silty sands:

- The weakly consolidated siltstones, sandstones, and (locally) mudstones of the Purisima formation underlie the entire Arana watershed.
- Marine terraces, with nearly flat-lying deposits of well-sorted sands with thin, discontinuous gravel-rich layers cover most of the flat upland benches in the southern half of the watershed, as well as the flat ridgetops near Santa Cruz Gardens and Pilkington Road in the northern half of the watershed.
- Sandy alluvium and stream terrace deposits along Arana Gulch and its headwater forks, widening from partly discontinuous valley floors in the headwaters to a single continuous valley flat up to 800 feet wide downstream from Highway 1.

Generally-available geologic maps generally do not recognize distinctions within the Purisima formation (c.f., Dibblee, 1978; Clark, 1981; Clark and others, 1989). Our experience has been that the Purisima is coarsest at mid-elevations within the watershed, overlain by bedded sandy mudstones, diatomaceous or porcellanitic siltstones that form the highest ridges. Beneath the middle sands is a clayier siltstone best exposed near Harbor High and at the lower levels of De Laveaga Park. The soils developed from these units are texturally different, with the sandiest and most prone to deep gullying derived from the middle sandstone. One of the older geologic maps (Hickey, 1968) also distinguishes three members (sub-unit A, B and C) of the Purisima formation in the Arana watershed, noting that middle member (sub-unit B) is a regionally significant aquifer with a recharge area primarily within the Arana watershed

(**Figure 3.2**). The three sub-units as defined by Hickey (1968) in ascending order are:

- sub-unit A is defined as a 'siltstone with a few sandstone interbeds near its top',
- sub-unit B is defined as a 'silty to fine to medium-grained sandstone with siltstone interbeds', and
- sub-unit C is defined as a 'very silty to silty, very fine to fine-grained sandstone with siltstone interbeds.'

The 'bedrock' Purisima sediments are composed of a series of almost flat-lying beds, seemingly continuous across the watershed. Both geologic and water-well evidence indicate that the bed slope, or 'dip', very gently to the southeast at a barely-discernible slope of 2 to 4 degrees.

The marine terraces form nearly flat and well-drained surfaces upon which deep, stable soils have developed. Erosion rates in relatively undisturbed small watersheds formed mainly in marine terraces can be very low – typically on the order of 5 percent of the rates observed in other Santa Cruz Mountains basins (Hecht, 1980). Most of urban uses within the Arana watershed are constructed on marine terraces, which although disturbed, are usually not major sources of sediment except during periods of construction activity.

The alluvium and stream terraces are formed of the material transported by Arana Creek and its tributaries. This material is typically moderately to extremely sandy. The alluvium is deepest in the lower portion of the watershed (**Figure 3.2**). Its composition, distribution, history, and properties are described in detail in the earlier 1982 report (**Appendix C**).

# Table 3.1: Properties of Selected Soil Series, Arana Gulch, Santa Cruz County

| Soil # | Soil Series[1] | Parent Rock Type | Slopes | USCS[2] | Depth Zone | Erosion Factor K[3] | Erosion Hazard Rating[4] | Permeability[5] | Runoff[6] |
|---|---|---|---|---|---|---|---|---|---|
| | **Upper Watershed** | | | | | | | | |
| **110-112** | **Ben Lomond Sandy Loam** | Sandstone or Granitic | 5-15, 15-50, 50-75 | SM | 0-19 inches | 0.17 | Slight to very high | Moderately rapid | Medium to Very Rapid |
| | | | | SM, ML | 19-46 | 0.17 | | | |
| | | | | - | 46 | - | | | |
| **113** | **Ben Lomond** | Sandstone or Quartz-Diorite | 30-75 | SM | 0-19 | 0.17 | High to very high | Moderately rapid | Rapid to Very Rapid |
| | | | | SM, ML | 19-46 | 0.17 | | | |
| | | | | - | 46 | - | | | |
| | **Catelli** | Sandstone or Granitic | 30-75 | SM | 0-7 | 0.20 | High to very high | Moderately rapid | Rapid to Very Rapid |
| | | | | SM | 7-37 | 0.20 | | | |
| | | | | - | 37 | - | | | |
| | **Sur** | Sandstone, Schist or Granitic | 30-75 | GP-GM | 0-18 | 0.10 | High to very high | Moderately rapid | Rapid to Very Rapid |
| | | | | GP-GM | 18-35 | 0.10 | | | |
| | | | | - | 35 | 0.10 | | | |
| **114-115** | **Ben Lomond** | Sandstone or Granitic | 30-50, 50-75 | SM | 0-19 | 0.17 | High to very high | Moderately rapid | Rapid to Very Rapid |
| | | | | SM, ML | 19-46 | 0.17 | | | |
| | | | | - | 46 | - | | | |
| | **Felton Complex** | Sandstone, Shale, Schist or Siltstone | 30-50, 50-75 | SM | 0-11 | 0.17 | High to very high | Moderately slow | Rapid to Very Rapid |
| | | | | CL, SC | 11-43 | 0.28 | | | |
| | | | | SM, ML | 43-63 | 0.37 | | | |
| | | | | - | 63 | - | | | |
| **116-117** | **Bonny doon Loam** | Sandstone, Mudstone or Shale | 5-30, 30-50 | CL, CL-ML | 0-11 | 0.32 | Moderate to high | Moderate | Medium to Rapid |
| | | | | - | 11 | - | | | |
| **118** | **Bonny Doon Rock Outcrops** | Sandstone: thinly bedded and horizontally oriented | 50-85 | CL, CL-ML | 0-11 | 0.32 | Very high | Moderate | Rapid to Very Rapid |
| | | | | - | 11 | - | | | |
| **142-144** | **Lompico** | Sandstone, Shale or Mudstone | 5-30, 30-50, 50-75 | CL-ML | 0-5 | 0.28 | Moderate to high | Moderate | Medium to Very Rapid |
| | | | | CL, SC | 5-37 | 0.17 | | | |
| | | | | | 37 | - | | | |
| | **Felton** | Sandstone, Shale, Siltstone or Schist | 5-30, 30-50, 50-75 | SM | 0-11 | 0.17 | Moderate to very high | Moderately slow | Medium to Very Rapid |
| | | | | CL, SC | 11-43 | 0.28 | | | |
| | | | | SM, SM-SC, ML, CL-ML | 43-63 | 0.37 | | | |
| | | | | - | 63 | - | | | |
| **146-148** | **Los Osos Loam** | Sandstone, Siltstone Mudstone or Shale | 5-15, 15-30, 30-50 | ML, CL-M | 0-19 | 0.37 | Moderate to high | Slow | Medium to Rapid |
| | | | | CL, CH | 19-36 | 0.28 | | | |
| | | | | - | 36 | - | | | |

## Table 3.1: Properties of Selected Soil Series, Arana Gulch, Santa Cruz County

| Soil # | Soil Series[1] | Parent Rock Type | Slopes | USCS[2] | Depth Zone | Erosion Factor K[3] | Erosion Hazard Rating[4] | Permeability[5] | Runoff[6] |
|---|---|---|---|---|---|---|---|---|---|
| **153** | **Maymem Rock Outcrop** | Sandstone, Shale or Granitic | 50-75 | SM, ML | 0-6 | 0.20 | Very high | Moderate | Very Rapid |
| | | | | SC, CL | 6-14 | 0.24 | | | |
| | | | | - | 14 | | | | |
| **156-158** | **Nisene** | Sandstone or Shale | 15-30, 30-50, 50-75 | SM | 0-10 | 0.20 | Moderate to very high | Moderate | Rapid to Very Rapid |
| | | | | SC, CL | 10-58 | 0.20 | | | |
| | | | | - | 58 | - | | | |
| | **Aptos** | | 15-30, 30-50, 50-75 | CL-ML, CL | 0-23 | 0.28 | Moderate to very high | Moderate | Rapid to Very Rapid |
| | | | | SC, CL | 23-29 | 0.20 | | | |
| | | | | | 29 | - | | | |
| **159** | **Pfeiffer Gravelly Sandy Loam** | Granitics, Sandstone or Marine Material | 15-30, 30-50 | SM | 0-38 | 0.17 | High | Moderately rapid | Rapid |
| | | | | SM, GM | 38-66 | 0.17 | | | |
| | | | | - | 66 | - | | | |
| **176-177** | **Watsonville Loam** | Alluvium | 0-2, 2-15 | ML | 0-18 | 0.28 | Slight to moderate | Very slow | Rapid to Very Rapid |
| | **Lower Watershed** | | | | | | | | |
| **116-117** | **Bonny Doon Loam** | Sandstone, Mudstone or Shale | 5-30, 30-50 | CL, CL-ML | 0-11 | 0.32 | Moderate to high | Moderate | Medium to Rapid |
| | | | | - | 11 | - | | | |
| **176-177** | **Watsonville Loam** | Alluvium | 0-2, 2-15 | ML | 0-18 | 0.28 | Slight to moderate | Very slow | Slow to Medium |
| | | | | CL, CH | 18-39 | 0.24 | | | |
| | | | | SC, CL | 39-63 | 0.24 | | | |
| **178-180** | **Watsonville Loam: Thick** | Alluvium | 0-2, 2-15, 15-30 | ML | 0-26 | 0.28 | Slight to High | Very slow | Slow to Rapid |
| | | | | CL, CH | 26-47 | 0.24 | | | |
| | | | | SC, CL | 47-63 | 0.24 | | | |
| **132-135** | **Elkhorn Sandy Loam** | Aluuvial Fan and Marine Terrace | 0-2, 2-9, 9-15, 15-30 | SM | 0-21 | 0.32 | Slight to high | Moderately slow | Slow to Rapid |
| | | | | SC, CL | 21-61 | 0.28 | | | |
| **161-163** | **Pinto Loam** | Alluvium and Marine Terrace | 0-2, 2-9, 9-15 | ML, CL-ML | 0-21 | 0.28 | Slight to moderate | Slow | Slow to Rapid |
| | | | | CL, SC | 21-65 | 0.17 | | | |

Notes: 1: Information taken from the August 1980, USDA soil survey for Santa Cruz County (Bowman and Estrada)
2: UCSC = United Soils Classification System, commonly used in geotechnical or soil-foundation investigations, and in routine engineering geologic logging
3: Factor K used in Universal Soil Loss Equation (USLE), indicates susceptibilty of soil to erosion by water, values range from 0.05-0.69, higher values indicate a higher susceptibility to erosion
4: The relative rates of erosion are dependent on soil surface slope, as slope increases the erosion hazard rating increases
5: The relative rates of permeability are dependent on the soil series / complex and are defined as:
**Very slow**: 0.06 in/hr, **Slow**: 0.06-0.20 in/hr, **Moderately slow**: 0.2-0.6 in/hr, **Moderate**: 0.6-2.0 in/hr,
**Moderately rapid: 2.0-6.0 in/hr,Rapid**: 6.0-20 in/hr, and **Very rapid**: > 20 in/hr
6: The relative rates of runoff are dependent on soil surface slope and apply to thoroughly wet soils, as slope increases the relative rate of runoff increases

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### 3.6.2 Soils

There are numerous soil groups present in Arana Gulch (**Figure 3.3**). The characteristics of these soils are given in **Table 3.1** and the spatial distribution of soils in the watershed is shown in **Figure 3.3.** Information presented in **Table 3.1** was culled from the 1980 issue of the Santa Cruz County Soil Survey published by the National Cooperative Soil Survey.

General soil characteristics differ from the upper watershed to the lower watershed. For the purpose of briefly discussing soils here, the upper watershed will be defined as that area upstream of the confluence between the main branch and the western branch, the lower watershed is respectively located downstream of this confluence. These two areas have markedly different physical characteristics and thus have had soils develop that are a product of these differences.

Soils[8] present in the upper watershed are deep to shallow with depth zones ranging from 0 to 4.5 feet, depending on hill slope where the soils are found. These soils range from well drained to somewhat excessively drained and consist of gravelly sandy loams, stony sandy loams, sandy loams, loams and shaly clay loams. The gravelly sandy loams, loams and the shaly clay loams are found on the steepest slopes in the upper watershed. The soils present in the upper watershed have formed in residuum derived from sandstone, shale, siltstone, mudstone, marine deposits and granitic rock. Erosion hazard rating for these soils range from slight to very high with most soils rated as moderate to very high (**Table 3.1**). Under saturated conditions, relative rates of runoff for these soils range from medium to very rapid (**Table 3.1**). In general, as slope increases, runoff rates for saturated soils increases.

Soils present in the lower watershed are deep to very deep with depth zones between 0 and 4 and a half feet and are well drained to somewhat poorly drained. These soils consist of stony loams, sandy loams, loams and shaly clay loams. Other than the Bonny Doon Loam, the soils in the lower watershed developed in residuum from different parent materials than those found in the upper watershed. Parent materials for most of

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[8] For this report, the term ‘soils’ refers to the soil map units which represent the kind of soils present in the watershed. Table 3.1 lists the characteristics of these soils.

the soils in the lower watershed (at least 95 percent) consist of marine deposits, old alluvium and weathered shale. Erosion hazard rating for these soils ranges from slight to high and rates of runoff under saturated conditions ranges from slow to rapid (**Table 3.1**).

## 3.7 Hydrologic Overview[9]

### 3.7.1 Storm hydrology

Stream runoff varies greatly from year to year and is highly dependent on the amount and distribution of rainfall, watershed size and land-use practices. Due to the nature of soils in the Arana Gulch Watershed, a very intense 3-4 hour storm can result in a higher-recurrence interval flow than will a storm of record[10] 24-hour rainfall amounts. This became evident following the January 1982 storm. Arana's peak-flow recurrence interval for this storm was less than that reported for other Santa Cruz County streams (adjusted for drainage area) and considerably less than the rainfall event, commonly reported to be in excess of 100 years. Hecht and others (1982) suggest a peak flow for the January 1982 storm event in the vicinity of 870 cfs and possible as high as 1000 cfs, which roughly correspond to recurrence intervals of 25 and 33 years respectively.

A stronger understanding of basin hydrology has been impaired by the lack of long-term records for streamflow in Arana Gulch. These records are a crucial component of all hydrologic assessments and investigations. They describe the basic and intrinsic watershed responses to storm events, land-use activities and changes and natural or human-induced episodic disturbances. As part of future, long-term projects, we have strongly recommended that stream gaging equipment be secured and installed. This will greatly aid future investigations and the long-term monitoring program described in Chapter 8 of this document. The Port District has recently (November 2001) purchased and installed a gage near the fish ladder, data from which will help frame AGWA's decisions.

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[9] Text adapted in part from Hecht and others (1982). See appendix C.

[10] Record here refers to the storm that produced the greatest amount of precipitation, over a 24-hour period for the period of record at the site.

### 3.7.2 Flood history

Historical accounts and records indicate that some flooding did occur in the eastern and central Santa Cruz Mountains during the years 1852, 1862, 1890, 1909, 1911, 1914, 1917, 1922, 1932, 1937, 1938, 1940, 1941, 1942, 1943, 1945, 1952, 1955, 1958, 1963, 1967, 1973, 1978, 1980, 1982, 1995 and 1998. The floods of 1938, 1955, 1982, and 1998 have been the largest in recent memory.

### 3.7.3 Ground water

Ground water is often a forgotten element of watershed management, especially when aquatic and riparian habitat are the focus of planning. In the Arana watershed, ground water is the source of water sustaining summer and autumn low flows, as well as the keeping the riparian woodland adjacent to the stream well watered. As discussed below, upper Arana Gulch is also a primary recharge area of the main aquifer providing high-quality ground water to the Soquel-Aptos area (**Appendix F**) and portions of Live Oak.

Water occurs with nearly all geologic formations within the Arana watershed. The Purisima formation is the largest unit bearing and transmitting ground water. Yields and permeabilities within the Purisima formation vary considerably amongst its three recognized subunits. The oldest subunit, (the Purisima "A"), which can be seen exposed in the Capitola Road roadcut just east of the creek, is composed primarily of clays and silts; it contains little or no water nearly everywhere it is known to occur (R. Stuart, pers. comm.), and the limited water present tends to be moderately salty. Hecht (1982; fig. 4) mapped the location of several springs emanating from the valley walls cut into this unit approximately 200 yards northwest of the culverts at the north end of the harbor at elevations well above sea level and with an ionic composition very different from sea water (Appendix A of the 1982 report, which is Appendix C of this report).

The Purisima "B" unit is sandy to varying degrees, ranging from sandy silt to coarse-grained partly-consolidated sandstones with an appearance similar to the Santa

Margarita formation of the Scotts Valley area. This unit yields substantial amounts of water of excellent quality where encountered in wells within the Arana, Rodeo, and adjacent watersheds, and is an aquifer of regional significance (Hickey, 1968; Luhdorff and Scalmanini, 1981). Ground water flows eastward to Soquel and Aptos, southeastward toward municipal wells at several locations in Live Oak, as well as sustaining baseflows in the streams of the Arana watershed. The Purisima “B” outcrop area is shown in maps by Hickey (1968), which are reprinted as Appendix F of this report. The unit is most clearly exposed in roadcuts on the eastside of Paul Sweet Road north of the East Branch crossing, and particularly in the half mile north of Arana Court. Gullies, trenches, and channels cut through the soils overlying the “B” unit transform into rapid runoff water which would otherwise percolate into the regional aquifer system, resulting in less volume of high-quality ground water flowing to wells east and southeast of the recharge areas in the upper Arana watershed.

Future addition of low-permeability or compacted surfaces such as roads and roofs will also reduce recharge, both directly and indirectly through their downstream effects. Similarly, if nearby or large wells are pumped at rates which steepen the hydrogeologic gradient away from the watershed, baseflow in Arana Gulch might be reduced. Protecting the aquifer recharge functions in and ground-water flows from the outcrop area in and around the Arana watershed can be a shared goal in land and water management, potentially linking practices in several mid-County watersheds.

The Purisima “C” is composed primarily of siltstones, but contains mudstone, shale, and sandstone beds. It is thicker and nearer the surface than the “B” unit, which dips eastward at about 200 to 400 feet per mile. East of the Soquel Creek valley, the “C” unit clearly is the predominant source of water drawn from wells. While not as high is found in the “B” unit, the quality of water drawn from most of the “C” unit is fully suitable for domestic or municipal supply.

Terrace deposits throughout the watershed contain and transmit water in amounts that can be ecologically significant. The water originates in part as rainfall, and in part as return flows from urban irrigation and other uses. Often, a row of vigorous vegetation is visible at the base of the terrace deposits, where water seeps out of these more permeable zones across the less permeable Purisima bedrock beneath the terraces.

Water also occurs within the alluvium beneath Arana Gulch, its floodplain, and low-lying terraces and benches along the stream. Shallow ground water within the alluvium sustains the riparian vegetation at times when flow in the creek is the very low or the stream has run dry. Alluvium is present along the main stem and all three branches, but most significantly along the lower West Branch. The extent and hydrogeological properties of the alluvial aquifer are analyzed in greater detail in the 1982 report.

## 3.8 Late Season Baseflows[11]

The focus of the baseflow investigation by the Coastal Watershed Council was to establish baseline, spatial low flow conditions in Arana Gulch. Questions to be addressed by the study included:

- Which branches in the upper and lower watershed contribute to summer baseflows?

- Do any reaches in the upper and lower watershed run dry during baseflow months?

- If reaches do run dry, do they overlap with key salmonid habitat reaches?

In 1999, during the months of October and November, and prior to the first runoff-generating rains, CWC staff measured baseflows at 10 locations throughout the watershed. Baseflows were measured by damming flow and subsequently timing the rate of outflow into a 10-gallon bucket. Locations where measurements were taken include (**Figure 3.1**):

- the main stem in the mid-greenbelt area,
- La Fonda tributary below the fish ladder,

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[11] Portions of text in this section was adapted from the Coastal Watershed Council draft report prepared by Jason Parke.

## Table 3.2 Baseflow measurements, Arana Gulch, October and November 1999.

| | Date of Measurement | | Date of Measurement | |
|---|---|---|---|---|
| **Baseflow Measurement Location** | **October 27, 1999** | **Gain (+) or Loss (-)** | **November 5, 1999** | **Gain (+) or Loss (-)** |
| | *cfs* | | *cfs* | |
| East Branch at end of trail north of Santa Cruz Gardens | 0.018 | | nmt | |
| East Branch at Paul Sweet Road Crossing | 0.144 | + | 0.145 | |
| Central Branch at Antonelli Property | nmt | | trickle | |
| Central Branch at Lance Bone's | nmt | | 0.022 | |
| West Branch at Confluence | nmt | | dry | |
| Chaminade Tributary at Paul Sweet Road | dry | | nmt | |
| Main Stem at Brookwood Drive | 0.039 | - | trickle | - |
| Main Stem at the High School Sediment Basin | nmt | | nmt | |
| Main Stem at the Fish Ladder | 0.178 | + | 0.189 | + |
| La Fonda Tributary at Confluence | trickle | | nmt | |
| Main Stem at Mid-greenbelt | less than at fish ladder | | less than at fish ladder | |
| | | | | |

*Notes:* 1. Nmt stands for no measurement taken
2. Sites are listed from uppermost reach in the watershed to lowermost
3. Gains and losses are relative to the site immediately upstream on the same date

Data from Coastal Watershed Council, 1999, Table formatted by Balance Hydrologics, Inc.

- the fish ladder,
- the Harbor High School sediment basin,
- the Brookwood Drive crossing,
- Chaminade tributary at Paul Sweet Road,
- the main stem-western branch confluence,
- the central branch at Lance Bone's home,
- the eastern branch at the Paul Sweet Road crossing, and
- the eastern branch above the Santa Cruz Gardens residential area.

Measurements taken at these locations indicate that the eastern and central branches accounted for all runoff that originated in the upper watershed during the two days when measurements were made in 1999 (**Table 3.2**). Furthermore, if flow in these two branches is summed, the eastern branch accounted for roughly ~89 percent of the total flow which originated in the upper watershed (**Table 3.2**). During this same period, the west branch was dry at the confluence with the main stem. In October 2000 during field mapping of sediment sources by Balance staff, the western branch was also observed to be dry from the confluence to Pilkington Road. Flow was observed in the central and eastern branches in October of 2000, however flow estimates were not made for either of the two branches.

During both days of measurements, baseflow diminished substantially in the reach on the main stem from the western branch confluence to the Brookwood Drive crossing (**Table 3.2**). Based on measurements made in the eastern and central branch, this reach was a losing reach with flow likely infiltrating into the bed and moving down stream as interflow just below the surface of the channel bed.

At the fish ladder near Harbor High School, baseflows had recovered to levels that were measured in the upper watershed, and during both days were measured as slightly higher than those measured in the upper watershed. Based on the methods used to measure flow, it is unclear if increases in baseflow measured at the fish ladder (with respect to flow measured in the eastern branch at upstream sources) truly represented a gain from the reach between Brookwood Drive and the fish ladder. Downstream of the fish ladders in the mid-greenbelt area, flow was observed to be slightly less than that which was measured at fish ladders. However, actual flow measurements were not taken at the mid-greenbelt site so it is unclear if loss of flow had occurred between the fish ladders and the mid-greenbelt.

It is important to note that these statements are based on two days of data collected in the fall following an average year in terms of precipitation. More baseflow studies need to be conducted at other sites and during other years to confirm the findings presented above.

## 3.9 Water Quality[12]

Water quality measurements made from November 26, 1996 to December 31, 1999 were the basis for the technical analysis. These measurements were the first significant water quality analyses performed on Arana Gulch beyond the harbor area. They addressed two major gaps in information originally outlined in the 1982 report – (1) establishing a baseline so that future changes in water quality can be evaluated, (2) providing a quantitative basis for identifying which constituents pose (and do not pose) problems for maintaining a successful steelhead run and a viable riparian corridor which can safely sustain recreation and other aquatic biota. The water quality measurements were made by CWC staff and community volunteers, serving to successfully draw many watershed residents into the issues which AGWA is now addressing, often with their help. The watershed-wide water quality monitoring program directed by CWC was the first of its kind in Santa Cruz County. Its successful completion and community involvement helped initiate similar programs elsewhere in the Monterey Bay region, and served to refine the methods used during such studies.

Measurements were made of water temperature, dissolved oxygen, turbidity, specific conductance and pH, some of which are constituents that had been identified in previous reports as potentially limiting to steelhead populations statewide. Stations where water quality was monitored included:

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[12] Text developed by Balance staff from the February 7, 2000 Monitoring Program report prepared by Jason Parke and Donna Meyers, and revised and annotated by Tamara Clinard in December 2001, all of the Coastal Watershed Council.

- The eastern, or main, branch at Paul Sweet Road (upper watershed)
- The Brookwood Drive crossing (middle watershed, and the furthest upstream on the main stem)
- The Fish Ladder site, adjacent to Harbor High, and just upstream from La Fonda Ave. (middle watershed)
- Capitola Road, in the upper Greenbelt area (lower watershed)
- The culverts at the entrance to the upper harbor (lower watershed and tidally influenced)
- Hagemann Gulch at its mouth (lower watershed and tidally influenced)
- The upper harbor at "L" Dock (lower watershed and tidally influenced).

Generally, water quality measurements were made quarterly, and on the same day. All measurements were made in the field, using meters and field test kits provided by CWC. Methods used are described in Appendix D. CWC staff were often present when measurements were made, and reviewed results prior to entering the data into spreadsheets.

### 3.9.1 Turbidity

Turbidity is a measure of how much particulates and other matter in water interfere with the water's ability to pass light. For all practical purposes, turbidity is an index of the concentration of sediment or algal matter in the water. During the period of monitoring, the highest turbidity[13] levels were consistently measured in the winter months, when turbidity is due primarily to sediment eroded from the watershed and moving to Monterey Bay; the lowest levels were consistently measured during summer,

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[13] Turbidity was measured in Jackson Turbidity Units (JTUs)

when the minimal turbidity that can be discerned is generally associated with algae and organic debris. Similar turbidity levels were measured in the upper as well as the lower watershed on most dates. The highest levels were measured at all stations during the wet and stormy 'El Nino' winter of 1997/1998.

