Codornices Creek Watershed Restoration Action Plan

Prepared for the

Urban Creeks Council

 

By

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The Codornices Creek watershed assessment and salmonid restoration planning project, the results of which are reported here, was funded by the Watershed Program of the California Bay-Delta Authority, through Contract No. 4600001722 between the California Department of Water Resources and the Urban Creeks Council.

The Urban Creeks Council is a non-profit organization working to preserve, protect, and restore urban streams and their riparian habitat. The Urban Creeks Council may be reached at 1250 Addison Street, Ste. 107, Berkeley, CA 94702 (510- 540-6669).

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Executive Summary

An assessment of Codornices Creek, Alameda County, California, was conducted between fall, 2001 and summer, 2003 by a team of fisheries and watershed scientists, a water quality specialist, and a restoration engineer, to determine the presence of steelhead (*Oncorhynchus mykiss*) in the stream; to evaluate the amount and quality of Codornices Creek's salmonid stream habitat in order to determine if the existing habitat can support a self-sustaining steelhead population; and to identify those actions which, if undertaken, could improve and expand Codornices Creek's stream habitat for steelhead.

The assessment determined that there are steelhead/rainbow trout in Codornices Creek, and that although they are using less than two miles of the potential 3.2 miles of suitable stream habitat, steelhead did spawn and produce young-of-the-year fish in each of the two study years. The project documented the presence of older salmonids in the stream, as well.

The stream habitat, although not good for salmonids by wildland standards, has survived more than 100 years of intense urbanization in the watershed surprisingly well. Several migration barriers below Albina Street appear to hinder adult steelhead upstream migration and the culvert under Albina Street [approximately the head of study reach 3, Figure 2] appears to stop steelhead altogether. There are a few apparent barriers to steelhead migration above Albina Street, as well.

An active watershed protection and restoration public outreach and education effort by the project has created awareness of the opportunities, and has generated community support for steelhead restoration within key elements of the community, including City of Berkeley officials and Codornices Creek property owners.

Recommendations are made for modifying the lowermost of the fish barriers, for stabilizing major sources of stream sediment, and for other fish-friendly actions to improve Codornices Creek stream habitat so that it can support a sustainable steelhead population.

Acknowledgements

This evaluation of Codornices Creek stream habitat could not have been possible without the support of the creekside landowners of Berkeley and Albany. The property owners were not only generous in granting the survey crew access to their backyards, but nearly all of them expressed support for the restoration of Codornices Creek's steelhead population.

The authors would like to give special thanks for their support of this Codornices Creek evaluation to Peter Husby of the Environmental Protection Agency's Richmond Field Station; Cristi Delgado of the City of Berkeley's Department of Public Works; Susan Schwartz of Friends of Five Creeks; and Gustavo Porras of Balance Hydrologics.

Bryan Flaig organized and supervised the stream habitat survey, as well as other project tasks, and Michelle Wallar and Jesse Quay conducted the survey in the field. Jesse took charge, as well, of the fish trapping and fish population assessment tasks.

Introduction

Codornices Creek flows from the Berkeley hills west to San Francisco Bay. From its source in the hills down to Monterey Avenue the stream flows wholly within north Berkeley. Downstream of Monterey Avenue, however, Codornices Creek serves as the border between the cities of Berkeley and Albany to the north.

Historically, the creek entered a tidal marsh that extended northwestward from the current Union Pacific Railroad tracks to the northeast corner of Fleming Point (Schwartz, 2003; Senter, 2003). Which is to say that the creek historically ended about where present-day Third Street is, but that the filling of the Bay over the years for waste disposal and for real estate development has pushed Codornices Creek's mouth three quarters of a mile northwestward (Prunuske Chatham, 1990) to the Bay. The Bay's tidal influence now reaches to Second Street, just east of Interstate 80 (Friends of Five Creeks, 2003).

The Berkeley-based Urban Creeks Council requested grant funds from the California Bay-Delta Authority's Watershed Program in 2001 with which to undertake this "Codornices Creek Watershed Restoration Action Plan" (CCWRAP) project. Funds became available in July 2002, by which time the UCC team, led by Kier Associates, had initiated project tasks.

<u>Fish and stream habitat records</u>

The project team was unable to locate any published record concerning Codornices Creek's fish population. There is no record of fish sampling in Codornices Creek in either of the principal publications concerning Bay Area stream fishes (Leidy, 1984; Leidy, 1999).

Dr. Thomas Dudley, formerly of the University of California's Department of Integrative Biology, currently at the University of Nevada, electro-fished Codornices Creek near the BART right-of-way, just above Masonic Avenue, on March 19, 2000 and recovered several juvenile salmonids up to, but no greater than, four inches in length.

There are numerous unrecorded reports in recent years of mid-winter sightings of adult salmonids up to 18 inches in length, as far up Codornices Creek as San Pablo Avenue (the most recent of these, according to a project team member, by a graduate fisheries student). Fish of that size, in this small stream, most certainly would appear to be sea-run steelhead.