Turbidity levels were suitable for growth of fish and all other aquatic or riparian biota during non-storm periods. Levels were elevated in winter during periods of storm runoff, indicating that sediment may directly affect spawning, egg incubation or emergence of steelhead from the gravels. This is consistent with observations that there is abundant mobile sand and silt on the streambed, and that sediment likely constrains steelhead populations (Chapter 7; Appendices A and G). In the absence of concurrent streamflow measurements at higher flows (perhaps not an appropriate or safe use of volunteers' time), the winter turbidity data can best be seen as pointing toward sand and silt as a major water quality issue for the watershed.

### 3.9.2 Dissolved oxygen

Dissolved oxygen, or "D.O.", is a measure of oxygen available in the water for fish and other aquatic biota to breathe. Healthful decomposition of organic matter and of waste products of fish and other animals (including humans) are also promoted by the presence of dissolved oxygen. D.O. is, in part, dependent upon the temperature of the water, with saturation concentrations decreasing with higher temperature[14]. Commonly, dissolved oxygen levels approaching or reaching saturation are considered beneficial for growth of salmonids at every life stage.

Dissolved oxygen levels of at least 80 percent saturation, with temporary levels no lower than 5 mg/L, usually meet the needs of migrating fish (Reiser, 1979). In the context of Arana Gulch, streams are typically fully saturated with oxygen in winter and spring at much higher than 5 mg/L. Oxygen might become a constraint to migration in short reaches of stream if high levels of biologically-active contamination, such as a sewage spill occurs. Once spawning has been completed, the eggs need to breathe, and their

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[14] The concentration of dissolved oxygen varies substantially over the course of a day, reaching a minimum at daybreak, and increasing to a maximum in the afternoon or evening; temperature and plant respiration (plants 'exhale' oxygen into the water) are usually responsible for this pattern.

metabolic wastes must be degraded, both of which require oxygen. Water flowing through the gravels at spawning sites must accomplish both functions. Therefore, incubating eggs need sufficiently sand- and silt-free gravels to allow for free flow, and water containing sufficient D.O. to meet the respiration needs of the eggs. The less permeable the gravels, the higher the oxygen levels needed, and vice versa. D.O. levels in excess of 8 mg/L are usually sufficient to meet egg needs where circulation is not appreciably impaired by fine sediment; survival of eggs and emergence of fry appear to diminish as oxygen concentrations decrease from 7 to 3 mg/L. The concentration of dissolved oxygen in streams is important to salmonids during rearing, primarily when temperatures are warm. Values in excess of 5 mg/L are commonly cited for streams with field temperatures typical of small coastal streams. At the local level, fishery biologist Don Alley (Alley, 1995) reports that steelhead have been observed in lagoons and streams with oxygen levels below 4 mg/L in many locations along the Central Coast. He notes that steelhead and rainbow trout in Arana Gulch can likely survive oxygen levels in the early morning as low as 2 mg/L provided that higher levels prevail in the warmer daylight hours[15]. Nonetheless, he recommends that the water quality goal for Arana Gulch should be to maintain D.O. levels above 5 mg/L because activity is likely restricted at lower oxygen levels.

Values observed in Arana Gulch confirmed a pattern of adequate dissolved oxygen in headwater and mid-basin reaches, coupled with moderately to chronically depressed D.O. within the tidal reach near the mouth. D.O. concentrations were almost always above 5 mg/L upstream of the culverts at the upper end of the harbor. Notable exceptions were observed shortly after major storm events, when significant amounts of freshly eroded sediment, soil and organic debris had entered the channel, likely exerting sediment oxygen demand on the winter and spring baseflows. Other measurements when the dissolved oxygen levels were depressed were probably made early in the day, or on overcast mornings, when D.O. levels are near their daily minima. Fish are able to reduce activity at such times, returning to active feeding when oxygen levels increase during the late morning and afternoon hours. Within the tidal reach, lower D.O. measurements are typical of seawater and tidal systems. Shallow, marsh-like measurements, such as those at the Hagemann sampling site, often have low D.O. levels,

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[15] Don Alley also cites Moyle 1976, who notes that rainbow trout withstand oxygen concentrations of 1.5 to 2 mg/L at low temperatures.

especially early in the morning. In this particular setting, urban runoff or human activities within the riparian corridor may also contribute to depressed D.O. values.

Barring accidental, large sewage spills into the creek, we do not anticipate any oxygen problems upstream of the tidal reach in Arana Gulch. If monitoring of D.O. is to continue, one of the more important objectives would be monitoring dissolved oxygen in unshaded areas during summer months of dry years, when flows are critically low. Monitoring should ensue in the event of reported fish kills, as well. Although steelhead do not use the tidal reach for spawning or rearing, low oxygen levels may affect other aquatic organisms. Fish kills of herring have been reported in the Upper Harbor in the past (Hecht and others, 1982). Monitoring for D.O. should resume if significant reductions in water circulation are made at the culverts just upstream of the harbor.

### 3.9.3 Specific conductance

Specific conductance is a measure of water’s capacity to transmit an electrical current. Specific conductance (or, informally, ‘conductivity’) is highly correlated with the concentration of total dissolved solids, or “salts”, in the water, and is used worldwide as a convenient field index for total dissolved solids. It is measured in millimhos or micromhos (the obverse of resistance, which is measured in milliohms or microohms) per centimeter, standardized to 25°C. For convenience, these units are commonly called millisiemens or microsiemens (mS or uS). Conductivity is rarely a limiting factor for fishes in freshwater streams except during accidental chemical spills, and was not limiting to steelhead in Arana Gulch above the tidal reach.

Above the influence of tidewater, specific conductance changes with streamflow in a relationship unique to each watershed. During winter storms, specific conductance can be a small fraction of the values observed during summer months. For example, the lowest value observed by CWC (0.1 mS) during a small rainstorm in 1999, was only 20 to 25 percent of typical summer values. Hence, there is no one standard for specific conductance as it applies to aquatic or riparian habitat. Generally, the lower the specific conductance at a given flow, the wider number of species that can be supported. The values observed in Arana Gulch were low relative to those measured in the full range of salmonid streams south of the Golden Gate, and, indeed were somewhat lower than in most municipal water supplies in Santa Cruz County.[16] These values were lower than others because (a) the geologic units north of the Zayante fault which typically yield high-salinity baseflows do not outcrop in the Arana watershed, and (b) measurements by CWC were made during a series of wet years beginning in 1993, during a period in the drought/wet-year cycle when lower-than-normal specific conductance values might be expected (Hecht and others, 2002). Values measured at the culverts above the harbor and other tidally-influenced stations can be much higher because they include a component of sea water, which has a specific conductance of about 51 mS.

Specific conductance can sometimes be used to detect where and when potential contaminants may be entering the stream. Examples of detectable contaminants, if present in sufficient volume, are sewer mains, many medical wastes, and others discussed in the 1982 report. In fact, one CWC reading of 0.9 mS at the Brookwood Drive station is an example of the response that might be expected in Arana Gulch while affected waters are flushed from the system, although there are other potential interpretations of this one measurement that would not involve introduction of constituents. In such cases, it is generally not the specific conductance that adversely affects the fish[17]; rather, the changes in specific conductance are a marker or surrogate for changes in other constituents that may prove harmful or toxic. Specific conductance can be monitored continuously with off-the-shelf instrumentation developed over the past decade, and would be appropriate for use in detecting periodic spikes or other possible indications of certain contaminants affecting habitat value, since it is virtually impossible to detect such spikes with periodic grab samples.[18] We suggest that a

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[16] On a given day, specific conductance in Arana Gulch may be 0.1 to 0.2 mS lower than in Soquel Creek for which a relationship of specific conductance to streamflow has been developed for a 24-year period of record (see Chartrand and others, 2002).

[17] Steelhead use and thrive in streams with specific conductances two or three times greater than those in Arana Gulch, among which are tributaries to San Gregorio Creek, Bear Creek (Santa Cruz County), and the Pajaro and Santa Ynez Rivers.

[18] Mike Rugg, water-quality biologist for the Department of Fish and Game in this region, notes that over 90 percent of fish distress or mortality cases in coastal California are due to very brief acute exposures, rather than chronic levels. Following up on his recommendation, we have found recurrent spikes in continuous specific conductance records from Santa Cruz Mountains streams that subsequent investigation concluded to be discharges of chlorine associated with regularly ‘freshening’ of a large community swimming pool or routine washing down of paddocks in a stable, both of which are serious water-quality issues during summer.

continuous record be developed over a period of several years to assess whether such materials are entering Arana Gulch. Monitoring would most effectively be conducted at either the fish ladder or upper Greenbelt sites, below most potential sources of contamination and upstream of tidal influences.

### 3.9.4 pH

For the period of monitoring, the range of pH values varied only slightly from a low of 7.00 to a high of 8.00. These are typical values for central coast streams in California, where pH is not limiting to fishes. The pH levels recorded in Arana Gulch were within the acceptable range for salmonids survival at all life stages and thus were not a constraining factor in habitat suitability, either directly or indirectly. Further monitoring of pH is deemed unnecessary except after accidental chemical spills.

### 3.9.5 Water Temperature

Water temperature of Arana Gulch is of interest principally for its effect on aquatic organisms. Stream temperature varies daily and seasonally, and over the course of a cycle of hot-sunny and cool-foggy days during the dry season. Similarly, steelhead and other aquatic biota have temperature tolerances that vary with their life stages and geographic location. Water temperatures throughout the streams of the Santa Cruz Mountains are typically suitable for all life stages of steelhead, though warm water conditions restrict juvenile steelhead to primarily fastwater feeding areas in lower, sunny reaches of the larger streams such as San Lorenzo and Soquel Creeks during warm summers (Alley, pers. comm.). Hence, this section is focused on stream temperatures in summer.

Central coast steelhead populations and those further south , including those of Arana Gulch, are adapted to warmer temperatures than those found further north.[19] As a

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[19] Temperature tolerances of southern steelhead have been most recently been studied in connection with developing a recovery plan for the endangered steelhead of the Santa Ynez River (Santa Ynez River Technical Advisory Committee, 2000 , see Appendix G), which concluded that:

- Given suitable dissolved oxygen and forage, steelhead will not select water warmer than 22ºC when given the choice of habitat with lower temperatures
- The incipient lethal temperature (the temperature at which half of rearing fish will die after relatively brief exposure) is approximately 26.2ºC, and that mortality will begin to increase above water temperatures of 24 to 25ºC.

result, knowledge of local behavioral or feeding response to warmer temperatures and associated increased metabolic demand becomes essential. Fishery biologist, Don Alley, has observed that when daily water temperatures reach approximately 21ºC (70ºF) or greater in summer, juvenile steelhead restrict their microhabitat distribution to fastwater habitat (riffles, runs and heads of pools) due to increased metabolic demand. He recommends a water quality goal of maintaining water temperatures at less than 21ºC or lower for steelhead in Arana Gulch, noting that temperatures above 26ºC (79ºF) for more than an hour or so may be lethal.

Measurements of water temperature in Arana Gulch were made at all sites, most commonly from December 1996 through April 1999. Data are presented in Appendix D. Summer temperatures recorded by CWC observers were generally below 18ºC (64.4ºF). It is likely that slightly higher temperatures occurred during this period when observers were not present. These cool temperatures were due to shading by riparian vegetation throughout most of the Arana watershed; sites with discontinuous riparian canopy (such as fish ladder and upper Greenbelt) were warmer than those with full shading. Sites with higher observations of water temperature, such as the culverts above the harbor or Hagemann Gulch, were not suitable for summer rearing due to flow and/or salinity limitations.

Although the CWC data suggest that stream temperatures are presently suitable for steelhead and rainbow trout, measures to maintain summer water temperatures at or below the measured values are warranted. The measured data probably understate the highest temperatures and related risks likely to affect Arana fish because:

- The measurements were limited to when observers were present, and warmer temperatures likely occurred at other times,

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- Salmonids require more food as temperatures increase; there is no evidence that southern steelhead can maintain their size at daily average temperatures greater than 22ºC.
- Under field conditions, steelhead concentrate in riffles (where foraging is more efficient) as temperatures increase, and the area of riffle habitat can be limiting.
- Temperatures above 21 to 22ºC can lead to smaller fish unless food is abundant, which likely reduces their return rate as adults.
- Increased delayed mortality may also occur above 21 to 22ºC as a result of disorientation or fatal delays in avoiding predators.

- Summer flows can be very low, prolonging periods when the sun can warm even relatively short unshaded reaches to levels well above the desired thresholds, and

- Measurements were made during a sequence of wet years, when summer flows were likely higher than typical.

Salmonids in Arana Gulch may be especially at risk of excessively warm water temperatures if the riparian corridor is compromised due to urban, recreational or agricultural encroachment, particularly in drier years.

Finally, stream temperature and flow are often inextricably intertwined for management purposes. Changes in the watershed that may reduce flows will aggravate the effects of warm periods during the summer-rearing period when high temperatures may constrain fish activity. Further diversion from the stream or land uses which may reduce summer flows pose a significant temperature hazard. A continuous record of stream temperature – and flow -- should be collected and analyzed, with emphasis on summer conditions. CWC data indicate that temperature monitoring might most usefully be conducted at the fish ladder site or in the upper Greenbelt area. The fish ladder site would be preferable, since the ladder provides a hydraulic control which will simplify measuring flows. This record will help identify when key thresholds are approached or exceeded, allowing AGWA to better choose riparian reaches meriting the group's attention.[20]

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[20] Based on recommendations developed earlier during this study, the Port District installed in November 2001 a stream gage equipped with temperature and specific conductance sensors at the fish ladder

# 4. STEELHEAD ASSESSMENT

*Text used in this chapter is excerpted or adapted from D.W. ALLEY and Associates May, 2000 report: Salmonid Densities and Habitat Conditions in 1999 for Arana Gulch, Santa Cruz County, California: Identifying Migrational Barriers, Streambank Erosion and Opportunities for Steelhead Enhancement. The full report is attached to this document as* ***Appendix A****. This chapter will present background information pertaining to steelhead life cycles and habitat needs as well as a synopsis of results from the steelhead assessment conducted by D.W. ALLEY & Associates. Assessment methods used by D.W. ALLEY & Associates are given in full in their report. For each section included in this chapter, the page numbers where the original discussion can be found in the D.W. Alley 2000 report is given.*

## 4.1 Steelhead Assessment Project Purpose

*(Alley, May 2000, page 5)*

The intent of habitat typing, fish sampling and habitat evaluation was to establish baseline data on salmonid production in Arana Gulch and to provide recommendations for enhancing conditions in the watershed related to steelhead fishery success. This project was conducted in conjunction with the Arana Gulch assessment and enhancement planning efforts.

## 4.2 Steelhead Life History and Habitat Needs

*(Alley, May 2000, pages 2–5)*

### 4.2.1 Migration

Adult steelhead in small coastal streams tend to migrate upstream from the ocean after several prolonged storms. The migration seldom begins earlier than December and may extend into May if late spring storms develop. Many of the earliest migrants tend to be smaller than those entering later in the season. Barriers such as major logjams, bedrock falls and shallow riffles may block adult migrants. Man-made objects, such as culverts, bridge abutments and dams are often significant barriers. The box culvert at the Paul Sweet Road crossing with associated concrete debris below its entrance is such a barrier.

Some barriers may completely block upstream migration, but many partial barriers in coastal streams are passable at higher streamflows. If the barrier is not absolute, some adult steelhead are usually able to pass in most years, since they can time their upstream movements to match peak flow conditions. However, in drought years when storms are delayed, these partial barriers may become serious impediments to migrating spawners and may make adults more vulnerable to predation or to angling mortality.

Smolts (young steelhead that have physiologically transformed in preparation for salty ocean life) in local coastal streams tend to migrate downstream to the lagoon and ocean in March through June. In streams with lagoons, smolts may spend several months in this highly productive aquatic habitat and grow rapidly. In some small coastal streams, downstream migration can occasionally be blocked or restricted when streams run dry (or at extremely low flows) where affected by percolation diversions or pumping from wells hydraulically connected to the channel. Flashboard dams or closure of the stream mouth or lagoon by sandbars are additional factors that adversely affect downstream migration. However, for most local Santa Cruz Mountain streams, downstream migration is not a problem except under extreme drought conditions when surface flow continuity to the ocean is lost. Sometimes, lower reaches of streams will lose surface flows for many months during droughts. Additionally, if sand sized material accumulates on the channel bed, additional water will be needed during baseflow months to maintain flow to the lagoon or ocean due to streamflow infiltrating into the sandy bed.

### 4.2.2 Spawning

Steelhead require spawning sites with gravels and small cobbles (from ¼” to 3 ½” diameter) having a minimum of fine material (sand and silt) mixed with them and with good flows of clean water moving over and through them. Females usually excavate their nests near the center of the channel at the tails of pools, where water infusion of the substrate is maximized, and streambed scour is minimized. They may be forced to spawn in deeper riffles and runs if stream depth is too shallow at pool tails. Increases in fine materials from sedimentation, or cementing of the gravels with fine sediment, restrict flow of oxygenated water through the redd (nest) to the fertilized eggs. These restrictions reduce hatching success. In many Santa Cruz Mountain streams, steelhead appear to successfully utilize substrates for spawning with high percentages of coarse sand, although the additional sand probably reduces hatching success.

Steelhead spawning success may be limited by scour during winter storms in many Santa Cruz Mountain streams. Steelhead that spawn earlier in winter months than other spawners, are much more likely to have their redds washed out or buried by sediment during winter storms. Eggs require 4 to 6 weeks to incubate, and sac-fry spend another 1 to 2 weeks in the gravel before emerging. Unless hatching success has been severely reduced, however, survival of eggs and larvae is usually sufficient to saturate the limited available rearing habitat in most small coastal streams. The production of young-of-the-year fish is related to spawning success, which is a function of the quality of spawning conditions and ease of spawning access to the upper reaches of tributaries, where spawning incubation and rearing conditions are generally better.

Because spawning habitat may limit populations in some years, there may be a temptation to try to add spawning gravels as a restoration measure. This temptation should be strongly resisted for three reasons. First, spawning gravels appear to be available beneath the sand mantling the bed in almost all spawning reaches, and would become available for spawning with a decrease in bed-impairing sand. Second, added gravels will likely also become buried in sand after a few storms. Finally, and most significantly, banks within or downstream from most existing spawning areas are composed of weak, unconsolidated floodplain sands that are often already eroding; the addition of coarse sediment will induce significant bank erosion at these locations, resulting in the filling of the few deep pools and undercut banks needed for rearing and for winter refuge habitat. Ongoing widening is already threatening the redwoods growing along the east branch immediately downstream from the Paul Sweet Road crossing, as one example; addition of sufficient gravels to stabilize riffles will substantially increase the risk to these trees.

### 4.2.3 Rearing habitat

Except in streams with high mean summer flow (greater than .2 to .4 cfs per foot of stream width), steelhead generally require two summers of stream residence before reaching smolt size. This is likely the case in Arana Gulch. Juvenile steelhead are generally identified as young-of-the-year (first year) and yearlings (second year). Slow growth and the common two-year residency of local juvenile steelhead indicate that low summer streamflows and related problems such as warm water temperatures, may adversely affect two separate year classes.

In most coastal watersheds, young-of-the-year steelhead appear to be regulated by available insect food, although cover (hiding areas, provided by undercut banks, woody debris, large rocks which are not buried or “embedded” in finer substrate, surface turbulence, etc.) and pool and riffle depth are also important, especially for larger fish. Pool habitat was the primary habitat for salmonids in summer in Arana Gulch, where escape cover was primarily under woody debris and undercut streambanks. The deeper the pool, the more habitat value it has. Therefore, the presence of large, stable scour objects are important for creating valuable pool habitat. Higher streamflow enhances food availability, surface turbulence and habitat depth, which are all factors in increasing salmonid densities and growth rates.

Densities of yearling and older salmonids are usually regulated by water depth and the amount of escape cover that exists during low-flow periods of the year (July-October). In most small coastal streams, availability of this “maintenance habitat” provided by depth and cover appears to limit the number of smolts produced by the smaller streams. The abundance of food (aquatic and terrestrial insects falling into the stream) and fast-water feeding positions for capture of drifting insects in “growth habitat” can also constrain the size of these smolts. Aquatic insect production is maximized in unshaded, high gradient riffles dominated by relatively unembedded substrate larger than about 4 inches in diameter. Substrate larger than 4 inches is extremely scarce in Arana Gulch (**see Figure 5.1**). This shortage of substrate suitable for aquatic insect production in riffles, may severely limit aquatic insect production for fish consumption. Salmonids in

Arana Gulch may rely almost totally on insects falling into the stream from streamside vegetation for food.

Yearling steelhead growth usually shows a large incremental increase from March through June. Some of the larger steelhead then smolt (physiologically change to adjust to saltwater and out-migrate to the sea). But for most steelhead, which stay a second summer, summer growth is very slight (or even negative in terms of weight) as flow reductions eliminate fast-water feeding areas and reduce insect production. Increased summer water temperature raises steelhead metabolic rate and food requirements to maintain growth and survival. A growth period may occur in fall and early winter after leaf-drop of riparian trees, after increased streamflow from early storms, and before water temperatures decline to less than about 8.8 degrees Celsius or water clarity becomes too turbid for feeding. The "growth habitat" provided by higher flows in spring and fall is very important, since ocean survival and rate of return as spawning adults increase exponentially with the size of the smolts that are produced.

In Arana Gulch, two primary size-class categories of juvenile steelhead were captured during fall sampling. Of these two size classes, the smaller consisted of those juveniles less than 75 millimeters (3 inches) Standard Length (SL). The size class boundary was drawn at 75 millimeters because it is thought that the juveniles less than this measure will require another growing season before smolting. The larger size class included juveniles that measured 75 millimeters or greater SL and are referred to as "smolt size" because they will out-migrate the following spring. This size class may include fast growing young-of-the-year steelhead and yearlings and older juveniles inhabiting mainstem creeks in Santa Cruz Mountain watersheds or lower reaches of larger tributaries in larger watersheds, such as the San Lorenzo River drainage.

When evaluating rearing habitat quality, water temperature and oxygen concentrations are water quality considerations. The relationship between water temperature and metabolic rate (measured as oxygen consumption) is basic to fish physiology and important in understanding fish distribution and ecology. Fish being poikilotherms (cold-blooded), their body temperatures increase along with metabolic rate as water temperature increases. At higher temperatures, steelhead oxygen requirements and metabolic rate increase, and steelhead are forced to fastwater habitat to obtain sufficient food. References which indicate that oxygen consumption by fishes increases with water temperature include Fry (1947), Beamish (1964) and Beamish (1970). Many fisheries textbooks refer to this relationship. An example is The Chemical Biology of Fishes by Malcolm Love (1970). The positive relationship between water temperature and metabolic rate leads to a positive correlation between lethal oxygen concentration and water temperature in fishes (Nikolsky 1963). As water temperature increases, the lowest oxygen concentration at which fish can survive also increases.

There are many central coast examples of steelhead surviving and growing well at water temperatures above 21ºC. Many of these come from coastal lagoons and lower reaches of unshaded drainages, where food is abundant and growth rate is rapid.

### 4.2.4 Overwintering habitat

Deeper pools, undercut banks, crenellations within rootwads or other large organic debris side channels, and especially large, unembedded rocks provide shelter for fish against the high flows of winter. In some years, such as 1982, extreme floods may make overwintering habitat the critical factor in limiting steelhead production. In most years, however, if the pools have sufficient large boulders or undercut banks to provide summer rearing habitat for yearling steelhead, then these elements are sufficient to protect overwintering steelhead against winter flows.

## 4.3 Designation of channel reaches

*(Alley, May 2000, pages 6-7)*

Reach boundaries for purposes of describing existing steelhead habitat were determined from habitat-typing and stream survey work in November 1999. Changes in habitat that necessitated reach boundaries often occurred when stream gradient changed. Gradient controls, the degree of stream meander and migrational impediments were important factors on Arana Gulch. Stream gradient is often associated with changes in habitat proportions (most importantly-- the proportion of pools), pool depth, substrate size and

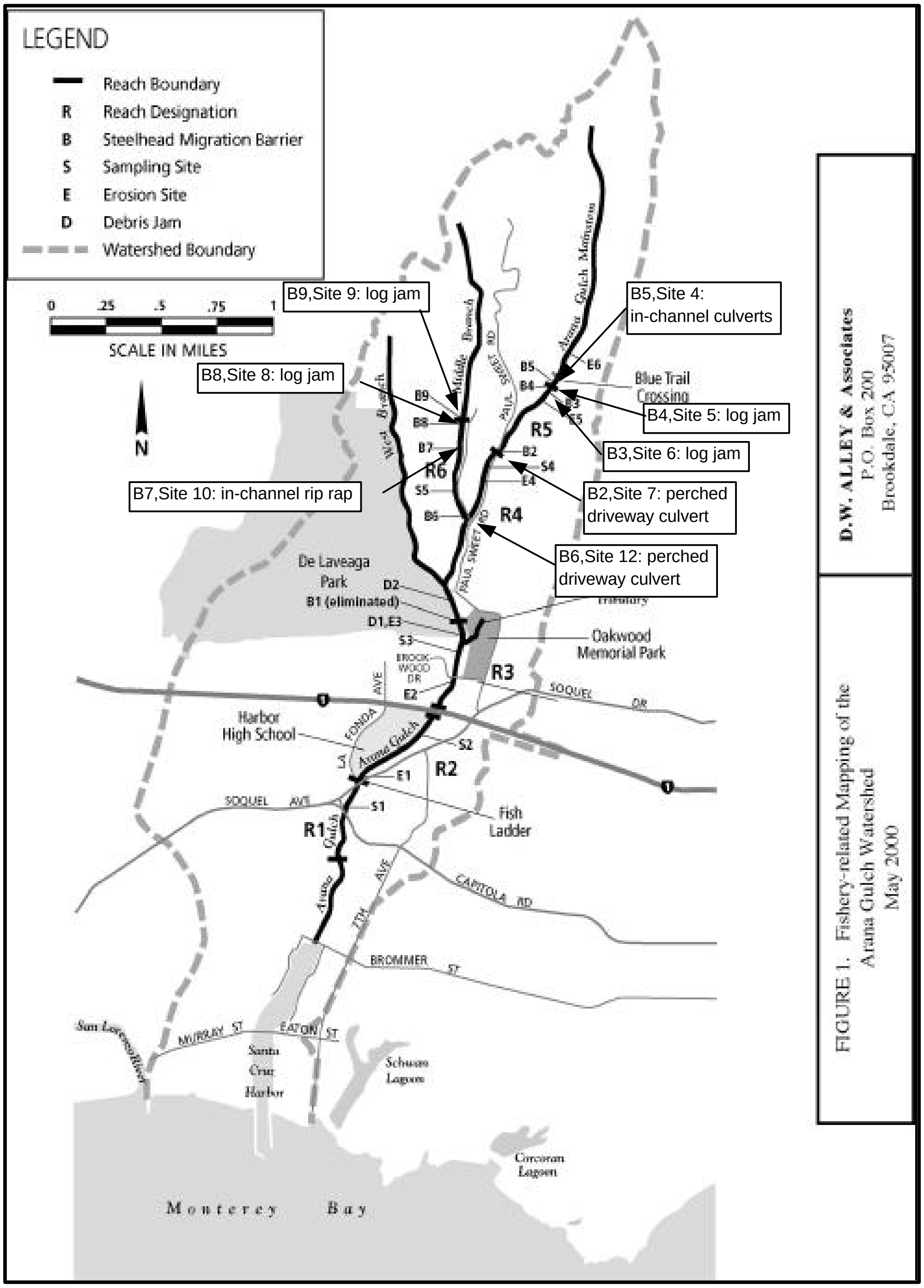

**Figure 4.1: Arana Gulch watershed with the locations of fish passage barriers,fish sampling sites and erosion sites noted.** Channel reaches as defined for the fisheries assessment are shown. Site numbers corresponding to the Chapters 4 and 7 are also given. Map borrowed from Alley (2000). Text boxes added by Balance Hydrologics.

channel type. Other important factors separating reaches are a change in tree canopy closure or significant tributary confluences that increase summer baseflow.

Roughly two linear channel miles (CM) of Arana Gulch that is upstream of tidal influence and likely accessible to steelhead was divided into 4 reaches (**Figure 4.1, R1 through R4**). A description of these reaches as derived for the fisheries assessment can be found below. A fifth reach (**Figure 4.1, R5**) on the eastern branch extended from the Paul Sweet Road culvert to a 7-foot high woody debris jam created by an old-growth redwood in the stream channel, followed by two impassable culverts creating another jam 50 feet upstream. This was just downstream of the crossing of the Chaminade Nature Trail designated as the “Blue Trail.” Another 1,200 feet of stream channel similar to lower Reach 5 was observed upstream of the Blue Trail crossing. This habitat could be used by steelhead if it became accessible. A sixth reach (**Figure 4.1, R6**) on the central branch was also identified and is likely inhabited by resident rainbow trout and steelhead. This reach extends upstream for roughly 0.4 miles from a perched, 4-foot diameter driveway culvert (that is located 112 feet from the confluence with the eastern branch) to a series of 3 logjams which together result in a 5-foot change in streambed elevation. Reach boundary descriptions for reaches 5 and 6 of the fisheries assessment are also described below:

- Reach 1: 2,168 feet in length: Upper extent of tidal influence near beginning of riparian forest to the fish ladder at Harbor High School (CM1.23 - CM1.64)

- Reach 2: 1,198 feet in length: Fish ladder to the sediment basin at Harbor High immediately down-stream from Highway 1 (CM1.64 - CM2.00)

- Reach 3: 2,182 feet in length: Upstream side of Highway 1 to former root-mass drop in eucalyptus grove adjacent to cemetery (CM2.04 - CM2.45)

- Reach 4: 4,805 feet in length: Former root mass-drop to Paul Sweet

Road box culvert (CM2.45 - CM3.36)

- Reach 5: 3,220 feet in length: Paul Sweet Road culvert to a point 1,200 feet past the redwood jam and culverts (Non-steelhead reach) (CM3.36 - CM3.97)
- Reach 6: 2,050 feet in length: Mouth of central branch to change in gradient and logjam (CM0.0 - CM0.41)

## 4.4 Channel Habitat Characteristics

### 4.4.1 Habitat characteristics and methods

*(Alley, May 2000, pages 8-9)*

Habitat characteristics were estimated during the stream survey and habitat typing of reaches. Some habitat characteristics were estimated according to the methods outlined in section III of the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds, 1998). The habitat characteristics estimated according to this manual include: habitat unit mean length, habitat unit mean width, habitat unit mean depth, habitat unit maximum depth, substrate composition, and tree canopy closure. Other habitat characteristics estimated or measured in this study included escape cover, substrate embeddedness, water temperature, and the location of bank instabilities, large woody debris jams and fish passage barriers. Survey sheets included in the Flosi and Reynolds (1998) manual were used during stream surveys.

Mean water depth and maximum depth were determined with a dip net handle, graduated in half-foot increments. Soundings were made throughout the habitat to estimate maximum and mean depth. Habitat length was measured with a hip chain while channel width was measured with the graduated dip net.

Quantitative estimates of tree canopy closure were made with a densiometer. Included in this measurement were trees growing on slopes which were located a considerable distance from the stream and trees which provided no immediate shade to the stream except at dusk and dawn due to their location. Measurements taken in late-October were under-estimates of summer conditions because leaf drop had already begun.

Escape cover for steelhead was measured as the total linear habitat length under which fish **= >** 75 mm (3 inches) Standard Length (SL) could find hiding places. The escape cover index for each habitat type was the ratio of the linear distance under submerged objects within the habitat type divided by the length of the habitat type. Sources of escape cover included undercut banks beneath trees' rootwads, submerged tree roots extending out from streambanks, submerged woody debris and overhanging tree branches and vines. Unnatural objects provided fish cover, including concrete fragments, plywood, tires, shopping carts, a 55-gallon drum and even a sofa. Numerous shopping carts were observed in the channel downstream of Soquel Avenue.

Substrate embeddedness was estimated as the percent that cobbles and boulders larger than 100 mm (4 inches) in diameter were buried in finer substrate. Substrate this large was rare in Arana Gulch, and in most habitat units, estimates of substrate embeddedness could not be made.

Water temperature was measured throughout all channel reaches with time of day of the measurement . Since field work did not begin until late October, temperature data had limited significance. Summer daily maxima would provide more meaningful data for assessing warm water effects upon salmonids.

At each encountered streambank erosion site a rate of erosion was estimated. If erosion sites had lost an estimated 2 cubic yards of sediment per year, sites were located on the watershed map and GPS coordinates were noted. Erosion sites were categorized as landslides (1), meander cuts in which the channel was cutting into the streambank (2), log-jam diversions into the streambank (3), gullies from road runoff (4), and bank failures (5). Erosion rate was estimated. Woody debris jams were also mapped, photographed and located with GPS coordinates (where possible). The locations of streambank erosion sites and large woody debris jams are shown in **Figure 4.1.**

## Table 4.1. Proportion of Habitat Types Delineated in Reaches 1-6 in Arana Gulch, 1999.

| Reach Number | Habitat Type | Units Measured | Total Length | Average Length | % of Surveyed Reach |
|---|---|---|---|---|---|
| | | *#* | *feet* | *feet* | |
| 1 | Pool | 17 | 1044 | 61 | 48.2 |
| 1 | Riffle | 7 | 95 | 14 | 4.4 |
| 1 | Run | 12 | 852 | 71 | 39.3 |
| 1 | Glide | 2 | 177 | 177 | 8.2 |
| 2 | Pool | 13 | 447 | 34 | 23.3 |
| 2 | Riffle | 4 | 78 | 20 | 4.1 |
| 2 | Run | 10 | 451 | 45 | 23.5 |
| 2 | Glide | 11 | 942 | 86 | 49.1 |
| 3 | Pool | 25 | 946 | 38 | 43.4 |
| 3 | Riffle | 0 | 0 | 0 | 0 |
| 3 | Run | 13 | 699 | 54 | 32 |
| 3 | Glide | 11 | 537 | 49 | 24.6 |
| 4 | Pool | 22 | 433 | 20 | 9 |
| 4 | Riffle | 15 | 180 | 12 | 3.7 |
| 4 | Run | 30 | 1567 | 52 | 32.6 |
| 4 | Glide | 23 | 2625 | 114 | 54.6 |
| 5 | Pool | 6 | 102 | 17 | 5 |
| 5 | Riffle | 16 | 259 | 16 | 12.8 |
| 5 | Run | 11 | 544 | 49 | 26.9 |
| 5 | Glide | 20 | 1054 | 53 | 52.2 |
| 6 | Pool | 19 | 259 | 14 | 37.1 |
| 6 | Riffle | 1 | 22 | 22 | 3.1 |
| 6 | Run | 10 | 151 | 15 | 21.6 |
| 6 | Glide | 8 | 267 | 33 | 38.2 |

99005 DA formatted fisheries tables.xls, Table 4.1

Data from D.W.Alley and Associates, 2000, Table formatted by Balance Hydrologics, Inc.

## Table 4.2 Summary of Average Habitat Characteristics for Surveyed Pools

| Reach Number | Units Measured | Total Stream Length | Mean Length | Mean Width | Mean Depth | Mean Maximum Depth | Mean Cover Index | Mean % Sand/Silt of the Bed | Mean % Large Cobble/Boulder | Mean % Embeddedness | Mean % Canopy Closure | % of Surveyed Reach as Pool |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *#* | *feet* | *feet* | *feet* | *feet* | *feet* | | | | | | |
| 1 | 17 | 1044 | 61 | 8 | 0.8 | 1.6 | 0.101 | 97 | 0 | 44 | 63 | 49.5 |
| 2 | 13 | 447 | 34 | 8 | 1.1 | 1.8 | 0.139 | 92 | 0 | 55 | 60 | 23.3 |
| 3 | 25 | 946 | 38 | 6 | 0.6 | 1.2 | 0.034 | 84 | 0 | 50 | 69 | 43.4 |
| 4 | 22 | 433 | 20 | 5 | 0.5 | 0.8 | 0.1 | 95 | 0 | N/A | 76 | 9 |
| 5 | 6 | 102 | 17 | 4 | 0.4 | 0.6 | 0.088 | 100 | 0 | N/A | 83 | 8 |
| 6 | 19*** | 259*** | 14 | 4 | 0.5 | 0.8 | 0.108 | 93 | 0 | 47 | 82 | 37.1 |

* Cover Index = linear distance under which steelhead 75 mm (3 inches) Standard Length or larger can hide, divided by the length of the pool habitat.

**N.A. = Not Applicable because no substrate was large enough to hide salmonids => 75 mm SL.

***Reach 6 was partially surveyed for a total of 699 ft, which included 19 pools from which averages were calculated. Length of pools in the reach were an estimate, based on the proportion of pools in the surveyed portion.

Embeddedness estimated by D.W. Alley & Associates

Data from D.W. Alley and Associates, 2000, Table formatted by Balance Hydrologics, Inc.

Steelhead passage barriers were mapped in all reaches of the channel surveyed. Abrupt changes in streambed elevation posed passage difficulties for migrating adult steelhead intent on spawning. Elevation drops were measured in height above the water surface and water depth was measured in each approach pool. Photographs and GPS coordinates (if possible) were taken for each passage barrier mapped. The locations of steelhead passage barriers in the Arana Gulch watershed are shown in **Figure 4.1.**

### 4.4.2 Channel habitat types and characteristics: summarized results

*(Alley, May 2000, pages 14-15, detailed by reach, pages 15-28)*

The proportion of general habitat types observed in 1999 for Reaches 1 through 6 is summarized in **Table 4.1**. General habitat typing consisted of four categories: pools, riffles, runs and glides. In reach 1, pool and run habitat accounted for roughly 88 percent of measured units. In reach 2, glide habitat accounted for roughly 50 percent of measured units while pool and run habitat accounted for roughly 23 percent, each. In reach 3, pool (43%), run (32%) and glide (25%) habitat accounted for all measured units. In reach 4, run (33%) and glide (54%) habitat accounted for roughly 87 percent of measured units while in reach 5 they accounted for roughly 80 percent of the total measured units. In reach 6, pool and glide habitats were each measured as roughly 38 percent with run habitat measured at 22 percent. With the exception of reach 5, riffle habitat accounted for the least distance of linear habitat measured in the channel reaches. Riffle habitat ranged, in percentage of total linear habitat per reach, from 0 percent to 12.8 percent measured in reach 5. A detailed discussion of habitat types and characteristics per reach can be found in D.W. Alley, May 2000, pages 15-28.

Nearly all salmonids were captured in pool habitat, with just a few Y-O-Y's found in run habitat and even fewer in glides. Average habitat characteristics of measured pools in Arana Gulch can be found in **Table 4.2**. Averaged, mean pool depths by reach ranged from a very shallow 0.4 feet in Reach 5 on the mainstem to 1.1 feet in Reach 2, adjacent to Harbor High School. Averaged maximum pool depth by reach ranged from 0.6 feet to 1.8 feet in those same reaches. These averages, by comparison, were well below those for San Lorenzo River tributary reaches in 1999. For example, 11 of 21 tributary reaches had average pool depths of at least 1.4 feet, and 13 of 21 had average maximum pool depth of at least 2.2 feet (D.W. ALLEY & Associates, 2000). Average pool width by reach decreased from 8 feet in Reaches 1 and 2, to 6 feet in Reach 3, to 5 feet in Reach 4, to 4 feet in Reaches 5 and 6.

Escape cover for salmonids occurred primarily in pools under woody debris, overhanging vegetation and undercut streambanks. The Escape Cover Index (linear feet of escape cover for yearling- sized fish per linear feet of stream channel) for pools by reach ranged from 0.036 in Reach 3 to 0.139 in Reach 2, averaging 0.095 for the six surveyed reaches (**Table 4.2**). Cover was less available in other habitat types. For comparison with higher quality salmonid streams, the pool cover index at sampling sites in Santa Rosa Creek, San Luis Obispo County, averaged 0.159 (Standard deviation (S.D.= 0.053). In 20 tributary reaches of the San Lorenzo River in 1998, the average pool cover index was 0.237 (Standard deviation (S.D.= 0.22), (Alley 1999).

Average reach embeddedness was high and ranged from 42 percent to 54 percent in reaches 1 through 6 (**Table 4.2**). The percent of habitats in each reach containing cobbles was generally low and ranged between 2 percent in reach 3 and 32 percent in the middle branch (Reach 6). Percent sand and silt on the streambed was generally high (**Table 4.2**). Glides were the worst in having the finest material in Reaches 1-4. Pools were next in their percentage of fine material in Reaches 1, 2 and 4, and had more fine material than any other habitat type in Reach 6. As expected, riffles had the lowest percentage of fine material, but were still consisted of mostly sand and finer materials, ranging from 60 to 76 percent by reach. For a detailed discussion of the habitat physical characteristics see D.W. ALLEY & Associates report, May 2000.

### 4.4.3 Steelhead migrational barriers

*(Alley, May 2000, pages 27-28)*

Nine steelhead migrational barriers were mapped in Arana Gulch with the subsequent elimination of the furthest downstream migrational barrier during the winter months of 2000 (**Figure 4.1**). Each migrational barrier is briefly discussed below with site numbers given to each barrier as well as the original site designation given in D.W. Alley, May

2000. Site numbers refer to potential enhancement projects discussed later in this report.

#### *4.4.3.1 Culverts at the mouth of Arana Gulch (near Brommer Street)*

The culvert system at the upper end of the estuary poses no difficulty for steelhead passage. The 4 culverts are 72 inches in diameter and 300 feet long. They were constructed at 2 feet below the grade of the stream prior to construction of the upper harbor (Hecht 1982). They are at an elevation such that even at low tide they are inundated sufficiently to provide adequate passage depth. The culverts are unlighted. However, since they are not an obstruction and steelhead typically migrate at night (both adults and smolts), we anticipate no difficulty in passage. In our smolt trapping on the San Lorenzo River in 1987-88, down-migrants did not appear in the trap until after dark. They were no longer trapped after dawn (Smith and Alley, unpublished data). There is concern that smolts may be inhibited from migrating down through the culverts if artificial lights were operating within the culverts at night. When Smith (1992) operated an adult trap on Waddell Creek in 1991-92, he captured adults only at night (personal communication). We have observed adults migrating over obstructions and up fish ladders during the day. However, this may be unique to obstructions, where more light is required to negotiate the obstruction. Dr. Smith has observed the culverts in question and agrees that they pose no passage impediment for steelhead.

Lauman (1976) stated that research has not indicated that lighting of long culverts is necessary to achieve adequate fish passage. Orsborn and Powers (1986) stated that light intensity appears to function as both a stimulus and an inhibitor. They stated that light is necessary for salmonids to ascend obstacles, but in unobstructed waters, a preference for darkness is seen (Banks, 1969). In Orsborn's and Powers' treatise, they stated that Stuart (1962) suggested that fish may be able to perceive the contrast between light and shade to locate obstructions and to indicate the height of barriers. In his observations, all leaping stopped at the onset of darkness. Orsborn and Powers expressed the need for incident light in fish ladders so that fish could orient towards surfaces of lighter colors and move through and out of the ladder. However, the culverts in the upper estuary of Arana Gulch are not obstructions (unless debris collects at the upper end from stormflows) and do not require a jump. Consideration should be given to constructing a trash-rack at the upstream end of the culverts to prevent the culverts from plugging with debris.

Flap gates or other structure that would close off the culverts in response to the tides should not be constructed because they may obstruct the downstream end of the culverts.

#### *4.4.3.2 Site 4: Culverts on eastern branch (SMB 5)*

Site 4 consisted of two 4-foot diameter culverts in the creek, which were jammed with woody debris at the upstream end. This old stream-crossing site was 50 feet upstream of site 5. Its GPS coordinates were N37 00.491', W121 58.787'. The barrier created a 4-foot drop without a jump pool and is probably impassable to adult steelhead (**Figure 4.1**).

#### *4.4.3.3 Site 5: Logjam on eastern branch (SMB 4)*

Site 5 was a 7-foot high redwood log-jam, 90 feet upstream of site 4 and just downstream of the Chaminade's Blue Trail (channel mile 3.74) (**Figure 4.1**). Stormflows would pass under and through this jam. No jump pool was present below. This barrier was probably impassable.

#### *4.4.3.4 Site 6: Logjam on eastern branch (SMB-3)*

Site 6 was a log jam located approximately 0.38 miles upstream of Paul Sweet Road crossing near the end of Reach 5 (channel mile 3.74) (**Figure 4.1**). There was a large concrete structure on the left streambank (looking downstream), with a stable redwood rootwad and woody debris stacked upstream. A 2-foot drop was present, followed by a 3-foot drop, 5 feet upstream. No jump pool existed below. The jam was probably passable at 20-30 cfs.

#### *4.4.3.5 Site 7: Culvert at Paul Sweet Road crossing (SMB 2)*

Site 7 (Figure 6.1) was located at the Paul Sweet Road culvert crossing (channel mile 3.36) at the boundary between reaches 4 and 5 (**Figure 4.1**). The concrete box culvert was 23 feet long, 4 feet wide and 3 feet high. The drop below the culvert was 4 vertical feet to the water surface, with water passing over concrete fragments that extended approximately 4 feet beyond the culvert outlet. This created an approximate 6-foot long cascade over the fragments into a plunge pool with a mean depth of 0.6 feet and a maximum depth of 0.9 feet. The pool was 9 feet wide and 13 feet long. The concrete fragments, combined with the shallow plunge pool made this barrier formidable, if not completely impassable except under rare circumstances. The box culvert (inside) also created passage problems.

#### *4.4.3.6 Site 8: Series of 3 logjams on the central branch (SMB 9)*

At the upstream end of reach 6 on the central branch, site 8 consisted of 3 woody debris jams within 110 feet of channel. It is located roughly 2,050 feet from the mouth (channel mile 0.39) (**Figure 4.1**). No helpful jump pools existed here. The lower logjam partially blocked the channel, with it extending 10 feet upstream and having a gap at the base at the lower end. This gap could become jammed after more debris collected there. The middle logjam is 60 feet upstream with a 2-foot drop in streambed elevation. The uppermost logjam was fifty feet upstream of the middle jam and is characterized by a 5-foot high jam in a narrow, incised channel that is likely impassable. The stream gradient had increased in this reach to make such drops common.

#### *4.4.3.7 Site 9: Logjam on the central branch (SMB 8)*

Further upstream on the central branch, site 9 was located 1,951 feet from the mouth (channel mile 0.37) (**Figure 4.1**). It was a 6-foot high logjam, creating a 3-foot drop in bed elevation into a plunge pool with a mean depth of 0.9 feet and a maximum depth of 1.9 feet. The 2- to 3-foot diameter redwood log at the center of the jam appeared very stable. The jam was 8 feet long and had GPS coordinates of N37 00.253’, W121 59.271’. A “NO DUMPING” sign and road pull-out were adjacent to the stream at this point.

#### *4.4.3.8 Site 10: In-channel rip-rap on the central branch (SMB 7)*

Located on the central branch, site 10 was 1,357 feet from the mouth (channel mile 0.26) (**Figure 4.1**). Here, a 2-foot high wall of rip-rap formed a partial dam 5 feet wide across the channel. The wall forced the streamflow around alders to create a 5-foot wide, 2-foot high chute across the root system. Its GPS coordinates were N37 00.152', W121 59.178'. This barrier was likely passable at 10-15 cfs.

#### *4.4.3.9 Site 12: Perched driveway culvert (SMB 6)*

Located roughly 112 feet upstream of the confluence with the eastern branch, site 12 consists of a perched driveway culvert which is estimated to be impassable under most flow conditions. The channel downstream of the culvert has downcut about four feet. The GPS coordinates for this site were N36 59.988', W121 59.196'.

## 4.5 Fish Sampling and Population Estimates

*(Alley, May 2000, pages 10-13)*

### 4.5.1 Fish sampling sites and methods

Sampling sites were chosen to represent typical habitat types within each reach in 1999. Sampling sites are shown in **Figure 4.1**. Reach averages for pool habitat characteristics such as depth, length and escape cover were used to choose sampling pools that represented the reach averages. Because steelhead tend to congregate in a few of the best pools in a stream like Arana Gulch, with its overall poor habitat, at least one deeper pool was sampled in each reach so as to adequately sample some better habitat along with the bad. All non-pool habitat was extremely poor and similar from reach to reach. Therefore, run, riffle and glide habitat was sampled adjacent to the pools chosen for sampling. At least three pool habitats were sampled at each site.

Five sites were sampled in five reaches likely to be accessible to steelhead. There were four mainstem sites in the lower four reaches and one site in the perennial middle branch tributary. In addition, 326 feet of habitat was sampled in the fifth mainstem reach above the Paul Sweet Road culvert despite the likeliness of being inaccessible to steelhead. It was sampled with one electrofishing pass to confirm the presence of salmonids. The primary focus of the sampling was to obtain the best estimate of steelhead / rainbow trout production in Arana Gulch where steelhead likely had access. The average stream length sampled at four mainstem sites was 357 feet in 1999. In the perennial middle branch tributary, 70 feet was electrofished.

## 4.5.2 Methods for calculation of juvenile steelhead densities at sampling sites

### *4.5.2.1 Juvenile steelhead densities at sampling sites*

Steelhead densities were determined by electrofishing at sampling sites by the multiple-pass depletion method. Sampling occurred on 4-5 November 1999, after Arana Gulch had been habitat-typed. Three passes were made in each habitat with its upper and lower boundary blocked off with nets. A total of 34 habitats were sampled at 5 sites, 16 of which were pools.

Depletion estimates of steelhead density were applied separately to two age-classes in each habitat type at each site. The densities of Y-O-Y fish were estimated separately from yearling (1+) and older juveniles (2+). The number of fish in each age class was recorded for each pass. The age-class boundary was determined for each sampling site, based on the length frequency histogram of captured fish at that site. At each sampling site, the dividing point between age classes was a break in the length- frequency distribution of fish lengths. Age class information was used to determine annual salmonid production. Length-frequency histograms and field measurements of salmonid Standard Length can be found in **Appendix A, D.W. ALLEY & Associates, May 2000.** For a detailed discussion of age-class boundary characteristics for salmonids sampled in Arana Gulch and other Santa Cruz Mountain streams see D.W. Alley, May 2000, page 11.

The depletion model is typically used with multiple-pass electrofishing data to estimate the number of fish in each sampled habitat type. The model is typically applied separately to two size categories; those less than (<) 75 mm SL (3 inches) (Size Class 1), those equal to or greater than (**= >**) 75 mm SL (Size Classes 2 and 3) or to age classes (young-of-the-year and older fish). However, in Arana Gulch the salmonid densities were so low and electrofishing was judged so effective in capturing all fish in each habitat, that the total count of salmonids in each size class captured after three passes was considered the density estimate for the habitat. Using the depletion model would have unrealistically inflated the actual fish density when dealing with such small numbers.

#### *4.5.2.2 Juvenile steelhead densities by Reach*

For Reaches 1-4 and 6, the number of juvenile steelhead estimated by age class per foot of stream in each sampled habitat type was multiplied by the number of feet of that habitat type in each reach. Then the number of fish estimated in each habitat type of the reach was added to the number of fish in the other habitat types to obtain reach totals.