And, finally, with regard to Codornices Creek fish present and past, there is evidence that there was some sort of fishing resort at about Ninth Street, where the creek, channelized in World War II, skirts University Village (Schemmerling, 2003).

A. A. Rich and Associates surveyed Codornices Creek's stream habitat from Fifth Street up to Codornices Park east of Euclid Avenue in the winter of 1989 (A.A. Rich, 1990). The Rich study reported the presence of stickleback between Fifth and Sixth streets and noted that there were a few unidentified fish between Bonita and Milvia streets, as well.

Rich compiled brief narrative descriptions of stream habitat conditions but presented no quantitative data. The Rich report concluded that Codornices Creek was not suitable for salmonids.

Mark Jennings conducted an evaluation of lower Codornices Creek aquatic resources (Jennings, 2001) in conjunction with the proposed Lower Codornices Creek Improvement Plan. According to his memorandum report, Dr. Jennings observed juvenile steelhead in the project area (San Pablo Boulevard down to the Union Pacific tracks) and noted that steelhead "seemed to be doing well" despite the obvious impacts of urbanization on the stream, crediting this to the "… presence of shading vegetation cover over most of the stream (thus keeping water temperatures below 70º F.), the presence of deep (>3 feet) pools in many sections of the stream – especially near concrete culverts, the presence of cobble-sized rock for spawning habitat, the presence of restored lagoon habitat at the mouth of the creek, and the lack of many introduced fishes and aquatic predators in the entire stream system."

The team was unable to locate any further studies concerning Codornices Creek fish or stream habitat conditions.

<u>Other Codornices Creek studies</u>

Other previous studies concerning Codornices Creek have addressed its water quality (Sloan and Stine, eds. 1983), creek restoration efforts (Kweskin, 1998; Waterways Restoration Institute, 2001), and erosion problems (Prunuske-Chatham, 1990).

Methods: How Each Element of the Project Was Undertaken

<u>Fish population assessment methods</u>

The fish species present in Codornices Creek, and their distribution in the system, were determined both by trapping, in 2002 and 2003, and by direct observation during the 2003 salmonid habitat assessment.

A downstream migrant trap, provided by the California Department of Fish and Game, was installed just above the Eighth Street bridge within a fenced enclosure. While the enclosure protected the trap from vandalism it also placed the trap in a narrow, incised channel, a section of Codornices Creek that was re-routed during World War II around the land just west of San Pablo Boulevard to enable development of shipyard worker- and military personnel housing – the present-day University Village.

The trapping site is about 0.3 mile above tidewater. The stream gradient in this reach, which is about two percent, continues on down to the Bay. The confined channel at the trap was only three feet wide. The water depth may have averaged about two feet during the roughly March-through-May trapping seasons, but was typically much shallower than that.

The trap began its life as a standard downstream migrant trap, with outstretched mesh wings reaching upstream either side of the channel to herd fish downstream into a mesh fyke net supported by a pipe framework, and, from there, into a mesh live box. The live box had a zippered top for quick and easy daily tending.

A storm in early April, 2002, much heavier than expected, caused Codornices Creek to rise so violently in this incised channel that the wings were torn from the trap before the project crew could reach it. With more storms on the way, no attempt was made to restore the trap's wings. The trap operated after that, and for the entire 2003 season, as a simple pipe trap, as shown in Figure 1.

Figure 1. Downstream migrant fish trap operated on Codornices Creek in 2002 and 2003

Fish were removed from the trap daily, their species were noted, and their fork lengths (from the tip of the nose to the middle of the fork in the tail) were measured to the nearest millimeter. Anesthetization was not used at any time. After gathering measurements from them, all of the fish were released downstream of the trap.

The trap was operated from April 3 to May 31, 2002, and from February 26 to May 31, 2003.

<u>Salmonid habitat assessment methods</u>

A salmonid habitat survey of Codornices Creek was conducted between March 6 and March 17, 2003. The survey covered 3.2 miles of the stream, from tidewater up to the downstream end of the culvert beneath the Berkeley Rose Garden.

The survey employed methods that were modified from those set out in the *California Salmonid Stream Habitat Restoration Manual* (CDFG, 1998). Neither streamflow nor Rosgen channel type information were collected, but median streambed particle size distribution, "D50", measurements were made using the Wolman pebble count method (Harrelson, 1994).

Salmonids were noted by direct visual observation during the survey. Selected stream features were noted and the location of each was recorded with a Trimble Pro-XR global positioning system (GPS) unit loaned to the project by the U.S. Environmental Protection Agency's Richmond Field Station. Pools, streambed gravel areas, drainpipes, significant erosion sites, culverts, bank revetments (walls and rip-rap), concrete-lined channel sections, the sites where stream temperatures were taken by the crew, and those where pebble counts were made, were all geo-located with the help of EPA's GPS unit.

The survey divided the study area into five study reaches based upon stream characteristics and the locations of major road crossings (see Figure 2).