### 4.5.3 Method for calculating an index of returning adult steelhead

Population estimates of each of the three size classes of juvenile steelhead were entered separately into the Dettman population model (Kelley and Dettman 1987) to obtain an index of returning adults. The predicted number of returning adults was based on survival rate of different size classes of juveniles returning as adults to Waddell Creek during the period, 1933-42 (Shapovalov and Taft 1954). It was found that steelhead survival rate to spawning adults increased exponentially with increasing size of steelhead smolts (J. Smith, personal communication). Kelley and Dettman (1987) developed a model based on the Waddell Creek relationship of average size of each age class as smolts and survival to returning adult. They estimated survival of juveniles from a reasonable estimate of densities in Waddell Creek in the fall to the down-migrant smolt stage for the different age classes. The relationship derived from Waddell Creek data was:

$$\text{Fraction of Survival} = (0.067)\ e\ {}^{\wedge (0.025)\ (\text{Fork Length of Smolt})}$$

Input data required for the Dettman model is an estimate of juvenile steelhead numbers by age class in the fall of the year sampled. The size classes were divided according to year class sizes typically found in Waddell Creek, based on Dr. Jerry Smith’s experience.

Young-of-the-year fish were up to 75 mm Standard Length. Yearlings were from 75 mm to 150 mm Standard Length. Steelhead were included in the 2+ age class if larger than 150 mm Standard Length.

To predict the number of returning adults with the Dettman Model, the Waddell Creek rate of return during the period 1933-42 was used with the number of juvenile steelhead by age/size class per foot of each habitat type in each reach of Arana Gulch. Returning adults consisted of two categories. The first category consisted of first time spawner; the second category consisted of the total number of returning adults expected with a 20 percent repeat spawning rate. The model emphasized the increased survival rate expected for larger size classes of juvenile steelhead.

To make a more realistic estimate of returning adults from juveniles present, estimates derived from the Dettman model were reduced by 50 percent, based on an estimate of returning adult steelhead to Waddell Creek in 1991-92 (Smith 1992). An underlying assumption in the 50 percent reduction of survival rate was that rearing habitat in Waddell Creek is currently capable of producing 1930's levels of juvenile smolts over the long term-this was judged likely by Dr. Smith (personnel communication). A complicating factor in applying the model to Arana Gulch was that some of the larger "steelhead" might have been resident rainbow trout, which had opted to remain in freshwater instead of out-migrating to sea. If so, the reduction factor of 50 percent may be too low.

Whether the reduction factor should be 50 percent or something else, the model provides an annual adult index for comparison to other years of production and to other streams. It is important to note that our annually applied model uses the same constant survival rates from juveniles to adults, and our correction factor is also constant. However, there are annual fluctuations in ocean survival that are impossible to account for. Despite this, the conservative nature of our estimate of adult returns will not likely over-estimate the actual adult returns from juvenile production.

## Table 4.3. Site Densities of Juvenile Steelhead by Age Class at Monitoring Sites in Arana Gulch, 1999. (Resident rainbow trout may be present at all sites).

| **Sampling Site*** | | **Fall Densities, 1999**** | | |
|---|---|---|---|---|
| *Age* | | *Young-of-Year* | *1+ and Older* | *Combined* |
| Above Capitola Ave | 1 | 0.2 | 1.6 | 1.8 |
| | | | | |
| Near Tennis Court | 2 | 0 | 0.3 | 0.3 |
| | | | | |
| Above Brookwood Drive Crossing | 3 | 1.9 | 3.4 | 5.3 |
| | | | | |
| Above Central Branch | 4 | 5.8 | 1.6 | 7.4 |
| | | | | |
| Central Branch | 5 | 12.9 | 4.2 | 17.1 |

* Refer to Table 1 for Site description and Figure 1 for Site Locations.
** Densities in number of fish per 100 feet of stream.

## Table 4.4. Reach-wide Juvenile Steelhead Densities by Age Class in Reaches of Arana Gulch, Based on Habitat Proportions in 1999. (May include resident rainbow trout.)

| **Reach Number**** | | **Fall Densities, 1999*** | | |
|---|---|---|---|---|
| *Age* | | *Young-of-Year* | *1+ and Older* | *Combined* |
| 1 | | 0.5 | 1.0 | 1.5 |
| | | | | |
| 2 | | 0.0 | 0.1 | 0.1 |
| | | | | |
| 3 | | 1.8 | 3.6 | 5.4 |
| | | | | |
| 4 | | 7.3 | 1.7 | 9.0 |
| | | | | |
| 5 | | - | - | - |
| | | | | |
| 6 | | 9.3 | 3.1 | 12.4 |

* Densities in number of fish per 100 feet of stream.
** Refer to Table 2 for Reach Designations and Figure 1 for Reach Locations.

Data from D.W. Alley and Associates, 2000, Table formatted by Balance Hydrologics, Inc.

## Table 4.5. Rating of Steelhead Rearing Habitat For Small Central Coast Streams (Smith, 1982)

| Rearing Habitat Rating | | Number of Smolt-Sized* Fish per 100 feet of Stream |
|---|---|---|
| Very Poor | | less than 2 |
| Poor | | from 2 to 4 |
| Below Average | | from 4 to 8 |
| Fair | | from 8 to 16 |
| Good | | from 16 to 32 |
| Very Good | | from 32 to 64 |
| Excellent | | 64 or more |

Notes:
* Drainages sampled included the Pajaro, Soquel and San Lorenzo systems, as well as other smaller Santa Cruz County coastal streams that totaled more than 100 sampling sites in 1981.
** Smolt-sized fish were at least 3 inches (75 mm) Standard Length.

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## Table 4.6. Estimated Number of Juvenile Steelhead By Reach in Arana Gulch, 1999, Divided into Age and Size Classes (some of the larger fish may be resident rainbow trout)

| Reach Number** | Size Classes | | | | Age Classess | |
|---|---|---|---|---|---|---|
| | *< 75 mm* | *>= 75 mm* | *>= 150 mm* | *Combined Sizes* | *Young-of-Year* | *1+/2+* |
| 1 | 10 | 8.0 | 14.0 | 32.0 | 10 | 22 |
| 2 | 0 | 0.0 | 2.0 | 2.0 | 0 | 2 |
| 3 | 24 | 70.0 | 24.0 | 111.0 | 39 | 78 |
| 4 | 160 | 38.0 | 0.0 | 138.0 | 160 | 38 |
| 5 | - | - | - | - | - | - |
| 6 | 160 | 42.0 | 21.0 | 265.0 | 190 | 63 |

Notes:
* Reach designations are defined in Table 2 and mapped in Appendix A

99005 DA formatted fisheries tables.xls, Table 4.5 and 4.6 Data from D.W. Alley and Associates, 2000, Table formatted by Balance Hydrologics, Inc.

### 4.5.4 Densities and steelhead/rainbow trout production: results

*(Alley, May 2000, pages 29-33)*

The density of fish sampled at the site and reach scale differed because the proportion of habitat types at sites was different than the proportion for the entire reach. If more pool habitat were sampled at a site than existed in a reach, the site density would be higher because pools contained most of the fish.

Atypical of most reaches in Santa Cruz Mountain steelhead streams, Reaches 1 to 3 on the mainstem of Arana Gulch had higher site and reach densities of yearling and older steelhead / rainbow trout than Y-O-Y juveniles (**Tables 4.3 and 4.4**). Based on fish scale analysis, some salmonids were 2 and 3 years old in Reach 1, indicating a freshwater, rainbow trout life history for some fish. Reach 4 on the mainstem and Reach 6 on the central branch had higher densities of Y-O-Y steelhead than older ones. A large salmonid in Reach 6 was aged at 2 years from scale analysis. Young of year steelhead population were very low in Reaches 1-4 and 6, with none detected in reach 2. Young of year steelhead reach densities were less than 1 fish per 100 feet in reach 1, about 2 fish per 100 feet in Reach 3, about 6 fish per 100 feet in Reach 4 and nearly 13 fish per 100 feet in Reach 6 (**Table 4.4**). Overall stream density of Y-O-Y steelhead was 3.0 fish / 100 feet.

Reach 1 produced an estimated 1.6 fish per 100 feet in the yearling and older age classes. Reach 2 had an estimated 0.3 fish per 100 feet (**Table 4.4**). Reach 3 had a density of 3.4 fish per 100 feet. The density of yearlings and older salmonids lessened in reach 4 to only 1.6 fish per 100 feet. The central branch had the highest density of non-Y-O-Y salmonids at 4.2 fish per 100 feet. Overall stream density of yearling steelhead and older salmonids was 1.6 fish per 100 feet.

In comparing 1981 county-wide site densities to reach densities of smolt-sized fish >= 75 millimeter SL (**Table 4.5**), Reaches 1, 2 and 4 were rated “very poor” and reach 6 in the central branch was rated “poor.” In these reaches, smolt-sized fish corresponded to yearlings and larger salmonids. In Reach 3, two captured Y-O-Y steelhead were smolt-sized, making the reach density of fish >= 75 millimeter SL to be 4.3 fish per 100.

## Table 4.7. Summary of Salmonid Densities by Age Class and Habitat Type in the Reaches Likely to be Accessible to Steelhead in Arana Gulch, 1999.

| Stream Reach | Juvenile Steelhead Habitat | Population Density | | Composition of Population | |
|---|---|---|---|---|---|
| | *linear feet* | *Age 0+* | *Age 1+/2+* | *Age 0+* | *Age 1+/2+* |
| Reach 1: pool | 1044 | 0 | 0.0217 | 0 | 22 |
| Reach 1: riffle | 95 | 0 | 0 | 0 | 0 |
| Reach 1: run | 852 | 0.0118 | 0 | 10 | 0 |
| Reach 1: glide | 177 | 0 | 0 | 0 | 0 |
| | | | | | |
| Reach 2: pool | 447 | 0 | 0.0055 | 0 | 2 |
| Reach 2: riffle | 78 | 0 | 0 | 0 | 0 |
| Reach 2: run | 451 | 0 | 0 | 0 | 0 |
| Reach 2: glide | 942 | 0 | 0 | 0 | 0 |
| | | | | | |
| Reach 3: pool | 946 | 0.0417 | 0.0753 | 39 | 72 |
| Reach 3: riffle | 0 | 0 | 0 | 0 | 0 |
| Reach 3: run | 699 | 0 | 0.0097 | 0 | 7 |
| Reach 3: glide | 537 | 0 | 0 | 0 | 0 |
| | | | | | |
| Reach 4: pool | 433 | 0.1733 | 0.0533 | 75 | 23 |
| Reach 4: riffle | 180 | 0 | 0 | 0 | 0 |
| Reach 4: run | 1567 | 0.0147 | 0 | 23 | 0 |
| Reach 4: glide | 2625 | 0.0235 | 0.0059 | 62 | 15 |
| | | | | | |
| Reach 6: pool | 761 | 0.25 | 0.0834 | 190 | 63 |
| Reach 6: riffle | 64 | 0 | 0 | 0 | 0 |
| Reach 6: run | 443 | 0 | 0 | 0 | 0 |
| Reach 6: glide | 783 | 0 | 0 | 0 | 0 |
| | | | | | |
| Totals | 13,124 feet | - | - | 399 | 204 |

Data from D.W. Alley and Associates, 2000, Table formatted by Balance Hydrologics, Inc.

Therefore, Reach 3 was rated "below average." These smolt-sized fish have most value when considering the number of juveniles that may survive to return as adults.

Reach densities of all sizes combined in Reaches 1 and 2 were extremely low at 1.5 and 0.1 fish per 100 feet, respectively (**Table 4.4**). Densities steadily increased in Reaches 3, 4 and 6, with densities of 5.4, 9.0 and 12.4 fish per 100 feet, respectively.

In 1999 the Y-O-Y production was 399, with Reaches 4 and 6 producing 88 percent of the juveniles (**Table 4.6**). The size class 1 production was 384. In 1999 the yearling and older production was 204, of which Reaches 3, 4 and 6 produced 88 percent (**Table 4.4**). The size class 2-3 production was 219. In 1999 the estimated salmonid population (all sizes combined) was 603 (**Table 4.6**). A summary of juvenile steelhead / rainbow trout by reach and habitat type is provided in **Table 4.7**.

### 4.5.5 Index of adult steelhead returning to Arana Gulch: results

*(Alley, May 2000, page 34)*

Using the Dettman model (Kelley and Dettman 1987) of Waddell Creek return data (Shapovalov and Taft 1954) and the 50 percent reduction factor, the number of returning adults was calculated from estimated production of juveniles in Reaches 1-4 and 6. The estimated adult returns from 1999 salmonid production was 12-13 adults, with a model prediction of 25 and a 50 percent reduction.

The estimated number of returning adults from the Dettman model was probably high before the 50 percent reduction was factored in. We have no data to indicate the actual survival rates of smolts to adulthood or the percent of repeat spawners. Additionally, the model assumed that all salmonids **=>** 75 mm SL will smolt and out-migrate. Some of the larger salmonids in Arana Gulch may have remained in freshwater, opting for the rainbow trout life history. But for comparison purposes in succeeding years, we have an index of returning adults. The model provides insight and a potentially conservative estimate of adult returns, assuming the return rate will not change significantly in the future.

## 4.6 Habitat Evaluation

*(Alley, May 2000, pages 35-36)*

### 4.6.1 Discussion of habitat conditions

In Arana Gulch, spawning habitat was extremely poor because substrate at the tails of pools where spawning is likely to be attempted was primarily fine silt and fine sand. Spawning gravels were essentially non-existent in hydraulically suitable spawning locations. Spawning conditions were so poor that egg mortality may severely limit young-of-the-year salmonid densities in Arana Gulch and ultimately regulate the number of steelhead smolts that may return as adult steelhead. Poor spawning success and limited rearing habitat (shortage of cover and food) were probable causes of low numbers of Y-O-Y's in Reaches 1-3. The presence of large individuals in these reaches may have resulted in predation of swim up fry in the spring, resulting in poor recruitment of Y-O-Y's. Poor spawning success, likely poor spawning access and poor rearing habitat (a shortage of cover and food) in Reaches 4-6 were likely explanations for low densities of Y-O-Y's there.

Salmonids in Arana Gulch probably rely heavily on insects falling into the stream from overhanging riparian vegetation as a source of food. Low densities of yearling and older salmonids were likely due to poor rearing habitat in shallow pools, limited cover and a shortage of food. Water depth affords cover when it becomes greater than 1.5 feet.

Field reconnaissance after the January 2000 stormflow indicated an increase in larger substrate in riffles, affording better aquatic insect habitat than seen previously. These periodic improvements in coarse substrate after large stormflow events are typical of coastal streams. However, considerable fine sediment also entered the channel to be rearranged during ensuing stormflows. This sediment may bury much of the coarser substrate before the winter rainy season ends. Streambed elevation in Reach 4 was more than 2 feet lower than after the 1982 storm event indicating that perhaps the watershed is recovering from massive sedimentation from that storm, and that substrate conditions may improve somewhat in the future.

Rearing habitat was generally limited due to shallow pool depths. In some instances, pool depth is controlled by the presence of scour objects. In Arana Gulch, scour objects such as bedrock and large boulders were lacking. Therefore, overall measured pool depths were shallow. Concrete structures and shopping carts were scour objects in reaches 1 and 2, with woody debris and tree rootwads being most important in upstream reaches. The fine sediment load filled in a high percentage of available pool habitat. If sediment input to the stream was reduced, pool depth and habitat quality may improve. However, the preponderance of shallow glides and fine sediment would not improve without increased natural or artificial introduction of scour objects to the system. Field reconnaissance after the January 2000 storm event indicated that deeper pools were scoured in reaches 4 and 5. Thus, rearing habitat was improved at least for the short-term. The escape cover index for all reaches in 1999 was on the low side for small coastal streams. Most Arana Gulch reaches had values close to 0.1 and averaged 0.095 (see Alley, May 2000, Figure 3), while 11 of 12 sampling sites in Santa Rosa Creek in 1998 had cover indices that ranged between 0.1 and 0.25, averaging about 0.16 (see Alley, May 2000, Figure 4; Alley 1999). In San Lorenzo River tributaries during 1998, only 4 of 20 reaches had cover indices less than 0.1, averaging over 0.2 (see Alley, May 2000, Figure 5; Alley 2000).

### 4.6.2 Discussion of water quality and effects on salmonids

There are many central coast examples of steelhead surviving and growing well at water temperatures above 21ºC. Many of these come from coastal lagoons and lower reaches of unshaded drainages, where food is abundant and growth rate is rapid.

As part of annual steelhead monitoring on the San Lorenzo River in 1997-2001, Alley (2001) measured water temperatures of 21ºC+ in August and September in the lower and middle River from Paradise Park to Brookdale in a number of reaches, except during the cool and high-flow summer of 1998. These reaches provide habitat for large yearling steelhead and fast-growing young-of-the-year fish.

Steelhead have been detected at water temperatures as high as 26º C in Pescadero Creek Lagoon (San Mateo County) and at 24º C on a regular basis in Pescadero and San Gregorio Lagoons (San Mateo County) and Uvas Creek in Santa Clara County (J. Smith personal comm.).

It has been reported that rainbow trout (same species as steelhead but with a freshwater life history pattern) survive temperatures from 0 to 28 C, provided that they are gradually acclimated to higher temperatures and that saturated oxygen conditions exist (Moyle 1976). Rainbow trout in Big Sulphur Creek, tributary to the Russian River, are often exposed to stream temperatures in excess of 20º C (Price et al. 1978). (Steelhead inhabited the Creek, downstream of where these data were collected.) This is particularly the case in Big Sulphur Creek below Little Geysers Creek where daily *minimum* temperatures sometimes exceed 20º C. Daily stream temperatures fluctuate up to, and perhaps greater than 28º C in Big Sulphur Creek in summer rainbow trout habitat (Price et al. 1978).

In Arana Gulch, water temperature is not likely to restrict steelhead activity to fastwater habitat and require excessive food intake until it reaches 21ºC (70ºC). Arana Gulch had limited aquatic insect habitat and likely limited food supply for steelhead. However, the lethal level for steelhead would probably be above 25ºC (77ºF) for several hours during the day. The water quality goal should be to maintain water temperature at 21ºC or lower in Arana Gulch.

Steelhead have been observed at oxygen levels below 4 mg/L in many locations along the central coast. Steelhead were captured from isolated pools at 3 mg/L oxygen and 16º C water temperature in Waddell and Redwood creeks in Santa Cruz and Marin counties, respectively (J. Smith personal comm.). During the period 16-17 August 1989 on the Carmel River, juvenile steelhead were observed in pools at three different sites where oxygen ranged from a minimum of 2-4 mg/L at the different sites before dawn to a maximum of 14-15.5 mg/L (super saturation) in the afternoon, with water temperature ranging from 61º F (16.1º C) in the morning to 72º F (22.2º C) in late afternoon (D. Dettman personal comm.). Bullfrog tadpoles were observed gulping air at the surface when oxygen levels were low at these Carmel River sites.

In San Simeon Creek Lagoon in 1993, 3 steelhead were observed at monitoring station 2 on 10 June, and 5 steelhead were observed on 29 July at the same location (Alley personal observation). On 11 June the maximum oxygen concentration at that station was 2.7 mg/L at 0603hr (at the surface), with water being 14º C (Alley 1995). On 8 July the maximum oxygen level was 1.7 mg/L with water at 16º C at station 2 at 0525 hr (Alley 1995). On 29 July the oxygen concentration was at a maximum of 2.82 mg/L with water temperature of 17.5º C at 0530 hr (Alley 1995). An adult steelhead was observed in the lagoon during sampling on 10-11 August (J. Nelson, CDFG, personal comm.).

At low temperatures, it was reported that rainbow trout withstand oxygen concentrations of 1.5 to 2 mg/L (Moyle 1976). Rainbow trout were found in Penitencia Creek (Santa Clara County) at 3 mg/L oxygen and 20º C water temperature (J. Smith personal comm.). Over 100 rainbow trout/ steelhead were observed during snorkeling in pools, runs and riffles on 24 July 1976 in Deer Creek, Tehama County, in water with a daily temperature fluctuation of 19-24º C (Alley 1977).

Steelhead/ rainbow trout in Arana Gulch can likely survive oxygen levels in the early morning as low as 2 mg/L. The water quality goal for Arana Gulch should be to maintain oxygen levels above 5 mg/L because activity is likely restricted at lower oxygen levels.

# 5. SEDIMENT ASSESSMENT

*This chapter will present the methods and results of the sediment assessment. It begins with the purpose and need of the sediment assessment. Next, the methods used for the assessment and the limitations to those methods are discussed. The chapter finishes with results from field identification of watershed sediment sources related to channel bank, bed and hillslope instabilities. The source types are presented in the chapter by stream branch and reach. Not all source types were found to occur in all branches of Arana Gulch.*

## 5.1 Purpose and Need

In an ideal situation where anthropogenic influences are not present, stream beds and banks are built from, and maintained by the sediment load produced and delivered to the channel by the surrounding landscape. The processes of sediment production and delivery are closely linked to regional variables such as climate, geology, tectonics and flora. Sediment production and delivery processes include, but are not limited to mass movements of slope material (slides, flows and heaves), channel bank failures and local incision of channel bed. A change in how, or how often these processes occur or the introduction of a new process could ultimately lead to an indefinite change in the condition of the channel beds, banks and hillslopes in a watershed.

Beyond the 1982 report, historic accounts of channel and watershed conditions are limited to those reported by Arana Gulch resident Robert Bixby (Bixby, 1999). Bixby (1999) reports that the depositional volume of silt sized material at several locations in the watershed have increased since 1994. He also notes that deposition of silt sized material at the Brookwood Drive crossing (**Figure 3.1**) during water years 1982 and 1983 was visually less in volume than that which was deposited at the same location in water years 1997 and 1998. The storm of January 4, 1982 resulted in flood flows of similar magnitude to those generated by the storm of December 23, 1955. Collectively, the 1955 and 1982 flood events account for the record instantaneous, peak flows for most regional basins since the late 1930's.

There were several purposes for conducting a sediment assessment in Arana Gulch:

1. To establish baseline conditions for channels and hillslopes in Arana Gulch,
2. To map and estimate volumes and rates of material contributed by major sediment sources to the channel,
3. To construct sediment delivery estimates for most of the past 20 years calibrated by harbor dredging records and field estimates of volumes and rates of material contributed to the channel,
4. To identify the size range of material found on the bed, banks and flood plains of Arana Gulch, and
5. To characterize sediment sources in the watershed which have potential for management through implementation of restoration activities.

## 5.2 Methodology

The sediment assessment was not conducted under ideal conditions due to a lack of scientifically based, historic data for streamflow, sediment transport rates and past watershed conditions. Under ideal conditions, rates of watershed sediment production and delivery are calculated and calibrated by actual measurements of suspended and bedload sediment transport rates over several, annual hydrographs. Since such historic, ideally collected data does not exist for Arana Gulch, other methods were explored and used to address the purposes of the sediment assessment. During this exercise, field visits are also made to map any large, discrete sources of sediment in the watershed and to observe tributaries during storm events.

### 5.2.1 Channel sediment sampling

Sediment samples were collected at several locations in the watershed to establish the size range of material which was deposited on the channel bed, banks and floodplains in the last several years. Locations and type of samples include:

- the upstream end and the downstream end of high school sediment basin (2 bed samples),
- a laterally deposited bar 300 feet downstream from the Brookwood Drive crossing (2 high flow bar samples)
- downstream side of the Brookwood Drive crossing (2000 high water sample),
- on the central branch of Arana Gulch roughly 500 feet upstream from the confluence (1 bed sample), and
- on the eastern branch, 100 feet downstream of the Paul Sweet Road crossing (2 bed samples)

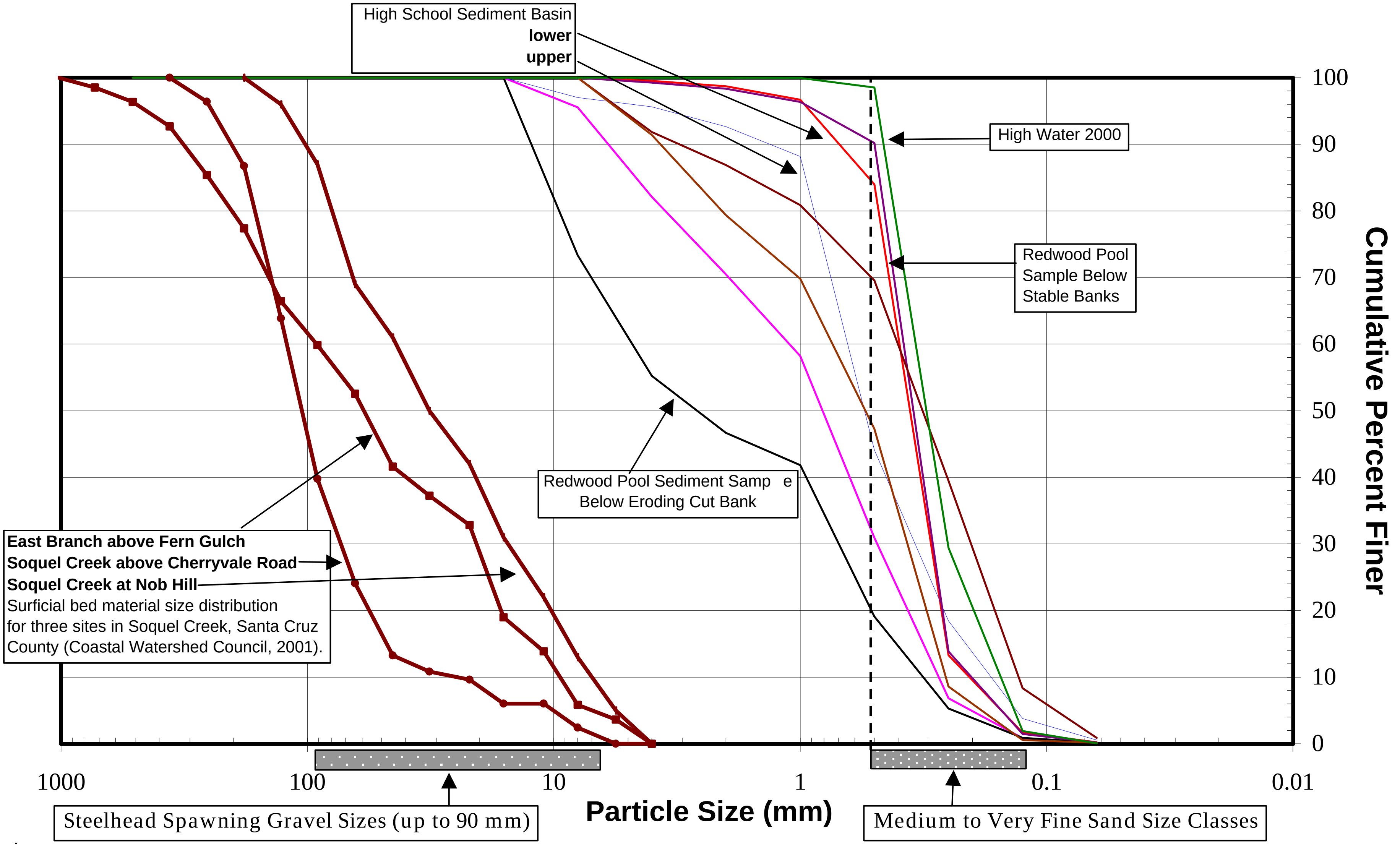
Bed samples were collected with a ¾ -inch orchard auger while bar and high water elevation samples were collected with a 1-liter core sampler. Samples were analyzed with a stack sieve.

### 5.2.2 Sediment source mapping

Balance Hydrologics, Coastal Watershed Council and D.W. Alley and Associates staff mapped and measured sources of active channel and hillslope instabilities throughout most of the watershed. Sources were catalogued on an enlarged orthophoto of the watershed with rough volumes of material lost and rate of loss noted.

### 5.2.3 Synthetic streamflow and sediment modeling

Synthetic streamflow and total sediment discharge records were calculated for Arana Gulch for the period 1980 through 1997. These records are useful tools when planning for fishery enhancement projects and design of sediment source management



Balance Hydrologics, Inc.

**Figure 5.1**: **Particle-size distribution of sediment samples from the channel and high water marks of Arana Gulch**. Note that the 50 percentile for 6 our of 8 samples falls within or near the medium to fine sand class sizes and that sizes needed for steelhead spawning were found in only three samples, one being situated below an eroding road bank. Three samples collected from nearby Soquel Creek are shown for comparison. The size distribution curves . illustrate that the coarsest material found in Arana corresponds to the finest size fractions sampled in Soquel Creek

99005 Sediment Samples Plot.xls, Figure 5.1

alternatives. The records also put current sediment transport trends into historical context and further enabling the development of appropriate management alternatives. **Appendix A** of this report discusses the methods used in constructing the synthetic records and presents the resulting data and estimated watershed sediment budget based on land-use. For our purpose here, we will briefly discuss the limitations that are inherent to our synthetic modeling approach[21].

Our synthetic record of streamflow is based on regional relationships and streamflow data collected by the United States Geological Survey (USGS) on Soquel Creek[22]. Using such relationships and regional data imposes storm-related characteristics of response measured at the Soquel Creek gage to Arana Gulch. Secondly, streamflow correlation is based on a single streamflow event. Therefore, the relationship generated from a single event is meant to capture relationships generated over a wide range of possible streamflow values.

Our synthetic sediment delivery model is based on 4 separate elements:

1. Discharge-sediment transport relationships for regional watersheds,
2. An estimate of peak streamflow on Arana Gulch during the January 1982 storm event,
3. An estimated volume of sediment deposited in the north harbor during the January 1982 storm event, and
4. Annual, dredging volumes for the north harbor for the period 1980 through 1997.

These model elements have several built in limitations. First, the initial estimate of the discharge-sediment transport relationship for Arana Gulch established the characteristics between streamflow and sediment discharge in the model. Therefore, the

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[21] When this final plan went to press, we were actively collecting sediment discharge measurements to calibrate our synthetic modeling. When sufficient data has been collected we will write a brief memo detailing the updated data results.

[22] Soquel Creek at Soquel, USGS Gage # 11160000

model relationship between streamflow and sediment discharge does not vary from year to year. Second, the volume of material dredged from the harbor each year does not represent the total volume of material transported to the harbor each year dredging occurred. This is because the finest size fraction of material transported to the harbor is transported out of the harbor by tidal dynamics and winter storm flows (see Hecht, 1982, chapter 5). Lastly, the harbor dredging records are not correlated to individual streamflow events so the characteristics of sediment transport in the watershed are left to qualitative statements.

## 5.3 Channel and Floodplain Sediment Size Distributions

Results from stack sieve analysis of sediment samples collected at five locations in the watershed indicate, that at the time of sampling, various depositional zones in and adjacent to the channel consisted of sand and fine pebble sized[23] material (**Figure 5.1**). The 50-percentile grain size for 6 out of 8 sediment samples falls at or within the very fine to medium sand class sizes. No material collected was found to be larger than 11 millimeters in intermediate diameter. The high school sediment basin was found to consist of primarily medium to coarse sand class sizes. One sample was collected on the eastern branch immediately downstream of a channel bank failure that is situated directly adjacent to Paul Sweet Road. This sample was found to contain the largest sized material collected in the watershed with a 50-percentile grain size of roughly 5 millimeters-equivalent to the fine pebble size class (**Figure 5.1**). Many if not most of the gravels in this sample were identifiable as quarry rock based on their angularity and distinctive rock types; material of this type is regularly imported for road base, drain rock or septic systems.

## 5.4 Sediment Source Inventory

**Table 5.1** presents data for the total volume of sediment lost at each sediment source mapped in the watershed. These sediment sources will be discussed below.

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[23] These size classes are based on Wentworth's classification of grain size.

## Table 5.1. Total Volume of Sediment Lost for Mapped Sediment Sources in Arana Gulch, September and October 2000

| Site | Site | Dimensions[1] | Volume | Volume |
|---|---|---|---|---|
| # | *name* | *(ft x ft x ft)* | *(cucic ft)* | *(cubic yard)* |
| | | | | |
| 1 | Blue Trail dam: right bank below dam | 20x40x12 | 9600 | 350 |
| 2 | Right Bank Meanders below blue trail dam | 49x18x8 | 7056 | 261 |
| 2 | Right Bank Meanders below blue trail dam | 35x15x6 | 2520 | 93 |
| 2 | Right Bank Meanders below blue trail dam | 25x6x5 | 750 | 28 |
| 3 | Blue Trail Gullies | 200x135x9 | 243,000 | 9000 |
| 13 | Pilkington Road drainage | 48x12x75 | 40300 | 1492 |
| 14 | Disc Golf Course (see Singer 1999) | ~ 1 acre | - | ~ 1700 to 3300 |
| 15 | Large Gully beneath Disc Golf Course | 8x6x1000 | 48000 | 1778 |
| 16 | Tributary from west at lower service road | 11x11x75 | 9000 | 333 |

*Notes:*

1. Source dimensions, except for site 14, were measured by Balance Hydrologics staff in the fall of 2000
2. Sites 18 and 19 were excluded from this table because source dimensions were not measured

## 5.4.1 Channel bank and bed sediment sources

### *5.4.1.1 East branch*

Sites 1 and 2 are sediment sources on the eastern branch which are attributed to channel bank failures (**Figure 5.2; Table 5.1**). Site 1 is characterized by a right-bank failure immediately below the Blue Trail Dam while Site 2 is a series of right-bank failures found at the apex of meander loops. When bank failures occur at these two sites, sediment is directly added to the channel and thus immediately available for transport. At this point, the sediment can quickly fill in spawning gravels, locally raise the bed elevation and cause sedimentation of public and private properties.

### *5.4.1.2 Tidal reach*

Site 19[24], illustrated and discussed in Hecht, 1982, is a significant source of fine to very fine sand in lower Arana Gulch (**Figure 5.2; Table 5.1**). Ongoing bank retreat has been characterized as a series of channel bank failures due to elevated sediment pore pressure following high tide (Hecht and others, 1982). Channel bank failure associated with Site 19 results in direct addition of sediment to the channel with correspondingly rapid transport time to the north harbor (1-3 days). They found that sites nearest to the inlet culverts have experienced the largest amounts of bank collapse while the largest percentage of increase in channel width has occurred in the upstream portion of the reach (for the period 1963-1982). Subsequent work conducted by the Coastal Watershed Council in 1999 showed that the channel widening in the tidal reach has continued since 1982, more or less at the same rate although individual sections vary. The Coastal Watershed Council also found that the bed through the tidal reach has aggraded an average of two feet since 1982[25]. Bed aggradation through the tidal reach is likely the result of increased sediment supplied from the upper watershed and increased rates of bank collapse in the tidal reach.

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[24] Site 19 includes 9 cross-sections through the 1000-foot tidal reach that is above the inlet culverts to the north Harbor. Cross-sections along this reach were measured in 1963, 1974, 1982 and 1999 to calculate the rate of channel bank retreat. Please see Hecht and others, 1982 and Coastal Watershed Council, 1999 for a complete discussion of the work completed.

[25] Aggradation estimate has an assumed possible error of +0.46 feet.

### 5.4.2 Slope sediment sources

#### *5.4.2.1 East branch*

Site 3 is a large source of sediment in the eastern branch which is attributed to accelerated gully expansion in the hillslope on the eastern side of the valley above the Blue Trail footbridge. The location of Site 3 is shown in **Figure 5.2** with the volume of sediment lost given in **Table 5.1**. These gullies are directly linked to the channel by a small drainage collecting water and sediment at the base of the gullies. Gully head cutting and lateral growth are threatening to washout part of the Blue Trail and a city water line. The City of Santa Cruz has recently taken steps to stabilize the public water line that cuts across the upper portion of the gullies.

#### *5.4.2.2 West branch*

Sites 13, 14, 15 and 16 are sources of sediment from hillslope instability in the western branch. Site 13 is located on Pilkington Drive immediately east of the large landslide near the entrance to the equestrian center. The current, rough dimensions of the gully are five feet in width, five feet in depth and ten to fifteen feet in length. This gully receives concentrated storm water runoff from residential parcels above (north of) Pilkington Road through a small culvert that emerges east of the large landslide. Without repair, growth of the gully will compromise the stability of the eastern hillslope above the West Branch and below the equestrian center.

Site 14 is roughly one acre in size and consists of holes one through five and hole twenty-seven of the De Laveaga Disc Golf Club (see Singer, 1999 for map of golf club). These holes are located to the west of the golf club parking lot and contribute surface runoff to a culvert found near the green for hole nineteen and the tee for hole twenty. As stated above, this site was previously used as a vineyard, a staging area for the National Guard (?) and as an off-road vehicles area (Singer, 1999). This area has lost most of its natural topsoil and vegetative cover.

Site 15 (**Figure 5.2; Table 5.1**) is a gully roughly 1000 feet in length and cross-sectional dimensions of eight feet by eight feet. The Site 15 gully is directly connected to the West Branch. The gully starts below a culvert found in between the green for hole 19 and the tee for hole 20 and receives concentrated storm runoff from Site 8 discussed above. The head of the gully has downcut to bedrock, and is now beginning to widen. The recent, accelerated growth of the gully is closely associated with concentrated storm runoff from Site 14.

Site 16 is located below the City maintenance road just upstream of the firing range. Its location is shown in **Figure 5.2** and volume of sediment lost given in **Table 5.1**. It can be described as a gully with rough dimensions of 10 feet in width, 10 feet in depth and 75 feet in length. The likely cause of the gully is concentrated runoff received from roads, parking areas and areas of shallow or absent soils in what is now the disc golf course. Site 16 is directly linked to the west branch of Arana Gulch.

#### *5.4.2.3 Lower Arana Gulch below Capitola Road*

Site 18 (**Figure 5.2; Table 5.1**) is located roughly five hundred feet downstream of the Capitola Road crossing on the western hillslope below the corner of Agnes Street and Park Way South (Figure 3.1). The rough dimensions of the gully are five feet in width, three feet in depth and one hundred and seventy five feet in length. The gully receives concentrated storm runoff from the development above the hillslope and has cut into younger marine terrace deposits and possibly the A subunit of the Purisima Formation.

## 5.5 Potential Sediment Source Locations

Please see **section 9.6** in this report for a discussion of areas with the potential to develop problems related to accelerated erosion and sediment contribution to the basin.

# 6. ASSESSMENTS SYNTHESIS AND DISCUSSION

*In this chapter, we will present and discuss implications for findings between the sediment and fisheries assessments, we will address the question of sedimentation trends and we will discuss processes likely responsible for the occurrence of mapped sediment sources in the watershed. The chapter will end with a brief discussion of data gaps and programs for further study.*

## 6.1 Impairing sediment sizes

Several different types of processes and activities produce and deliver sand to Arana Gulch. These include streambank failures, accelerated incision of the channel bed, scour of 1st order tributaries, accelerated gully formation, overuse of previously damaged areas within the City's De Laveaga Park and landsliding of oversteepened hillsides. The material produced and delivered to the stream pose many problems for the watershed with perhaps the most troublesome being degradation of existing steelhead habitat due to sedimentation.

In Chapter 5, it was presented that fine to medium sand class sizes constituted the 50-percentile grain size for 6 out of 8 samples collected from in-and near-channel depositional zones in Arana Gulch during the fall of 2000. Samples did not include material of appropriate sizes for steelhead spawning (**Figure 5.**1) with the coarsest material sampled measuring roughing 11 millimeters in effective sieve size. In Hecht and others (1982) results of grain size distribution analyses for core samples and dredge spoils collected in the upper harbor in 1971, 1973, 1980 and 1982 are presented. It was found that sediments in the upper harbor were predominantly of very fine to coarse sand class sizes with 50-percentiles clustered in the fine to medium sand class sizes. It is interesting to note that the extreme range of class sizes present in the 1982 dredge spoils was more fine and more coarse than samples collected in the other three years. Fifty-percentile size classes in the 1982 samples were of very fine to medium sand class sizes and the 95-percentile grain sizes included medium pebble sized grains.

Alley (2000) presents data which indicates that a high percentage of habitat surveyed in

Arana Gulch was covered with silt and sand sized material (fines). Of the four general habitat types samples (pools, runs, glides and riffles), channel bed area through riffles had the lowest percentage of bed area covered by fines-this was as expected. However, the percentage of bed area covered by fines through the riffles was high ranging from 50 to 76 percent. For glides, the percentage of bed area covered by fines ranged from 68 to 100 percent, and in pools it was 84 to 100 percent. Alley (2000) further states that the condition of spawning habitat in Arana Gulch in 1999 was very poor due to the presence of fines (silt and fine sand sized material) at the tails of pools and a lack of appropriately sized spawning gravels (gravels). Rearing habitat (pools) was also poor in 1999 due, in part, to the partial filling of pools with sand sized material. These conditions were reported to have improved during the 1982 storm event but quickly degraded to previous states thereafter due to the introduction of additional fine material during the storm event.

These results suggest that sand size material that has entered the channel in the past has potentially limited steelhead production in Arana Gulch. Because much of the sand production occurs in the upper watershed, we are faced with many difficulties when it comes to managing these sources. However, the small watershed area suggests that positive results could be seen more rapidly than in larger watersheds and that it is appropriate and feasible to design and implement sediment management practices. Additionally, Alley (2000) states that enhancement of salmonid habitat can likely be improved by repair of in-channel and upslope sources of sediment.

## 6.2 Sediment Production Trends

It is unclear at this point if the levels of sand production which currently occur in the watershed are typical of the past 50 or even 100 years. In the Hecht report (1982) this same question was addressed in terms of rates observed in 1982. To answer the question, aerial photography analyses and stream reconnaissance were done in hopes of locating large, individual sources of sediment that could account for the sediment removed at the mouth. They found that numerous sources of sediment occurred throughout the watershed and additionally noted many small and medium sized slope failures. The inventory was conducted in the months following the 1982 event, thus the basin was in a highly disturbed state with the possibility that chronic sources of sediment were visually obscured or just overlooked. The big picture conclusion in the 1982 report is that cumulative sediment production for a 10-year period which included the 1982 event was probably about normal for the longer term. However, large events similar in magnitude to the 1982 event can definitely distort sediment production in the short term. Given that an event similar to the 1982 storm could occur once in every 25 to 33 years, Arana Gulch has the potential for repeated recovery in terms of sediment movement through the watershed following such events. The recovery in terms of time is unclear and highly dependent on the level of disturbance associated with each event. The one source of anecdotal information which points to the conclusion that conditions are currently worse than in the past is that put forth by Robert Bixby (Chapter 5). He concluded that sediment deposition at the Brookwood Drive crossing has increased over the past 5 years and is greater than the volumes deposited during the 1982 event.

## 6.3 Reaches with High Habitat Value and Estimated Increases in Juvenile Steelhead Production

### 6.3.1 Reaches with High Habitat Value

**Figure 6.1** illustrates the reaches of highest fish habitat value (thick red line)in Arana Gulch along with the watershed sediment sources and fish passage barriers. The reaches of highest fish habitat value account for 1.4 linear miles of stream and are located on the eastern branch (0.6 miles)[26], central branch (0.4 miles)[27] and the mainstem (0.4 miles)[28]. These reaches were chosen to have the highest fish habitat value from:

- reach fish densities measured in 1999 in reaches 3, 4 and 6 (figure 4.1),
- potential fish densities if all downstream fish passage barriers were removed, and
- habitat characteristics of the additional upstream channel reaches (above barriers) such as the availability of spawning gravel on the channel bed.

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[26] High habitat value reach on the eastern branch extends from Site 4 to Site 1.
[27] High habitat value reach on the central branch extends from site 12 to site 9.
[28] High habitat value reach extends from Highway 1 upstream to old fish passage barrier 1 (Figure 4.1).

## Table 6.1. Steelhead Benefits from Removal of Fish Passage Barriers[a]

| Passage Barriers to be Removed | Location of Habitat Added with Barriers Removed | Linear Distance of Habitat Added | Estimated Increase in Juvenile Steelhead Production | | Estimated Cumulative Increase in Juvenile Steelhead Production | |
|---|---|---|---|---|---|---|
| *site #* | *reach limits* | *(feet)* | *(number of steelhead)* | | *(number of steelhead)* | |
| - | - | - | *young-of-year* | *yearlings* | *from* | *to* |
| 12, 11 and 10 | site 12 to site 8[b] | 1900 | 177 | 59 | 367[f] | 603 |
| 7 and 6 | site 7 to site 6[c] | 2000 | 146 | 34 | 603 | 783 |
| 6, 5, and 4[d] | site 6 to site site1[c] | 3000 | 219 | 51 | 783 | 1053 |
| 1 | upstream of site 1[c, e] | 4000 | 292 | 68 | 1053 | 1413 |

*Notes* : a. The estimated increase in total juvenile steelhead production was based on the assumption that passage barriers and impediments would be removed in the order listed in **Table 8.1.**

b. Estimated increase in juvenile steelhead production for the reach from site 12 to site 8 was based on steelhead/resident trout densities estimated for Reach 6 in 1999 (**see Figure 4.1**).

c. Estimated increase in juvenile steelhead production for the three reaches defined from site 7 to site 6, site 6 to site 1 and upstream of site repsectively, were based on steelhead densites estimated for Reach 4 in 1999 (see **Figure 4.1**).

d. Sites 6, 5 and 4 are in close proximity and should be removed at the same time to have benefit for the steelhead population.

e. Production estimates made for the reach upstream of site 1 were based on the assumption that perennial flow exists for several thousand feet upstream of site 1 in most years. If the reach goes dry, no benefit would be realized by the steelhead population.

f. Represents the total number of juvenile steelhead produced in 1999 in reaches 1, 2, 3 and 4. Totals for reach 6 in 1999 were not included.

g. Table input data was prepared by D.W. Alley & Associates while the table was prepared by Balance Hydrologics.

The reaches of high habitat value on the central branch and eastern branches are currently limited by accessibility due to fish passage barriers (sites) 12 and 7, respectively. The reach of high habitat value on the eastern branch is further limited in access by fish passage barriers (sites) 6, 5 and 4. These passage barriers are currently limiting the migrational success of steelhead and need to be removed or modified to improve access to the upstream reaches of high habitat value.

The reach of high habitat value on the mainstem corresponds to Reach 3 in Alley, 2000 (**Figure 4.1**). This reach is not impacted by downstream fish passage barriers but is however, impacted by sand size sediment which is found on the channel-bed and banks through this reach (**Figure 5.1**). Alley (2000) estimated Reach 3 to have the highest number of yearlings during sampling in 1999. To the extent possible, conditions through this reach (deeper pools and cover) should be maintained in order to support the yearling class of steelhead in Arana Gulch. Repair of upstream sediment sources and preservation of summer baseflows are central to maintaining the high habitat value through this reach. It is important to note that this reach (Alley, 2000 Reach 3) is downstream of all the sediment sources mapped in the upper watershed. Therefore, this reach is impacted cumulatively from upstream sediment sources. The dam breach at site 1 sometime in November or December of 2001 has undoubtedly exacerbated the existing problem and will continue to do so until all previously stored sediment is transported downstream of Highway 1. Immediate repair of the larger sediment sources in the upper watershed, such as sites 3, 13 and 14 are key to the recovery of downstream habitat in the future.

### 6.3.2 Estimated increase in total juvenile steelhead production from 1999 production values in the central and eastern branches

**Table 6.1** indicates that the production of juvenile steelhead in Arana Gulch would increase by 375% from the 1999 production estimates[29] (367 juveniles to 1,413 juveniles) if the reaches above fish passage barriers (sites) 12, 7 and 1 were made accessible to steelhead. This estimate is dependent on removal of all downstream fish passage barriers and does not account for potential habitat improvement following repair of all

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[29] Nineteen ninety-nine production numbers include all reaches except reach 6 above the Lance Bone driveway, which was assumed to be impassable in some years (Figure 4.1).

upstream sediment sources. Repair of these sediment sources does not necessarily guarantee that habitat conditions downstream will improve over time. Many other factors are a part of this equation including the future occurrence of episodic storms and the potential development of new sediment source

The estimates of increased juvenile steelhead production above barriers were made with reach estimates for steelhead production in 1999 in reaches 4 and 6 (**Figure 4.1**). Using these reach estimates to predict potential increases in production obviously has its limitations. Nonetheless, this method of estimating potential production is reasonable, based on watershed-specific data and sets the stage for discussion of steelhead benefits to implementation of watershed restoration projects.

## 6.4 Erosional Processes

### 6.4.1 Processes acting on the channel banks and bed

Channel bank failures are likely the response to three distinct, but related forces. The first is bank failures associated with a channel that is widening due to a near-by in stream sediment deposit. The sources for this newly deposited sediments are most likely upstream channel bank failures or gullies in the surrounding hills that have a direct path of delivery to the channel. When material is deposited, the channel bed becomes elevated or aggraded and, as a result, streamflow moving through that reach begins to cut at the channel banks in an attempt to maintain its local profile. The second likely cause is linked to the first. The increased elevation of stream-flow due to bed aggradation will lead to a near-channel water table that becomes elevated. The increased pore pressures associated with an elevated water table could supply energy to blow out channel banks that have recently been exposed. The third likely cause is those channel reaches that are incising rather than aggrading and widening. As channel beds incise, the banks become taller and likely more steep. This could likely result in channel bank failures due to an imbalance between forces acting to hold the bank together (resisting forces) and those acting to bring the banks down (driving forces). The resisting forces are generally referred to as those attributing to shear strength and the driving forces as those attributed to shear stress. In the case of Arana Gulch, the removal of lateral support due to incision will increase the shear stress while increased pore pressure during rain events will decrease the shear strength.

Local channel incision in Arana Gulch can likely be explained by the historic introduction of grade control structures, the accumulation of large woody debris (LWD) following intense storms and poorly sized culverts under road crossings. During winter rains, streamflow in these areas will have an increased amount of energy resulting from drop over a grade control structure or a large woody debris jam or an increase in streamflow velocity due to over pressurization of flow through undersized culverts. In all cases, the increased amount of energy will tend to transport bed material out of the reach below these structures and effectively lower the elevation of the bed. It is also likely that concentrated storm-water runoff resulting from development in the upper watershed is contributing to bed incision. However, an analysis of storm-water outlets in the upper watershed was not conducted as part of this assessment so the relative role of this factor can only be estimated. Significant sources of sediment from channel banks and beds were found to occur in the east branch and through the tidal reach.

### 6.4.2 Processes acting on slopes

Hillslopes in the eastern and western branches of Arana Gulch have been subject to increased rates of gullying over the last ten to fifteen years. In contrast to the eastern and western branches, the central branch is bordered by very minor gullies. A large set of gullies in the eastern branch is located below the Chaminade Blue Trail roughly a ten minute walk from the northern edge of Santa Cruz Gardens neighborhood. On the western branch, the gullies are located at the head of Pilkington Road near the equestrian center, near holes 19, 21 and 22 of the disc golf course and below the City of Santa Cruz maintenance road just upstream of the shooting range.

The cause of increased rates of gully expansion in the western branches is concentrated storm runoff originating from residential parcels or areas of the disc golf course which have lost most its vegetative cover and overlying soils (Singer, 1999). At the head of Pilkington road, the concentrated storm runoff is fed into an undersized culvert where it gains the excess energy (from increased velocity) that is responsible for the gullying on the south side of the road.

Processes acting at the disc golf course are different from that at Pilkington Road. Site characteristics, site history and current land use all contribute to the increased rates of gully expansion below the disc golf course (Singer, 1999). For a detailed account of the site please see Singer, 1999. Briefly, the site is underlain by the Purisima Formation (subunit c) and patches of coastal terrace deposits. Much of the soil which had developed at the site has been lost and mapped soil series at the site are characterized by high rates of runoff (during saturated soil conditions) and have moderate erosion hazard ratings (Singer, 1999). These factors have led to increased rates of surface runoff from the disc golf course with resulting erosion of the natural drainage network on the western side of the valley above the western branch.

## 6.5 Data Gaps and Recommendations for Further Work

### 6.5.1 Riparian assessment

A formal riparian assessment was not conducted as a part of this project. Understanding riparian conditions is important as the riparian community is closely tied to the production of food for steelhead, it helps to moderate summer water temperatures and it promotes a healthy streamside ecosystem. In our site repair plans, we call for the removal of exotic species and replacement with native species during project implementation.

### 6.5.2 Baseflow assessment

Baseflow monitoring was conducted in conjunction with this project, however it was limited to two days worth of data. Sufficient flow is a basic need during summer months for salmonids. At this point, it is unclear if baseflows are limiting steelhead production in the watershed. We know that in the fall of 1999 and 2000, the western branch was dry. Furthermore, reach 3 was observed to be a losing reach during baseflow monitoring in 1999. During periods of drought, it is possible that reach 3 could run dry. If baseflows do become an issue in the future for salmonids, additional baseflow data will be needed.

### 6.5.3 Sediment transport data

Sediment transport data does not exist for Arana Gulch. Our understanding of sediment problems in the watershed is limited to an understanding of the current sediment sources in the watershed, anecdotal information on sedimentation trends and the synthetic model discussed in Appendix A. To increase our understanding of sediment production and transport in the watershed, suspended and bedload sediment discharge data should be collected in conjunction with stream gaging (**see Chapter 8**).

### 6.5.4 Blue Trail Dam

The relative merits of repair, removal, or conversion of the dam and reservoir at the head of the Blue Trail should be carefully considered. In mid-January 2002, biologist Marty Gingras and watershed coordinator Roberta Haver found sediment emanating from the bottom of the dam. Mr. Gingras reports that a wooden plug at the base of the dam has failed, and that sediment is entering Arana Gulch largely unrestricted. Two alders within the sedimented pond have fallen. At the time, an estimated 90 percent of the sediment originally stored behind the dam was reported to remain in place leaving a large volume of sediment (potentially 2000 cubic yards) available for transport to downstream reaches. While a road to the site existed during the early decades of the 20th century, when the dam was built, present access to the site by vehicles is not feasible.

The dam is owned by Chaminade, which is presently assessing the situation. Further information will be forthcoming, and may guide a recommendation to repair, remove, or convert the dam and its site to other uses. Breach of the dam was discovered approximately two weeks prior to production of this final plan. Information available at present is not sufficient to prepare a recommended treatment approach for this sediment source. At the moment, we assume that the plug will be repaired, and that repair of the dam face, as described below, is the most likely near-future action which may be followed. At some later date, however, a more complete assessment of alternatives should be developed.

## Table 7.1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **East Branch Arana Gulch** | | | | | | |
| 1 | **Right Bank below the Blue Trail Dam** | Would avoid an extremely large volume of sediment in the event of dam failure | Right bank below the Blue Trail Dam is experiencing accelerated erosion and could compromise dam structure | Treated sandbag spillway to protect further bank erosion and dam failure | $10,000-$20,000 | Chaminade, Fines Funds (county and State), Community groups | NMFS, CDFG, County of Santa Cruz, RWCQB |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Repairs must be done without vehicular access, large volunteer crew will be needed, wheelbarrels etc. | | | | | |
| 2 | **Right Bank Meanders below Blue Trail Dam** | Would avoid direct addition of moderate volumes of sand to the channel and protect the existing Blue Trail | Numerous right bank failures in conjunction with meander bends: downstream of the Blue Trail Dam and upstream of the Blue Trail foot bridge | Protect eroding face with log cribbing , suitably keyed into the banks, plant alders or other vegetation behind cribbing | $5,000-$10,000 | **Small grant**: CAB / NREP, CCC's (labor force) | NMFS, CDFG, County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Repairs must be done without vehicular access, large volunteer crew will be needed, wheelbarrels etc. | | | | | |
| 3 | **Blue Trail Gullies** | Would restabilize the hillslope, part of the Blue Trail, the Citiy's water line and dramatically reduce sediment input through the reach | Several very large gullies are contributing large amounts of sediment to the channel and have compromised a City water line | Drain the bottom of the gullies with perforated piping, add structured support, backfill the gullies with appropriate material and plant | $50,000 + | **Large Grant:** City and Chaminade supervision, RCD / NRCS tech assist, Done by contractor | County of Santa Cruz Grading Permit |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | We should seek Jen Hyman's involvement; could run a shoot down the trail to transport soil for filling | | | | | |
| 4 | **Steelhead Migrational Barrier (B5) roughly 40 feet upstream of site 5** | Allow for fish passage to the upstream reaches on the eastern branch and stabilize downstream banks | Two four-foot diamter culverts placed in the middle of the channel are jammed with LWD at the upstream end. Barrier is impassable. | A) Manual clearing of debris and culverts from stream recommended. Use of large volunteer team suitable (5-6 people) | 500 + permit fees | County of Santa Cruz Fish and Game Commission, California Youth Authority Crews | CDFG, County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Manual removal of jam could be conducted with a chain saw and supervision by a Fisheries Biologist | | | | | |

## Table 7.1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **East Branch Arana Gulch** | | | | | | |
| 5 | **Steelhead Migrational Barrier (B4) roughly 90 feet upstream of site 6** | Allow for fish passage to the upstream reaches on the eastern branch and stabilize downstream banks | Redwood log jam roughly seven feet in height at time of stream survey. Barrier is probably impassable. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Manual removal of jam could be conducted with a chain saw and supervision by a Fisheries Biologist | | | | | |
| 6 | **Steelhead Migrational Barrier (B3) roughly 0.37 miles upstream of Paul Sweet Road** | Allow for fish passage to the upstream reaches on the eastern branch and stabilize downstream banks | Log jam anchored by large redwood rootwad and concrete structure in left bank. Barrier might be passable at 20-30 cfs. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Manual removal of jam and culverts is recommended with the help from a volunteer team of 5-6 people. Fisheries Biologist should be present | | | | | |
| 7 | **Culvert Beneath Paul Sweet Road** | Allow for fish passage to the upstream reaches on the eastern branch, reduce local flooding potential and stabilize downstream banks | Culvert has downcut roughly 6 feet. Downcutting has accelerated erosion of banks downstream of culvert and impedes fish passage at all flows | A) build channel elevation up to the current culvert mouth elevation using step-pools<br>B) (optional) construct settling pond and trash rack roughly 50-yards upstream of redwood cathedrals | $100000 + | Prop 13, County Public Works, DFG (partial), Road Association supervision, Done by contractor | NMFS, CDFG, County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Local observers report repeated blockages of culvert by woody debris; Don Alley suggest new bridge; need some mechanism to slow water upstream of culvert | | | | | |

## Table 7.1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County (continued)

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **Central Branch Arana Gulch** | | | | | | |
| **8** | **Steelhead Migrational Barrier (B9) roughly 0.39 miles upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | A current series of 3 woody debris jams that is likely impassable. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | | | | | | |
| **9** | **Steelhead Migrational Barrier (B8) roughly 0.37 miles upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | A six-foot high log jam that is likely impassable. | A) Remove log jams manually with supervision by a Fisheries Biologist | $500 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | | | | | | |
| **10** | **Steelhead Migrational Barrier (B7) roughly 0.27 miles upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | Rip-rap piled instream has created a partial dam and destabilized banks by forcing flow around the rip-rap into the banks. | A) Remove rip-rap manually with supervision by a Fisheries Biologist | $500-$1,000 | County of Santa Cruz, California Fish and Game Advisory Commission, FYA Crews | CDFG, County of Santa Cruz |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | | | | | | |
| **11** | **Rebedding of Maybee Lane from roughly 0.05 miles upstream of the confluence with the eastern branch to mile 0.5** | Would avoid massive bank destabilization and increased localized flooding potential along the central branch of Arana Gulch. | Stretch of old road roughly one-quarter mile long is showing signs of gullying and concentrating runoff from the drainages above. Concentrated runoff is leading to bank destabilization along the central branch upstream of the Bone property. | Restore original cross slope along road, repair gullies and restore vegetation where needed with appropriate material | $20,000-$50,000 | **Large grant (useful as a demonstration grant)** | NMFS, CDFG, County of Santa Cruz Grading Permit |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Will require cooperation and interest of owners; county riparian permitting could prove difficult | | | | | |
| **12** | **Steelhead Migrational Barrier (B6) roughly 112 feet upstream of the confluence with the eastern branch** | Allow for fish passage to the upstream reaches on the central branch and stabilize downstream banks | Perched driveway culvert which is likely impassable under most flow conditions and contributing to bank destabilization downstream. | Construct new crossing | $20,000-$50,000 | **Large grant** | NMFS, CDFG, County |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | At the time this report was prepared, it was understood that this project had been awarded funding and was slated to begin in the next year | | | | | |

## Table 7.1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County (continued)

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **West Branch Arana Gulch** | | | | | | |
| **13** | **Pilkington Road Drainage** | Reduce potential for massive landsliding on the eastern hillslope and direct input of large volumes of sediment to the system. Protect property owners near the site (equestrian center) and downstream. | Concentrated runoff from hillslope above Pilkington Road is causing increased gullying in slope adjacent to existing landslide at head of the west branch. Could cause extensive landsliding and massive input of sediment to the system. | Stabilize banks near culvert outlet, general drainage repairs above road | > $20,000 | Grant to Road Association and Community groups | Santa Cruz County Grading Permit |
| | **Property Ownership** | private property | | **Property Jurisdiction** | County of Santa Cruz | | |
| | **Comments** | Need access and participation from homeowners | | | | | |
| **14** | **Disc Golf Course** | Restore natural capacity of soils to absorb water thus reducing the volume of runoff during storm events. Restoration of grasses and 'top soil' on these holes will help reduce the rate of growth in the gully draining to the west branch. | Disc Golf Course holes 1-5, 25 and 27 have lost large amounts of soil1 and currently is by and large devoid of grasses. Increased runoff through the area has resulted in accelerated growth of the gully which follows holes 20 and 21 and drains to the west branch of Arana | Moderate re-grading, major re-soiling and planting of resilient golf course related turf | > $100,000 | City of Santa Cruz | Santa Cruz County Grading Permit |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Roughly 9 acres need 6 inches or more of soil for planting-to prevent further erosion and to slow bank erosion seen in the associated gully due to high runoff rates. 1: Steve Singer (June, 1999) has estimated that most areas near these holes have lost at least 10 inches since the 1880's | | | | | |
| **15** | **Large Gully below Disc Golf Course** | Reduce volume of sediment input to the west branch and protect the adjacent holes of the disc golf course. | This site is directly linked to site 8 above. Gully contributes large volumes of sediment to the west branch and is growing. | To be closely monitored and considered for active repair if re-establishment of golf course groundcover does not halt bank erosion seen in the gully | ? | City of Santa Cruz | |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Roughly 300 yards long, completely overgrown with poison oak | | | | | |
| **16** | **Tributary from West at Lower Service Road** | Reduce volume of sediment input to west branch, reduce flooding potential for residents of the former Paul Sweet House and protect service road. | Increased rate of tirbutary growth due to concentrated runoff. Tributary contributes moderate volumes of sediment to west branch. | Step-pool ladder similar to site 4 above | $5,000-$10,000 | City of Santa Cruz | |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Roughly 40 yards long, material used to build step-pools needs to considered | | | | | |

## Table 7.1: Description of Major Sediment Point Sources and Migrational Barriers, Arana Gulch, Santa Cruz County (continued)

| I.D. | Sites | Benefits | Problem | Repair Method Sought | Estimated Cost | Potential Funders / Cooperators | Permits |
|---|---|---|---|---|---|---|---|
| | **Main Stem Arana Ck.** | | | | | | |
| **17** | **Capitola Road Crossing** | - | Monitor site for future incision and bank instability downstream of the existing culvert. Site has the potential to become a fish passage barrier. | - | - | - | - |
| | **Property Ownership** | private property | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Monitoring should be taken very seriously. Upstream projects are limited in effectiveness if this project is not taken seriously | | | | | |
| **18** | **Greenbelt Gully** | Increase removal of sand and sediment from Tidal reach and Harbor | Accelerated erosion of hillslope below the corner of Agnes Street and Park Way South has resulted in a gully which directly delivers sediment to the Tidal reach. | Reconstruct stormwater outlet and consider new drainage plans. Backfill gully and plant. | $20,000-$50,000 | City of Santa Cruz, Port District and/or other AGWA participants | ???? |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Need access clearance from homeowners and cooperation from the City of Santa Cruz | | | | | |
| **19** | **Tidal Reach** | Stabilize Tidal reach, dramatically decrease sediment loading to the Harbor. Maintain current marsh habitat that is unlike any other in Santa Cruz County and perhaps the central coast of California. | Accelerated channel headcutting and channel bank failure through the tidal reach resulting in increased loading of sandy sediment to the harbor and the tidal reach | ??? | $100,000+ | City of Santa Cruz, Port District and/or other AGWA participants | NMFS, CDFG |
| | **Property Ownership** | City of Santa Cruz, DeLaveaga Park | | **Property Jurisdiction** | City of Santa Cruz | | |
| | **Comments** | Could be a cooperative project between the Port District and the City of Santa Cruz. | | | | | |

# 7. OPPORTUNITIES FOR ENHANCEMENT

*Chapter 7 presents our suggested, site-specific conceptual repair plans for sediment sources and migrational barriers discussed in chapters 4 and 5.* ***Table 7.1*** *summarizes our approach, estimated cost and presents a list of potential funders as well as permits that will likely be needed to begin work at each site. The list of potential funders is obviously incomplete and should be used as a guide rather than as an absolute list. Likewise, the estimates of cost were developed in a manner similar to that of an architect estimating costs for a new home (on a square footage basis)- the estimates likely leave room for much interpretation.*

## 7.1 Enhancement Objectives

Our conceptual, restoration plans were developed with several objectives in mind. These include:

1. To improve, protect and increase accessibility to and use of steelhead habitat throughout Arana Gulch. It is hoped that this can be accomplished by:
    a. Decreasing the volume of sandy sediment that reaches the stream annually,
    b. Decreasing the volume of sandy sediment that is deposited on the streambed,
    c. Improving passage conditions through barriers,
    d. Allowing sufficient large woody debris to remain in the channel, and
    e. Restoring the riparian corridor in reaches near the High School fish ladder and the Brookwood Drive stream crossing

2. To reduce erosion of public and private property throughout the watershed.

3. To reduce sedimentation of public and private property throughout the watershed.

## 7.2 Channel Bank Instabilities

### 7.2.1 Site 1: Right-bank adjacent to the Blue Trail Dam

We suggest a treated sandbag spillway to protect the bank form further erosion. As discussed in Chapter 5, the remote nature of Site 1 provides the most difficulty in implementing repairs. **Figure 7.1** illustrates the repair approach. At treated sandbag spillway will serve to stabilize the bank and dissipate energy from runoff over the bank. A cost estimate for Site 1 is $10,000-$20,000.

### 7.2.2 Site 2: Right-bank meanders below the Blue Trail Dam ( 2 locations)

We propose stabilizing the previously failed banks at each location with log cribbing, suitably keyed into the banks, and planted with appropriate vegetation behind each crib structure. As with Site 1, the remote nature of Site 2 (three-bank failures) provides the most difficulty in implementing repairs. **Figures 7.2 and 7.3** illustrate the repair approach. Log cribbing and plantings will stabilize the banks and provide field friendly approaches that do not require heavy equipment. A cost estimate for Site 2 is $5,000-$10,000 per bank failure.

### 7.2.3 Site 19: Tidal reach bank failures

Various parties have suggested several conflicting repair recommendations for site 19. For a detailed discussion of several repair options see Hecht and others, 1982 (**Appendix C**). At this point, consensus has not been reached as to a single repair plan amongst the project consultants and the California Department of Fish and Game. If consensus is reached, the solution will be included in a later update of this report.

## 7.3 Accelerated Erosion of Hillslopes

### 7.3.1 Site 3: Blue Trail gullies

Our general approach to stabilizing the Blue Trail gullies is to enhance natural drainage of the area, backfill the gullies and plant with aggressive, fast growth native species. **Figures 7.4 and 7.5** illustrate the repair approach. Specific steps would include a)filling the bottom of each gully with several inches of coarse gravels, b)lay perforated piping over the coarse gravel for the full length of each gully, and c)follow this with burial of the piping with several more inches of coarse gravel. Additional anchoring of the perforated piping may be needed. The remainder volume of each gully with non-engineered soils and aggressively planted with fast growing native species. Additional stabilization of the area with root wad cuttings or something similar may also be warranted until planted vegetation matures. A cost estimate for composite site 3 is $50,000 +.

### 7.3.2 Site 11: Maybee Lane above Lance Bone's property

Stabilization of Maybee Lane would include repairing minor gullies in a manner similar to that proposed for Site 3, followed by restoration of the cross-slope grade with non-engineered fill and planting with fast growing native plant species. The approach for this site is intended to restore pre-road conditions and promote natural drainage of the hillslope through streamside soil and vegetation buffers. A cost estimate for Site 11 is $20,000-$50,000.

### 7.3.3 Site 13: Pilkington Road drainage

Stabilization of the Pilkington Road drainage will require cooperation from existing landowners and possibly the Santa Cruz County Public Works Department. Repair and stabilization of the culvert outlet will not solve the problem. It is likely that stabilization of the hillslope below the culvert outlet will require efforts upslope to address drainage characteristics of all contributing properties coupled with installation of a new, more effective culvert outlet. Installation of a new culvert outlet will likely include removal of the existing culvert beneath Pilkington Road. Repair approach is illustrated in Figure

7.7. Removal of existing culvert will require approval from and coordination with landowners due to the lack of alternate routes to town. A cost estimate for Site 13 is $20,000-$50,000.

### 7.3.4 Site 14: De Laveaga Disc Golf Course-area across from parking lot

Repair of this area, roughly 1 acre in size, will require minor grading with 6 or more inches of soil followed with planting of a resilient golf course related grass seed mixture. Depending on depth of the existing soil material (high in clays), grading with topsoil may need to be coupled with tilling of the existing surface up to 10 inches in depth and mixing the graded soil with organic material. If the existing soil surface is not broken down, topsoil that is applied to the area could easily wash away before grasses mature. A cost estimate for Site 14 is $20,000-$50,000. For a different set of site repair recommendations, please see Singer, 1999.

### 7.3.5 Site 15: Large gully adjacent to holes 19, 20 and 21 of the Disc Golf Course

We propose to monitor Site 15 in conjunction with repair to Site 14, which is hypothesized to be the root problem of Site 15. Appropriate monitoring of the gully would include establishment of permanent monitoring locations. At these locations, bi-annual measurements of gully depth and width should be recorded. Appropriate months would include September or October and April or May. From these bi-annual measurements, the volume of sediment lost and the growth rate of the gully could be calculated for each monitoring location. Conditions should be monitored for several years following repairs to Site 14. If the gully continues to grow following this period appropriate steps should be taken to stabilize the gully. For an alternate set of site repair recommendations, please see Singer, 1999.

### 7.3.6 Site 16: Tributary from west at lower service road

We propose to stabilize this reach with step-pool morphology built from boulder-sized material. A cost estimate for this work is $5,000-$10,000. Care should be used in selecting rock, such that it is sufficiently durable to remain effective, yet also appear to originate in the area. Figure 7.8 illustrates the repair approach for site.16.

### 7.3.7 Site 18: Greenbelt gully

We recommend stabilization of this hillslope gully in a manner analogous to that discussed for Site 3. The bottom of the gully should be filled with baserock up to several inches thick with perforated piping lain over the gravels and subsequently buried with more coarse gravels. The remaining gully volume should be filled with non-engineered fill and planted with a fast-growing native plant. Drainage configurations in the overlying roads should also be addressed with possible re-directing of runoff to decrease volumes moving through the gully during storm events. An estimate of cost for repairing the gully alone is $20,000-$50,000. This estimate could jump to $100,000+ if significant work is done to drainage configurations for the overlying development.

## 7.4 Fish Barriers

### 7.4.1 Sites 4, 5 and 6: Fish barriers on the east branch

We propose parallel approaches to these three fish barriers. In conjunction with a fisheries biologist, a small volunteer team could effectively clear woody material causing passage problems at Sites 5 and 6. A chain saw would likely provide all the power necessary to reduce material to manageable sizes. The fisheries biologist would guide the volunteers as to which material should be removed and which material/structures should remain because of habitat value. Removed material could be carried several hundred feet away from the channel and deposited in the forest where it would be left to natural decomposition processes.

Site 4 is complicated by the presence of two culverts in the channel. A larger volunteer team might be necessary for this site. Material that is jammed upstream of the culverts should be removed in a manner similar to that discussed above. Material (sediment and woody debris) that has been deposited in the culverts could be removed with flat shovels and the culverts then lifted out the channel by the volunteer team. It might be necessary to lever the culverts from the bed so appropriate materials should be considered. Once the culverts are removed, they should be carried out and trucked away. A cost estimate for removal of each fish barrier with a volunteer work team is $500-$1000.

### 7.4.2 Site 7: Culvert beneath Paul Sweet Road on the eastern branch

Site 7 is characterized as a fish barrier at most flows, the responsible factor in downstream bank destabilization and as increasing flooding hazard for upstream homeowners. Due to these compounding issues, a simple, inexpensive repair would not be effective and would likely solve only one of the problems. Therefore, it is highly recommended that the existing bridge and culvert be removed and replaced with a new bridge that can properly and safely convey the estimated 100-year flood for Arana Gulch. In conjunction with replacing the bridge and culvert, the western banks immediately downstream of the existing bridge may need to be stabilized in a manner similar to that for Site 2. Additionally, the streambed downstream of the bridge may need to be stabilized with a step-pool reach built with boulder sized material. **Figure 7.6** illustrates this approach to streambed stabilization. To ensure compatibility and functionality, conceptualization of new bridge plans should include consultation by a qualified fisheries biologist and geomorphologist. Cooperation from and approval by upper watershed residents will be key for implementation of these recommendations. An estimated cost for all suggested work is $200,000 +.

### 7.4.3 Sites 8, 9 and 10: Fish barriers on the central branch

For Sites 8, 9 and 10, we propose approaches similar to those discussed for Sites 4, 5 and 6 above. As with the above sites, the goal for these sites is to restore passage for migrating steelhead. Removal of the instream barriers with chain saws and other simple tools is recommended, as is field guidance from a fisheries biologist. Attention should be given to disposal of material removed from the channel. If material is left in the watershed, it should be moved up to several hundred feet from the channel and situated to minimize future movement.

## Table 7.2: Recommended Implementation of Repair Projects in the Arana Gulch Watershed

| Site # | Site-Specific Projects | Priority | Project Iniation Phase | Comments |
|---|---|---|---|---|
| | | | | |
| 1 | Blue Trail Dam: right-side of dam structure bank failure | High | Phase 1 | Repair here avoids massive pulse of sediment |
| 3 | Blue Trail Gullies | High | Phase 1 | |
| 4 | Fish Barrier #5 - 4' drop, in-channel culverts | High | Phase 1 | Eastern branch below the Blue Trail crossing |
| 5 | Fish Barrier #4 -7' drop, log jam | High | Phase 1 | Eastern branch below the Blue Trail crossing |
| 6 | Fish Barrier #3 -log jam, root wad | High | Phase 1 | Eastern branch below the Blue Trail crossing |
| 7 | Culvert Beneath Paul Sweet Rd, ID barrier #2 | High | Phase 1 | |
| 12 | Fish Barrier #6 - perched culvert | High | Phase 1 | Lance Bone's driveway crossing: project has been initiated |
| 14 | Disc Golf Course: west of parking area | High | Phase 1 | |
| - | Grade control at fish ladder | High | Phase 1 | Project is roughly 80% complete |
| | | | | |
| 2 | Right Bank Meanders below Blue Trail Dam | Medium | Phase 2 | |
| 13 | Pilkington Road Drainage | Medium | Phase 2 | Repair here avoids potential landsliding |
| 15 | Large Gully below Disc G.C. | Medium | Phase 2 | Try to stabilize gully profile with repair of site 8 |
| 16 | Trib. From West at Lower Service Rd. | Medium | Phase 2 | |
| 18 | Greenbelt Gully | Medium-High | Phase 2 | Gully delivers sediment directly to the greenbelt |
| - | 1-bank erosion sites at Harbor High | Low | Phase 2 | |
| | | | | |
| 8 | Fish Barrier #9 - 3 log jams in succession | Low | Phase 3 | Central branch above Lance Bone's property |
| 9 | Fish Barrier #8 - 3' drop log jam | Low | Phase 3 | Central branch above Lance Bone's property |
| 10 | Fish Barrier #7 - rip-rap dam | Low | Phase 3 | Central branch above Lance Bone's property |
| 11 | Rebedding of Maybee Lane | Low | Phase 4 | Central branch above Lance Bone's property |

*Notes:*

1. Site # refers to notation in Figures 4.1 and 5.2 as well as Table 7.1
2. Priority Categories: High, Medium and Low
3. Initiation Phases: Phase 1: 1-3 years, Phase 2: 3-5 years, Phase 3: 5+ years
4. Implementation order is based on consensus among AGWA TAC memebers
5. Site 17 (Capitola Road) is to be monitored for rate of incision and right bank stability downstream of existing culvert

## Table 7.3. Cost Benefit for Repair of Sediment Sources Related to Landslides, Gullies and Channel-bank Failures, Arana Gulch, Santa Cruz County, California

| Site | Site | Volume Lost[c] | Estimated Cost of Repair [d, e] | Estimated Rate of Sediment Loss[g] | Cost Benefit of Repair |
|---|---|---|---|---|---|
| # | *name* | *(cubic yards)* | *($)* | *(cubic yard / year)* | *($ / cubic yard)* |
| 1 | Blue Trail dam: right bank below dam | 350 | 15000 | 15 | 1000 |
| 2 | Right bank meanders below blue trail dam | 261 | 7500[f] | 11 | 682 |
| 2 | Right bank meanders below blue trail dam | 93 | 7500[f] | 4 | 2500 |
| 2 | Right bank meanders below blue trail dam | 28 | 7500[f] | 1 | 7500 |
| 3 | Blue Trail gullies | 9000 | 50000 | 300 | 167 |
| 13 | Pilkington Road drainage | 1200 | 20000 | 47 | 426 |
| 14 | Disc Golf Course[a] | 1700 to 3300 | 100000 | 300 | 333 |
| 15 | Large gully beneath Disc Golf Course[b] | 1778 | - | - | - |
| 16 | Tributary from west at lower service road | 333 | 7500 | 13 | 577 |
| 19 | Tidal Reach | - | 100000 | 330 | 303 |
|  | Totals for Sediment Sources: | 14743 to 16343 yards$^3$ | $315,000 | 1021 yards$^3$ / year[h] | ~ $ 300 / yard$^3$ [i] |

*Notes:*

a. See Singer, 1999 for detailed discussion of the Disc Golf Course, reported range for volume of sediment lost varies with applied depth of soil cover lost

b. Repair cost was not estimated for site 15 because it is recommended that the site be monitored in conjunction with repair of site 14

c. Source dimensions, except for site 14, were measured by Balance Hydrologics staff in the fall of 2001

d. Estimate of repair costs developed by Balance Hydrologics and Toni Danzig, 2001. Estimates were developed using a cost per unit volume approach, and are preliminary based on costs of similar treatments implemented elsewhere.

e. Estimated repair costs do not account for inflation after 2001

f. Estimated cost of repair equals average of the range indicated in Table 7.1

g. Estimated rate of sediment loss is based on interpretation during fieldwork conducted from 1999-2000 by Barry Hecht, Shawn Chartrand and Jason Parke

h. Total for annual rate of sediment yeild corresponds to sediment source 2 and 5 (less 4 yards$^3$ / year), Table A-7, Appendix A to this report

i. Total cost benefit of repair represents the estimated benefit gained if all enhancement projects (for sites listed above) were implemented and successful

j. Site 18 was not included in this table because site dimensions were not measured

### 7.4.4 Site 12: Central branch crossing at Lance Bone’s property

If the culvert beneath Lance Bone’s property is to be replaced or removed, the channel bed downstream of the existing culvert should be stabilized so that head cutting does not occur at the existing location. We suggest stabilizing the bed downstream of the existing culvert in a manner similar to that which was discussed for Site 7 above. Checkdams sized and spaced for a stable step-pool morphology could be built in the bed downstream of the existing culvert. This would stabilize the bed and incrementally step the bed up in elevation to the current elevation of the culvert base. Rigorous geomorphic criteria should be used in developing the design (c.f., Chartrand and Whiting, 2000). The step-pool design should be constructed with oversight from a fisheries biologist who has experience with fish passage of weir type structures. Estimated costs for removal of the culvert and construction of the step-pools is $50,000+. If a bridge is constructed to replace the existing culvert, costs are likely to reach $150,000+.

At the time this draft was prepared, AGWA had confirmed landowner consent to remove the existing culvert and construct a free spanning bridge just upstream of the culvert location.

## 7.5 Preliminary Implementation Plan: The Next Steps

We have assembled the repair sites into **Table 7.2** with the preliminary, relative ranking of each repair and the corresponding project initiation phase. The intent here is to present the ecological future of Arana Gulch in a realistic light bearing in mind the visionary, long-term framing of this plan. The implementation strategy outlined in **Table 7.2** was born out of numerous discussions and meetings and amongst the consultants and the Arana Gulch Technical Advisory Committee. **Table 7.3** breaks down the relative cost benefit for repair of sediment sources discussed in section 5.4. The cost benefit for each sediment source is expressed as dollars spent per cubic yard of material potentially removed from the annual watershed sediment budget.

### 7.5.1 Implementation strategy

In reviewing **Table 7.2**, it is important to note that project initiation phase refers to the timetable under which the Arana Gulch Watershed Coordinator will actively pursue implementation of the project following release of this report. Among countless items to consider, this will include researching and securing funding, researching and applying for applicable permits, contacting landowners and assembling a construction and volunteer team. The project initiation phases considered are:

- Phase 1: 1-3 years
- Phase 2: 3-5 years, and
- Phase 3: 5-7 years.

Within Phase 1, projects were divided between high and medium priority. Within this relative ranking scheme, it is intended that those projects listed as ‘high’ should be initiated before those listed as ‘medium’. The order in which ‘high’ and ‘medium’ ranked projects are initiated is left to the discretion of the watershed coordinator but will also be controlled by unforeseen circumstances. Site specific projects given a relative priority of high include the Blue Trail gullies, the De Laveaga Disc Golf Course area west of the parking lot, the Capitola Road crossing, the grade control at the Fish Ladder and the culvert beneath Paul Sweet Road. Those given a relative priority of medium include the Tidal reach, fish barriers 3 through 6 and the right bank below the Blue Trail dam.

Under Phase 2, projects were divided between high, medium and low priority. Initiation of projects under Phase 2 should be carried out in a manner parallel to that in Phase 1. The greenbelt gully was the sole site to be given a ranking of high. The Pilkington Road drainage, the right-bank meanders below the Blue Trail dam, the large gully below the De Laveaga Disc Golf Course and the tributary on the lower service road which feeds the west branch were ranked as medium. The bank erosion site upstream of the weir and the fish ladder near Harbor High School was ranked as low.

Under Phase 3, all projects were ranked as high and include fish barriers seven through nine on the central branch upstream of Lance Bone's property.

### 7.5.2 Cost benefit for repair of watershed sediment sources

The relative cost benefit for repair of watershed sediment sources related to landslides, gullies and channel-bank failures is discussed in **Table 7.3**. The relative cost benefits are expressed in dollars spent per cubic yard of material potentially removed from the annual watershed sediment budget. The cost benefit calculations are based on estimated total repair costs and estimated rates of annual sediment loss for each site. The repair cost estimates used are preliminary, were based on similar projects implemented elsewhere and were developed using a cost per unit volume approach. Rates of sediment loss at each site were developed from site interpretation during fieldwork conducted in 1999 and 2000. Cost benefits ranged from $ 167 per cubic yard of material potentially removed (site 3) to 7500 (site2).

### 7.5.3 Site-specific implementation considerations

#### *7.5.3.1 Sites 1 and 2*

The remote nature of Sites 1 and 2 pose the biggest problem in terms of implementing repairs. At best, walking time to Sites 1 and 2 from an access point in the Santa Cruz Gardens neighborhood is 25 and 20 minutes respectively. The lack of roads means that all work will have to be completed with hand tools and all materials brought in by backpack and wheelbarrow. As with all sites, arrangements with property owners should recognize their need to limit liabilities while also enabling restoration activities.

#### *7.5.3.2 Site 3*

Site 3 is easily accessed by foot (in roughly five minutes) from the Santa Cruz Gardens neighborhood. A non-maintained road along the ridge could be used to transport materials to within several hundred feet of the site. Due to the proximity of Site 3 to the City water line, it might be possible to implement a joint effort by AGWA, the landowner (Chaminade) and the City of Santa Cruz with the goal of restoring the hillslope to more natural conditions. A joint effort would distribute the cost of repairs amongst parties and would better provide for follow-up inspection and maintenance. It would also broaden potential sources of funding and possibly draw in volunteer assistance, as many local residents use the Blue Trail. It is critically important that this site be repaired, as it is contributing a significant amount of sediment each wet year which causes appreciable damage to the banks and habitat of east branch, and to a lesser degree, Arana Gulch downstream to the harbor. This site alone is likely directly contributing several percent of the sandy material transported by Arana Gulch at present. Additionally, the gullies are accelerating runoff which once moved toward the east branch as sheetflow, contributing to higher peak flows in the East Branch and channel segments downstream.

#### *7.5.3.3 Site 13*

This site is easily accessed via Pilkington Road. Timing of repairs will need to be coordinated with residents to avoid road blockage during key times of the day.

#### *7.5.3.4 Site 14*

Site 14 is easily accessed and there is ample parking for work crews and repair materials. The disc golf community has been supportive of restoration and it seems likely that a contingent of golfers might volunteer their time for repair work. The volunteers are likely to have useful suggestions about the look-and-feel of the restored surface, and how follow-up may best be integrated into course maintenance. An important challenge will be providing sufficient post-repair time before the site resumes use as a disc golf course. Timing the repair to avoid tournaments and other key scheduled events, dividing the repair program into phases, and allowing for partial or restricted access are some approaches that merit consideration as a part of a cooperative effort. Although part of De Laveaga Park, this area is owned by the National Guard, which might also wish to affirmatively participate in this program.

#### *7.5.3.5 Site 15*

The head of the gully is easily accessed from Upper Park Drive, while the midstem of the gully would be accessed from holes 20 and 21 and the lower segment of the gully is inaccessible. Access through holes 20 and 21 should be approached with caution, as it is possible that repair activities could aggravate an already degraded system. As with site 14, it might be possible to recruit a team of volunteers from the disc golfing community or other interested groups to help implement repairs to the gully.

#### *7.5.3.6 Site 16*

Site 16 is easily accessed via the City's maintenance road with approach from the south being the most direct. Constraints with this site are limited to coordination with the City of Santa Cruz Public Works Department to avoid obstructing this narrow one-way road during repair implementation.

# 8. MONITORING AND REPORTING

*Chapter 8 presents the framework for suggested, future monitoring and reporting programs. It includes the ingredients and skills which a volunteer monitoring team should possess as well as the parameters that should be monitored in the future. The chapter ends with a discussion on reporting strategy for future monitoring results.*

## 8.1 Arana Gulch Watershed Monitoring Team

A community-based Watershed Monitoring Team should be assembled to minimize costs and maximize the value, credibility, and continuity of the data. Ideally, the team would consist of eight to ten members from the local community that could be organized into four or five teams of two or three with one floating alternate. Program direction and support by a volunteer-monitoring organization such as Coastal Watershed Council (CWC) is recommended. Yearly, two- to three-day training sessions should be required of monitoring team members to ensure a consistent level of understanding and data collection methods. The following list highlights topics that might be included in a training session:

- Basic level-surveying techniques,
- Suspended and bedload sediment sampling techniques,
- Streamflow measurement techniques, and
- Water-quality sampling techniques.

While in the field, monitoring team members would record observations and data in either field templates printed on water-resistant paper or field books such as those sold by Forestry Suppliers. After data are gathered, they would be forwarded to the watershed coordinator and then to a qualified professional with appropriate California registration charged with reducing and interpreting the data. Copies of all field notes should also be made and stored offsites in the event that such notes are lost or misplaced.

## 8.2 Continued Monitoring of the Watershed

The different assessment components outlined in Chapters 3, 4 and 5 have provided baseline data from which future efforts can build and increase our understanding of the Arana Gulch watershed. These assessments have provided snapshots of the conditions throughout watershed and do not necessarily communicate trends or historical conditions. Longer-term data will be needed to protect and guide enhancement. The following list highlights monitoring efforts that we think will be the most useful and educational.

### 8.2.1 Streamflow, sediment and water quality

It is recommended that a stream gaging station be installed near the Harbor High School fish ladder during the fall 2001[30]. The stream gaging station should be equipped to continuously record water level, water temperature and specific conductance (a measure of salinity). These variables should be recorded at a 15-minute interval (an interval we have found most useful in characterizing basin hydrology and water quality while maximizing data storage space) and should be used to develop an annual hydrologic record. This is accomplished by measuring discharge throughout the year with some emphasis placed on capturing flood events throughout the winter season and flow and water quality conditions during the baseflow season. Additionally, maintenance and downloading of recorded data are typically needed every 30 to 60 days.

It is also recommended that several locations in the upper watershed serve as baseflow monitoring sites to establish baseflow hydrology in Arana Gulch. This information will be crucial if future attempts are made to increase/sustain summer baseflows as a part of preserving aquatic life. Baseflow measurements should be made on the same day, preferentially starting in the upper watershed and working down to the fish ladder. Several monthly measurements during the summer period should be sufficient. To the extreme possible, we also recommend that sediment discharge data be collected at the gage location to better understand when and where sediment enters the streams and moves through the watershed.

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[30] The Port District installed a gaging station at this location in November 2001.

These data will build on the work conducted by the Coastal Watershed Council and will prove invaluable in understanding the response of the watershed to storm events. Flow measurements are perhaps the most important missing ingredient in understanding Arana Gulch. They are crucial for quantitatively describing existing hydrologic conditions, which serve as the baseline for evaluating the effectiveness of the enhancement plan. The measurements may also prove important as a basis for future documentation of entitlements to “water right” to sustain the habitat enhanced through this plan. Gaging also offers a means of establishing flows and computing loadings at the time of any water-quality or sediment sampling, so that the results can be compared with those obtained from other similar waters or from Arana Gulch in later years. We suggest that a small housing for a water-level recorder be incorporated into the design of the second phase of the fish-ladder improvements.

We are aware of only a few samples collected over the years from the La Fonda tributary. This is an important, but oft-neglected branch of the watershed for which more baseflow and water-quality data are merited. We suggest that this channel be monitored regularly, perhaps by a community group or through one of the programs at the high school. Basic information on how flow and water quality vary seasonally and spatially throughout this sub-watershed are needed.

### 8.2.2 Annual reconnaissance of watershed conditions and salmonid densities

Watershed conditions and salmonid densities need to be assessed on a recurring basis through direct field observations. Watershed conditions could be assessed annually or biannually and should be conducted by qualified professionals with the appropriate reports prepared following fieldwork. It is recommended that the following sites be visited and characterized during future monitoring efforts:

- monitoring sites highlighted in Chapters 3, 4 and 5 and Appendix B of this report,
- areas that are discussed as prone to developing problems in Chapter 9 and

- all projects that have been implemented to some degree or completed.

Concurrent sampling of fish populations (with an emphasis on salmonids) and habitat conditions in the main, western, central and eastern branches of Arana Gulch should be conducted. Fish sampling is recommended every 2 to 3 years or following periods of drought or flood when critical conditions may exist. Fish sampling should occur in the fall.

## 8.3 Reporting on Watershed Conditions and Project Implementation

The continued monitoring and assessment efforts outlined above should be summarized and presented to all involved or interested parties as completed. The Technical Advisory Committee should develop a list of parties to receive copies of these annual or bi-annual reports with possible parties which may include:

- Present and past project funders,
- Present and past technical advisory committee members,
- Members of the Arana Gulch Watershed Alliance, including the Port District and active agencies,
- Public works and resource agencies participating in channel maintenance and management,
- Pertinent U.C. Santa Cruz and Cabrillo College libraries as well as faculty members with histories of watershed service,
- City of Santa Cruz and Harbor High libraries,
- Owners (such as the school district, De Laveaga Park or Chaminade) participating in AGWA's efforts, and
- Residents and groups (perhaps such as Harbor High classes or disc

golfers) who have taken on specific projects.

The current AGWA newsletter format may prove to be a very appropriate venue for communication purposes and could be assembled by the watershed coordinator with assistance from monitoring team members and consulting scientists. In addition, it might be conducive at times to present major findings and observations during meetings of the Technical Advisory Committee or other public forums. The key to these recommendations is communication of all that is learned in an informative and concise manner.

# 9. LONG-TERM HORIZON

*Chapter 9 discusses the 30- to 50-year and beyond vision of the enhancement planning effort for Arana Gulch. Detailed discussion is given to effects of expected and likely episodic events such as earthquakes, floods and fires. Other long-term management issues are also discussed including flooding, sedimentation and trends observed in the tidal reach, areas with the potential for developing sediment source related problems in the future and long range water quality goals. We identify certain measures or management directions which can be advocated or implemented when opportunities arise; we believe it is part of the enhancement program to be prepared with policies and programs as these opportunities develop. One of these, for example, is encouraging construction and operation of properly-designed in- and near-channel sediment storage basins, and potential locations in the watershed are highlighted. The chapter ends with a discussion of future floodplain and channel management strategies appropriate to this watershed as well as past successes in Arana Gulch with these issues.*

## 9.1 Expected and Episodic Events

A useful management plan for a coastal watershed in Central California should logically anticipate climatic cycles and episodic events. Although these may not have occurred in recent memory, certain events such as major wildfires or floods should reasonably be expected in the 30- to 50-year intended lifetime of this plan. Similarly, extended droughts or wet periods will almost certainly occur during the plan’s envisioned period of effect.

### 9.1.1 Eucalyptus: The issues

Groves of eucalyptus, most notably in De Laveaga Park, provide a valued visually prominent forested aspect to much of the Arana watershed. They form continuous belts of woodland on the scarp separating the golf course and other activities on the main park flats from the Prospect Heights neighborhood just below the park. Isolated groves or individual trees occur throughout the watershed.

Although eucalyptus was usually planted as windbreaks and for slope stability, many land managers now question the value of these Australian imports in the coastal California landscape. A number of parks and natural areas in the Santa Cruz vicinity have management plans that call for removal of this non-native species. It is not difficult to envision a concerted effort to remove eucalyptus under a number of possible scenarios:

- a fire leaves behind tall snags and widowmakers that merit removal to protect public safety from falling limbs or trunks, or to prevent subsequent infestation of plant pests,
- a hard freeze affects the trees, killing the standing crop, and (as above) requiring removal of the trees,
- the trees become subject to a plant disease or attack by insects or fungus which attacks the eucalyptus, requiring their removal either to prevent injury (as above) or to inhibit the spread of the blight,
- other management needs.

Large-scale removal of eucalyptus could result in significant erosion and sedimentation, particularly in the West Branch and in the La Fonda tributary and its headwaters. In effect, removal of eucalyptus would be a timber harvest in the sandy, locally-erodible soils in which it presently grows (c.f., Singer, 1999). Additionally, the roots of the fallen trees – which presently stabilize some of the slopes in De Laveaga and elsewhere, would gradually decompose, resulting in a second wave of sediment delivery from shallow landslides, perhaps 5 to 15 years later. A harvest of eucalyptus wood in this setting may prove more damaging than a typical timber harvest because:

- there is little undergrowth to hold the soil,
- oily surface residues may generate rapid runoff resulting in gullying, and
- the existing protective blanket of long, interpenetrating leaves would likely be broken during the cut, exposing fresh and erodible soils.

Control of erosion and sedimentation associated with eucalyptus removal can be approached as either an element of land management (such as at De Laveaga Park, or also Chaminade, other private land owners, or easement holders such as PG&E or the City of Santa Cruz Water Department); or as a contingency plan for protection of the stream, high school or harbor. As a land-management planning tool, it might be elaborated by City staff resource specialists or it can serve as the subject of a senior thesis or graduate project in environmental management. As a contingency plan, it might be explored through hazard-assessment entities such as CDF, FEMA, fire departments, or state pest-management specialists.

### 9.1.2 Highway prism detention

At present, the capacity of the culvert beneath Highway 1 constrains peak flows and provides a degree of flood control for segments of the creek further downstream. The properties need to be maintained at this location to protect reaches further downstream. Ponding to depths of 5 to 8 feet were observed during the January 1995 and February 1998 storms, extending upstream to points a short distance upstream of Brookwood Drive. The ponding helped to diminish peak flows at Harbor High and stream segments to the south. Both sediment and small woody debris were retained on the floodplain and lower slopes of the valley upstream from the culvert. The culvert and highway prism, as presently sized and configured, act as a sediment and debris basin during very large storms; little if any effect is seen at flows with recurrences of less than perhaps 5 years. During the large storms, these functions are especially important in maintaining the integrity of the channel downstream. Bridges, crossings, the Capitola Road culverts and creekside facilities downstream of highway do not have the ability to retain or withstand logjams which might be formed by the material of the sizes settling out upstream of Highway 1.

Measures to retain peak-flow attenuation, sand deposition, and trapping of woody debris at this site should be encouraged. These may include further documenting these effects during subsequent floods, attempting to incorporate these functions into future highway improvements, as well as into facilities which may be built in the future in the Highway 1 and Brookside rights of way. Significant aquatic and riparian habitat has developed at this site. Opportunities to acquire easements or other public vestiture in the privately-held lands on both the City and County sides of the creek might be sought if and when there are willing sellers. Over the long term, among possible sources of funding might be:

- City and County agencies responsible for flood control and drainage
- Riparian and flood-zone acquisition programs which may arise
- Caltrans mitigation initiatives
- Funds from fines levied by Fish and Game or open-space management agencies
- Mitigation or penalties associated with Riparian or Sensitive Habitat Ordinance violations
- Interested donors from any one of several sectors.

### 9.1.3 Massive falling wood

At some point during the coming 30 to 50 years, it is likely that an event or condition will occur which will bring large volumes of woody debris into the channel of Arana Gulch. The event might be a major windstorm (such as occurred in December 1996), a heavy snowfall (such as the one on January 2, 1974, which brought down innumerable hardwood limbs and trees throughout the San Lorenzo Valley and Soquel watersheds or slightly higher elevations), or a flood larger than those experienced during the past several decades. It may also result from blight affecting the hardwoods which hold many of the hillslopes above Arana Gulch in place. Or the woody debris may fall into the creek following a sequence of events, which may include (for example) an earthquake during a very wet winter period, compounded by a windstorm with effects magnified by the already partially-opened canopy.

A plan or set of criteria to guide removal or retention of woody material in the channel would be especially valuable in the Arana watershed because slopes immediately above the channel are steep and sandy. Excessive removal can induce ongoing erosion by damaging the banks and slopes; insufficient removal can induce ongoing erosion, as the wood and fallen trees deflect the stream into the slopes. Additionally, large wood has an important role in maintaining pools in this channel, in which waves of sand can fill other pools and holes. Yet, as we noted above in connection with the Highway 1 fill prism, large pieces of wood or large volumes or pulses of limbs may pose risks to channel stability, especially in the lower segments of the channel.

This type of plan would perhaps most likely be developed as a thesis project by a student in the watershed or forest sciences, abetted by AGWA's members and staff. Alternatively, plans of this type might evolve from revisions of plans and operations at some of the larger open-space holdings in the immediate regions, such as De Laveaga Park, the Forest of Nisene Marks State Park, or perhaps the Soquel Demonstration Forest, from which AGWA might develop a version adapted to the conditions of the Arana watershed. It would likely include:

- A field assessment of the role of large wood in stabilizing and de-stabilizing the Arana channels in different types of soil and at various points from the headwaters to the harbor
- Guidelines for retention, removal, and replacement of large wood in the stream
- Locations where mechanized and foot access to the channel is feasible
- Reaches or slopes where new temporary or permanent roadways into the channel corridor should or should not be constructed[31]
- Suitable locations for stockpiling (or distribution) of removed wood
- Suggestions for re-using the wood in stabilizing damaged reaches of the channel or controlling bank and slope erosion
- Outlining processes for review and amendment of this plan in the context of AGWA's role as a consensus-based group

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[31] Relatively small and non-invasive roadways had keys roles in catalyzing both the Locatelli and 'Blue Trail' gully systems, or perhaps in affecting the Pilkington Road landslide. Similar settings and soils occur throughout the Arana drainage, and should be mapped. Also, certain soils have demonstrated properties allowing roads to be constructed on relatively steep slopes without undue maintenance needs.

- Suggestions for building and communicating this plan with the support of both local residents and agencies with disaster-response obligations
- Ideas on how to incorporate the consensus plan into the general plan and emergency-response plans for the County, among other pertinent venues.

Once in place, provisions of this informal plan could be implemented through AGWA's activities and through the policies and capital-improvements plans of public works and fire agencies. As one example, if water-quality enhancement basins were to be constructed for control of urban runoff, as part of individual private or public projects in the watershed, portions of their sites may prove suitable and designated for stockpiling debris.

### 9.1.4 Large landslides

Sudden delivery of sediment and debris to the Arana streams should be expected from time to time. Relatively few 'large' landslides or unstable slopes presently occur in the Arana watershed, but the potential exists, as the Pilkington Road slide indicates.[32] Most such failures likely result in delivery of several hundred to several thousand tons of sand-sized material to the channel, we believe.

In many respects, slope failures of this magnitude and large gullies incising into filled swales (such as Blue Trail and Locatelli) are similar in their effects on the channel system. The main difference is that landslides can introduce larger material which can induce widening of the channel downstream. In most portions of the watershed, coarser material is highly weathered and will rapidly break down to readily-transportable silts and sands.

Slopes and gullies should be stabilized in place where feasible. Once the soil has entered the channel, we believe that catching as much of this debris as is feasible in sedimentation basins downstream is perhaps the most suitable strategy for controlling potentially-destabilizing pulses of sediment from either slope failures or rapid gully

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[32] The watershed may be more prone to these events a few years after a wildfire, as roots presently stabilizing steep slopes decay. Since there is little experience with wildfires in this and adjoining watersheds, there is no empirical basis for confirming or refuting this inference.

incision. The distribution of basins that we have proposed reflects our interpretations of where effects of slope (or swale) instabilities are best able to be controlled once this material has entered the channels.

### 9.1.5 Rising sea level

Within the 30- to 50-year timeframe envisioned for this watershed enhancement plan, changes in sea level may take place that affect the lower reaches of Arana Gulch. One approach to estimating future sea level 50 years hence is to project forward the increases in sea level that have been observed over the past century. The San Francisco Bay Conservation and Development Commission (1988) uses this approach. Based on observations at long-term fixed tidal gages at the Golden Gate and other Bay Area locations, BCDC projects a rise of 0.48 feet by the year 2050, the end of the 50-year planning horizon used for Arana Gulch. Another approach is analytical – a cause-and-effect interpretation of results from climatic change simulations. The Environmental Protection Agency uses this approach (Titus and Narayaran, 1995), which leads to estimates that there is approximately a 50 percent likelihood of a rise of 0.65 feet, and about a 10 percent change of a rise of 1.08 feet.

At Arana, sea-level rise may have two primary effects. First, high tides are likely to frequently rise up onto the low steam terrace into which the tidal channel is cut. This terrace—now supporting willows and blackberries and fresh- or brackish-water tolerant grasses – is likely to either (a) transform to a pickleweed *(Salicornia spp.)* plain, or (b) erode away to a small remnant as the dense-rooted grasses give way to tidal species with small root systems not adapted to holding soil in place. If significant erosion of the terrace occurs, the volume of the tidal prism which must pass through the four culverts every 12.5 hours will increase moderately. A second major effect will be an increase of approximately 30 to 50 percent in the volume of the tidal prism during higher high tides due solely to the rise in sea level. Increased scour at either end of the culverts may be anticipated but also increased risk of blockage will arise unless the culverts are raised. Continued northward expansion of the tidal and salt-water marsh system is expected as sea levels rise. Should sea levels decline, gradual trends back toward the conditions prevailing in 1982 may be expected, including incision of a new tidal channel into the existing aggraded bed and gradual recolonization by the existing vegetation.

## 9.2 Flood Management

In planning 30 to 50 years into the future, watershed enhancement should also anticipate likely changes in both regional flood-management standards and conditions along Arana Creek. A few likely changes that we believe merit consideration include:

Design flows and inundation elevations are likely to increase. This reflects inclusion of data from the (wet) 1990s in the database used to estimate design flows, more suitable selections of streams used for regional flood curves, and (perhaps most significantly) an awareness that aggrading channels, debris jams, vegetation in the floodway and floodplain and other factors not conventionally assessed in engineering hydrology play a significant role in risks of flooding. These may be partially offset by improved understanding of the role of riparian or floodplain vegetation in the hydraulics and stability of coastal California channels.[33] We suspect that a higher level of protection (e.g., designs to higher flood recurrences) will be required for roads and improvements near public facilities central to public safety, such as the medical and transportation centers near the central third of the main stem of Arana Gulch. Long-term planning should be based on expectations that design flows and inundation levels will be slightly higher than at present.

Arana Gulch has minimal storage for floods or sediment within its floodplain. There are few areas where the floodplain is wide enough to help attenuate storm peaks or sediment pulses. AGWA can help sustain and enhance floodplain functions by (a) re-connecting the wetland immediately east of the high school sediment basin to the floodplain, (b) seeking additional floodplain wetlands at times when larger projects or retrofits are planned on parcels fronting on Arana Gulch and its tributaries, (c) encouraging construction of naturalized drainage improvements and best-management practices BMPs storm-water quality as well as peak-flow attenuation, on both the City and County side of the watersheds, perhaps to the point of enabling retrofitting older

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[33] Coastal California is one of very few places in the United States where tree-sized vegetation is generally not in leaf during the flood season. To our knowledge, no provisions for this very basic condition are made in using standard FEMA models to simulate inundation levels in streams such as Arana Gulch.

projects such as Santa Cruz Gardens, (d) carrying through with important projects, such as restoring the disc golf course or the Blue Trail gullies, which reduce peak runoff rates, and (e) taking measures to protect or maintain the functions of existing detention areas, such as the segment of the creek immediately upstream from the Highway 1 culvert.

## 9.3 Long-Term Sediment Management Challenges

From a technical perspective, the decision to accept a long-range planning horizon in a small coastal watershed requires acceptance of five key challenges:

a) Anticipating the types of new events and processes reasonably likely to occur during a plan with a 30- to 50-year horizon (see Sec. 5.4)

b) Sustaining the repairs and projects implemented as part of the initial phase of enhancement

c) Quickly identifying and responding to new sources of sediment or water-quality concerns, since in sandy soils new problem areas can develop and expand very rapidly

d) Coming to better understand how fish populations and riparian vegetation respond to the repairs, new events and climatic cycles, and adjusting this plan accordingly, and

e) Protecting existing baseflows, either from appropriation or from loss of a live stream caused by accumulations of sand on the bed, recognizing that many management issues begin where – and when – flows cease.

We are able to directly assist substantially in this plan with only the first of the challenges. Meeting the others will require continuity in a group of stewards with diverse skills and inclinations, ranging from those who enjoy systematically walking the creeks following major storms, to those able to comprehensively review water-rights appropriations and regulations. Perhaps the key individual may prove to be the biologist who commits to following the long-term changes during a few days a year, and many years running.

## 9.4 Tidal reach and culverts

Site 19[34], illustrated and discussed in **Appendix C**, may be the source about 5 to 10 percent of the sediment deposited in the harbor. Ongoing bank retreat has been characterized as a series of channel bank failures due to elevated sediment pore pressure following high tide (Hecht and others, 1982). Channel bank failure associated with Site 19 results in direct addition of sediment to the channel with correspondingly rapid transport time to the North Harbor (1-3 days). Hecht and others (1982) found that sites nearest to the inlet culverts have experienced the largest amounts of bank collapse while the largest percentage of increase in channel width has occurred in the upstream portion of the reach (for the period 1963-1982). The subsequent work conducted by Jason Parke (Coastal Watershed Council) in 1999 this watershed plan showed that the rate of channel widening has continued to increase since 1982 with percentage of increase ranging from 100 to 400. The Coastal Watershed Council also found that the bed through the tidal reach has aggraded an average of two feet (with an assumed possible error of +0.46 feet) since 1982. Bed aggradation through the tidal reach is likely the result of increased sediment supplied from the upper watershed and increased rates of bank collapse in the tidal reach.

## 9.5 A Stitch in Time: Avoiding Future Repairs

### 9.5.1 Areas underlain by Purisima subunit B

A logical place to begin in the analysis of areas that might be prone to accelerated erosion would be locations of existing and past problems shown in Figure 2. Spatial examination of present and past erosional problem areas is not complete unless it is conducted in conjunction with the Geology and Soils basemaps (Figures 3.2 and 3.4 respectively).

If we examine these locations with respect to the spatial distribution of different geologic units: it is apparent that a high number (7 out of 11 sources in the upper watershed) of

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[34] Site 19 includes nine cross-sections through the 1000-foot tidal reach that is above the inlet culverts to the north Harbor. Cross-sections along this reach were measured in 1963, 1974, 1982 and 1999 to calculate the rate of channel bank retreat. Please see Hecht and others, 1982 and Coastal Watershed Council, 1999 for a complete discussion of the work completed.

major sediment sources mapped occur within the Purisima sub-unit B (Figure 3.2 as mapped by Hickey, 1968). To focus this analysis, we chose the Locatelli gully and the Blue Trail gullies as source types that are likely to develop in the future. We chose these two sediment sources because:

A. Both sources formed in soils developed from Purisima subunit B,

B. Both sources are the primary response to identifiable causes,

C. The inferred causalities could be used in analysis of the watershed for locations that bear the same or similar characteristics, and

D. The volume of material introduced to the system by each source is and was very large relative to other identified sources.

Based on these criteria, areas to monitor can be delineated and include:

- The hillslopes lining the eastern branch from the upstream limit of blue line to just below the Chaminade Blue Trail creek crossing.
- The hillslopes lining the upper portion of the central branch and most of the hillslopes to the east and northeast of this branch in the vicinity of the recently-repaired Locatelli gully.
- The hillslopes to the northwest of the central branch above Lance Bone's Property.

The area upslope from the Chaminade tributary should also be monitored as it is also underlain by Purisima subunit B. Please refer back to Figure 3.1 which illustrates the geology of Arana Gulch.

### 9.5.2 Central and western branches: channel reaches below the equestrian center

During our mapping of sources in the western and central branches, several problematic gullies were noted in areas below the equestrian center located at the head of the western branch. The gullies noted on the central branch are draining the western hillslopes (below this side of the equestrian center) and were relatively small at the time of observation. However, the density of these gullies seemed high which could have dramatic effects in terms of sediment delivery if the gullies were to grow at similar rates. The gullies noted on the western branch may be associated with drainage from the southwestern area of the equestrian center and the occurrence of marine terrace deposits. The gullies found in this area feed directly into the large gully below the Pilkington Road slide and the upper western branch of Arana Gulch. At the time of observation, it was apparent that landowners had tried to stabilize parts of the gully but without much success.

### 9.5.3 Capitola Road crossing

The Capitola Road crossing has the potential to develop into a fish passage barrier if the current condition at the crossing worsens. The channel bed on the downstream side of the crossing has been lowered of the bed by roughly 4 feet. The crossing was not characterized as a fish passage barrier in Alley 2000. However, Don Alley has confirmed that if the bed continues to downcut downstream of the culvert, it could become a fish passage barrier. Additionally, the right bank downstream of the crossing should be monitored for in the future due to a history of bank failures at the site.

## 9.6 Long Range Opportunities for Enhancement

### 9.6.1 Sedimentation basins and off-channel storage

To effectively deal with the sand produced in the Arana Gulch watershed, we need to remove it from the water column during storms and from the bed between storms. Sediment basins act to remove sediment from the water column by slowing down stream velocities that in turn leads to increased deposition of bedload and perhaps suspended load. Based on criteria discussed below, a total of five, new sedimentation basin locations have been identified and can be observed in **Figure 9.1**. Sedimentation basins have been identified as a viable and effective solution due to the nature of sediment that is produced and transported through Arana Gulch. Sand-sized sediment is the dominant class produced and transported through Arana Gulch. From our knowledge of in-stream hydraulics, we know that consolidated sand sized particles are mobilized form storage on the channel bed at the lowest threshold velocities. Because of this phenomenon, sand-sized particles will be transported on more days throughout the year than any other size class of particles. Sediment basins and off channel storage basins are an effective means of removing sand sized particles form the water column and from deposition in vital steelhead habitat. They also can absorb pulses of coarse sediment resulting from bank or slope failures, reducing downstream impacts.

The sedimentation basins are all located in the upper watershed and above the Brookwood Drive crossing. Several criteria were developed to aid identification of candidate locations:

- The basins should be located downstream of the identified sediment sources (chapter 4) to effectively reduce the volume of sediment transported to the lower watershed,
- The basins should be accessible from established roads to facilitate construction and maintenance,
- Basin locations should minimize flood potential to upstream and downstream residents, and
- Where possible, basins should be located in reaches that present additional over-bank storage area with the potential for development of seasonal wetlands (see section 5.5).

The sedimentation basins have been sized to store roughly 300 cubic yards of material. This corresponds to a total reduction of 1500 cubic yards in the volume of material transported from the upper watershed to the lower reaches. This volume is more than the median for annual sand transport. Depending on how often the basins were mechanically or naturally cleaned out, a reduction of 1500 cubic yards is a significant step towards achieving decreased downstream sedimentation and enhanced fish habitat.

## 9.7 Water Quality Measures

### 9.7.1 Water temperature

High summer water temperatures in Arana Gulch can be approached from several different perspectives. Channel banks that are a part of repair projects should be revegetated to help stabilize them in the long-run and to provide streamside shading. Channel banks that intercept southeastern or southwestern sun and have reduced vegetative cover should also be given priority. Aggressive bank revegetation plans should be included as an objective of the evolving greenbelt plan in the lower watershed.

Repairs discussed in the preceding sections may help to curb high summer water temperatures by reducing sedimentation of existing pools. If pool sedimentation is reduced, pool depth may increase in subsequent years following winter rains so that cooler alluvial ground water is intercepted or (perhaps) to depths which naturally stratify, especially in Reach 2 (**see Figure 4.1**).

### 9.7.2 Prevent releases of toxics from specific land uses within the watershed

Community education programs targeting specific land uses and activities within the watershed will aid general environmental awareness and understanding. Specific land uses and activity groups to target might include the medical industry, orchard owners and professionals, homeowners and businesses (Chaminade, cemeteries, parks, and municipal golf courses) engaged in promoting lawn and turf growth, similar groups engaged in road and driveway maintenance and users of the small craft harbor.

Corollary measures to follow community education might include construction of wetlands or pollution-control measures for specific uses, such as storm runoff and return flows from areas of irrigated turf or dense housing units (e.g. Santa Cruz Gardens). Additional target locations for runoff control measures might include larger maintenance sheds for the municipal golf course, small craft harbor, high school, and probably the cemetery. County and City master plans should logically include measures for improved maintenance of storm sewers and contingency planning for new large-scale drainage systems within the watershed. If an emergency plan is not already in place, spill-response procedures at the City and County level should be prepared and response teams assembled and trained (see section 5.3.5).

### 9.7.3 Reducing inflows of general urban contaminants

Reductions in the inflow of general urban contaminants can again be addressed from several different perspectives. Proper maintenance of existing curb-inlet basins, proper disposal of or moving debris that is prone to chemical leaching away from the stream and storm sewers, incorporating wetlands in the greenbelt park and general education programs through local primary schools. Large improvements here can come from increased participation and vigilance among land and homeowners, volunteer clean-up efforts from school and watershed groups and increased, general environmental awareness among watershed users and residents.

## 9.8 Flood Conveyance and Floodplain Management

During 2000, AGWA was able to bring together a group of agencies and volunteers to re-establish the sedimentation basin at Harbor High School. The public works departments of the City and County provided the equipment and staff to clear the basin under a plan developed in cooperation with the Department of Fish and Game and school district; the Port District performed finish grading and with the help of CWC staff installed monitoring hardware, while volunteers from the high school and AGWA re-vegetated the edges of the basin with native plants. AGWA staff plan to work with the two public works departments to empty the basin during the summer of 2001.

This watering group may potentially serve as a forum for reaching agreement on how to manage vegetation, woody debris, and accumulated sediment such that the stream's capability to convey floods can be maintained while also meeting aquatic and riparian habitat needs. Technical bases for guidelines affecting channel maintenance are becoming increasingly familiar to both habitat and floodplain management agencies. Maintenance of the channel at specific levels or energy grade lines, or at set hydraulic roughnesses ("Manning's n") can be utilized. In locations where more precise guidance is needed, site-specific criteria may be developed in consultation with the owner(s), or the methods and guidelines for quantifying the effects of clearing practices on conveyance developed for AMBAG can be applied (c.f., Hecht and Woyshner, 1986).

Practices for maintaining stream corridors in Santa Cruz County are evolving. It may prove worthwhile to defer corridor-wide guidelines for Arana Gulch until these are developed and negotiated in some of the larger stream systems. Nonetheless, AGWA should be prepared to assist owners and various agencies reach agreement on how individual segments of the stream will be maintained (see also Sec. 5.4.3 for actions appropriate after very large events).

# 10. LIMITATIONS OF THIS REPORT

We again ask that all readers, regardless of their background, note that the purpose of the applications and recommendations in this report are to inform the choices that must be made in developing a workable watershed plan. They are for general planning purposes only, and -- consistent with that framework – to phase and fund work in a logical progression. Further analysis, design, environmental review, and permits will follow on a site-specific basis. Similarly, nothing in this plan should discourage individuals who wish to put forth other means or methods of realizing the plan's specific goals and implementing the tasks for which it calls; suggestions are welcomed.

As a result, the applications and recommendations are expressly not intended to serve as a basis for permitting, enforcement, disclosures (or lack thereof) such as in the sale or lease of property, contracting of construction, and – above all – for setting neighbor against neighbor.[35] Additionally, the plan will need to be regularly updated[36], as sources of sediment[37] and the preferred techniques for their repair change, much as a capital-improvements plan or a zoning plan must be updated in light of changing conditions and technology if it is to meet the goals of the master plan. New scientific and resource-management information should also be incorporated as it comes available. Planning for enhancement benefits from a 30- to 50-year timeframe; it is possible that new conditions will arise within that time. Those who use the plan are encouraged to participate in the watershed council (at present, AGWA), or at a minimum discuss their use of the plan with the watershed coordinator; regular participation or consultation are suggested for those who may regularly use the plan in their businesses, duties, or classroom instruction.

The scientists, engineers, and design professionals who have helped prepare this report continue to seek new information (including accounts of historical conditions) or key observations of conditions or events. We encourage all potential contributors to contact us, and most especially those residents or other individuals familiar with the watershed. Whenever feasible, we will try to respond to each contribution. We can be reached through AGWA, or at the addresses and other contacts on the signature page of this report, or at the contacts given in the appendices to this report.

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[35] Use of information for purposes other than those for which it was intended can lead to misunderstandings, danger to life or property, and / or environmental damage.

[36] The frequency and process of updating will be developed in the near future, with AGWA welcoming pertinent suggestions from all of the plan's users.

[37] or locations of fish barriers, or other specific challenges

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## Pertinent GIS or Data Files

- Santa Cruz County Watershed Boundaries
- Santa Cruz County Stream locations and names
- Santa Crux County Geology
- Santa Cruz County Soils
- Santa Cruz County digitized USGS Quads: Soquel, Laurel and Santa Cruz
- Santa Cruz County 10-meter digital elevation files
- Santa Cruz County streets and names
- City of Santa Cruz property lines

# 12. GLOSSARY OF TECHNICAL TERMS

**aggrade** – to build up a river bed and flood plain with deposited sediment; is the opposite of degrade.

**alluvium** – sand, silt, and clay deposited by moving water as it slows down. The shape of the deposit depends upon the size of material and the characteristics of the flow.

**alluvial fans** – form when a swift stream flows down from higher land onto a nearly level valley floor. The abrupt change in gradient causes the sediment to be deposited in a fan that radiates from the point where the stream meets the broader valley floor.

**anadromous fish** – fish that migrate from the sea to freshwater for reproduction.

**bankfull flow** – the discharge of flow at which the water level begins to exceed the height of the most pronounced banks.

**bar** – an alluvial deposits of sand, gravel, or other stream sediments that forms when a decrease in flow velocity cause deposition of sediments.

**bedload** – large, heavy material that moves along the streambed by rolling, sliding, or bouncing. Generally refers to material larger than 0.5 mm in diameter, such as sand, gravel, cobble, and boulders.

**bedrock** – the solid rock that underlies all soil, sand, clay, gravel, and loose material on the earth’s surface. When exposed to the air, it may be referred to as an outcrop.

**cfs** – cubic feet per second. A unit of measurement used to describe the quantity of water that passes a fixed point per second.

**chronic** – prolonged, continuing, or consistent condition. Chronic erosion is that which will continue to occur unless physical conditions change.

**coarse sediment** – is a broad category that includes both coarse sand and gravel particles that are smaller than 6.4 cm in diameter.

**cobble** – rocks that are larger than gravel and smaller than boulders. While the definition of size range may vary, it is usually between 6.4 cm and 25.6 cm in diameter. Small fish seek refuge from predators by hiding in the space between cobbles. The space between cobbles is reduced by the accumulation of fine sediment.

**colluvium** – loose soil and material that has accumulated at the base of a slope.

**degraded** – reduced in quantity or value.

**degradation** - the geologic process by which streambeds and flood plains are lowered in elevation by the removal of material. It is the opposite of aggradation.

**downcutting** – a decrease in streambed elevation caused by erosion.

**embedded** – rocks or portions of rocks at the surface of a streambed that are buried in finer sediment. Measurements of embeddedness provide information about the amount of resting of refuge habitat available for juvenile and yearling salmonids.

**entrained** – carried along; used to refer to woody debris or sediment that is carried by or entrained in flowing water.

**episodic** – related to an incident or series of separate incidents that are relative to a continuous event, for example, a landslide that is activated periodically by storm events.

**fines** – small particles of gravel and sand, usually defined as particles smaller than 6 mm in diameter. Gravel with a high proportion of fines tends to have low dissolved oxygen levels, which delay or limit embryo development.

**first order stream**– Stream order is a classification used to describe the branching pattern of river systems. A first order stream is the smallest unbranched tributary to appear on a 7.5 minute USGS quadrangle. When streams of equal coverage, they form the next higher order of stream. For example, when two first order streams join, they form a second order stream. When two second order streams join, they form a third order stream.

**fluvial process** – formed or produced by the action of flowing water.

**geomorphology** - the landscape and physical processes that shape land forms. The form of s stream channel is influenced by the hydrology of the stream as well as the underlying geology – the presence of large rocks, the gradient, stability of bank material, sediment supply, etc. The term hydrogeomorphology is often used to describe the combination of these factors.

**glide** – habitat category characterized by moderately shallow water (10 to 30 cm deep) with an even flow that lacks pronounced turbulence. Frequently located at the transition between a pool and the head of a riffle or in low gradient streams with stable banks and o flow obstructions. Substrate usually consists of cobble, gravel, and sand.

**gradient** – a slope or rate of inclination.

**gully** – a depression or channel that is formed when water flows over the surface of the land. Erosion at the head of the gully lengthens it, and water washing down the sides widens it.

**headcut** – a break in slope at the top of the gully or section of gully that forms a waterfall, which in turn causes the underlying soil to erode and the gully to extend uphill.

**hydraulic** – of, involving, moved, or operated by the movement of a fluid, especially water.

**hydrology** – study of the properties, distribution, and effects of water on the earth’s surface, in the soil, in underlying rocks, and in the atmosphere.

**incised** – extensively eroded or downcut; used to describe a stream or river bed.

**impairing or detrimental sediment** – sediment that diminished the quantity or quality of salmonid habitat. For example, increases in the proportion of fine sediment in a redd reduces the number of salmonids that will emerge from the gravel.

**large woody debris (LWD)** – in this report, LWD is used to describe wood that is at least 12 inches in diameter and 6 feet long or larger (Flosi and Reynolds, 1994).

**left bank** – refers to the streambank on the left side looking downstream. This is the convention used by hydrologists and the authors of this report.

**low flow channel** – the river channel containing the lowest or residual flow reached in a given year; also called the wetted channel.

**mass wasting** – erosion that has occurred on a large scale, such as landslides and debris torrents.

**morphology** – the scientific study of the form or structure of an organism or physical process.

**outcrop** – a portion of the bedrock under the earth’s surface that is above ground.

**overhanging banks** – undercut banks that occur when water velocity is sufficient to erode the lower portion of a stable streambank. The stability of the bank depends upon a combination of geology, protective vegetation, and the magnitude of flows.

**pool** – depression in a streambed that is formed by scouring or removal of sediment during periods of high flow. After formation, the velocity of water within the pool is reduced, causing the surface of the water to appear smooth. The velocity of the water is different depending upon the location within the pool. The boundary of the pool may be composed of solid material and/or gravel and sand deposits. Pools are usually described in terms of location within the stream channel or by the type of structure(s) contributing to the formation of the pool.

**reach** – sections of a stream or river between two specified points or possessing some common characteristic(s).

**recurrence interval** – the average time interval between occurrences of a hydrological event of a given or greater magnitude.

**redd** – fish spawning nest or group of nest dug in a gravel bed. Usually located in the tail of a glide, 25 to 50 feet upstream from a riffle. It is very important not to walk on or disturb the redd.

**riffles** – stream reaches with moderate turbulence caused by water falling over rocks.

- Low gradient riffles are shallow (<20cm deep) with moderate current velocity (20-50 cm / sec) and moderate turbulence. Partially exposed substrate is dominated by cobble sized particles (2-256 mm). An upper limit for gradient is usually set at 4%.

- High gradient riffles exceed 4% and are moderately deep, swift, and turbulent. The amount of exposed substrate is relatively high and is dominated by boulders.

**right bank** – the streambank on the right side looking downstream. This is the convention used by hydrologist and the authors of this report.

**riparian vegetation** – vegetation associated with riparian ecosystems. Includes living as well as dead plant material both on the ground and in the water. The root systems of trees and understory vegetation contribute to the stability of soil and influence the direction of water currents. The canopy of vegetation near the stream limits the amount of sunlight reaching the stream, which helps to maintain water temperatures. Plant material also provides essential nutrients as well as refuge habitat.

**riprap** – heavy stones used to protect soil from the action of fast-moving water.

**root wad** – the bases of dead trees are called root wads if they are no longer attached to the earth by their roots. The distinguishes them from stumps. They are also called root fans root fans, root masses, and root crowns.

**run** – swiftly flowing water with little surface agitation and no major flow obstruction. Often appears as flooded riffles. Typical substrate consists of gravel, cobble, and boulders.

**salmonid** – common name for the family Salmonidae, an essemblage of several genera, that include *Oncoryhnchus*. Within the genus *Oncoryhnchus*, there are several species including steelhead (*Oncoryhnchus mykiss* ) and coho salmon (*O. Kisutch*).

**scour** – localized erosion by flowing water.

**sediment** – rock fragments that range in size from clay particles to boulders.

**sediment transport** – the movement of sediment by water.

**sediment yield** – the amount of sediment transported from a river basin that can be used to compute the average rate at which the basin landscape is lowered by erosion.

**slumping –** movement of earth and rock that occurs when supporting material is removed. For example, streambanks slump when the toe of the streambank is washed away.

**smolt** – life stage of juvenile salmon or steelhead when they migrate out to sea. Smoltification refers to the physiological changes that are necessary for fish to tolerate salt water and typically occurs after the first summer and winter spent in freshwater.

**spawning habitat** – habitat with suitable velocity, depth, and substrate characteristics to foster spawning. Though requirements are slightly different for coho and steelhead, studies conducted by Bratovich and Kelley (1998) reported that all fish in Lagunitas Creek spawn in velocities higher than 0.7 feet/second, depths ranging from 0.5 to 3.0 feet, and spawning substrate with a mean particle diameter $D_{50}$= 0.8-4.5 cm

**spawning adult holding habitat** – pools or other areas where adult fish may rest and find shelter from predators.

**substrate –** any object or material upon which an organism grows or is attached; the underlying layer or substance.

**stability –** absence of fluctuations; ability to withstand perturbations without large change in composition. The stability of a stream channel is an indication of its ability to withstand channel-altering effects of large storm events; it determines the availability of suitable aquatic habitat.

**suspended load** – clay, silt and sometimes sand that are held in suspension by the turbulence in river water.

**toe** – the base or lower edge, such as of a checkdam or streambank.

**trash rack** – a barrier at the upstream end of a culvert to trap debris but still allow water to flow through.

**watershed** – the land area that drains into a particular stream or river. It includes major and minor creeks and seasonal drainage. Large watersheds often have distinct subwaters that drain into the main creek. For example San Geronimo Creek and Nicasio Creek watersheds are subwatersheds in the Lagunitas Creek watersheds. Watersheds are sometimes referred to as drainage basins or catchment areas.

**weir** – a structure across a ditch or stream used to divert water flows.

**woody debris** – pieces of wood that vary in shape and size. Wood contributes to the formation and maintenance of pools, provides refuge for fish and aquatic insects during periods of high flow, contributes to the retention of beneficial sediment, and contributes to the supply and duration of nutrients in the systems. The loss of woody debris from stream has been clearly linked to the decline in salmonid populations.