Reach 1 skirts the Golden Gate Fields racetrack property from the mouth of the creek up to Freeway 80. This reach is entirely under tidal influence. Reach 2 runs from the east side of Freeway 80 up to San Pablo Avenue. The lower half of this reach is in an industrial area and includes the extensive Union Pacific tracks. The upper half of the reach, where the project's problematic fish trap was operated, is the subject of a California Department of Water Resources Urban Streams Restoration Program project to restore natural streambanks, a stream meander, riparian habitat, and to eliminate two fish migration barriers.

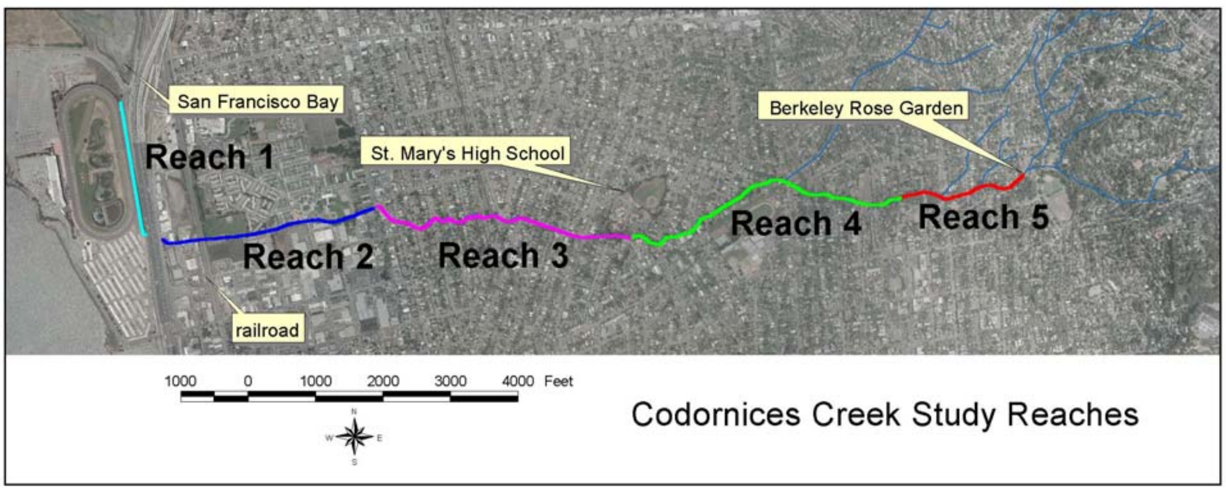

Figure 2. The project salmonid habitat survey divided Codornices Creek into five study reaches.

Reach 3, which extends from San Pablo Avenue to Albina Avenue, forms the boundary between the cities of Berkeley and Albany. This reach, running through a neighborhood of single-family homes, was the last section in which the project's habitat surveyors observed any salmonids. Reach 4 runs from Albina Avenue up to Shattuck Avenue in North Berkeley and reach 5 stretches from Shattuck Avenue to the bottom end of the culvert beneath the Berkeley Rose Garden. This last reach includes Live Oak Park, which contains good quality stream habitat. The steep pitch of the Rose Garden culvert is generally regarded to be a permanent fish barrier.

Salmonid migration barrier and streambank assessment methods

As we noted above, the stream surveyors saw no salmonids whatsoever upstream of Albina Avenue, the head of study reach 3. The survey identified 13 potential barriers in reaches 2 and 3, all the apparent result of channel down-cutting at the downstream end of old street culverts.

The survey team gathered data at these potential barrier sites, including the slope of the culvert inverts and the position of the upstream and downstream inverts vis-à-vis the stream's water surface elevation. These data were then provided to the project engineers, FarWest Restoration Engineering. FarWest used the Fish-Xing© model to determine the severity of each potential barrier and formulated a preliminary fish passage solution for each site that was found to be a likely barrier.

Details of the FarWest engineering assessment of the Codornices Creek barriers can be found in Appendix A.

Water quality assessment methods

To support the restoration of a sustainable steelhead population the water quality in Codornices Creek must be suitable not only for the several salmonid freshwater life history stages (adult migration, spawning, egg incubation, emergence, juvenile growth and survival, and, finally, juvenile emigration), but for the production of steelhead prey, like aquatic macro-invertebrates, as well.

The project water quality specialist, Dr. Robert Coats of Hydroikos Associates, consulted with the staff of the San Francisco Bay Regional Water Quality Control Board to identify those water quality parameters regarded as problematic for salmonids in Bay Area streams like Codornices Creek. Based on his consultations, Dr. Coats subsequently filed a project Quality Assurance Project Plan (QAPP) with the SFB RWQCB staff.

The project QAPP laid out the process for collecting, handling, and analyzing Codornices Creek water samples, which were typically gathered immediately following significant rain/run-off events. These water samples were tested for organophosphate pesticides, especially diazinon and chlorpyrifos.

These analyses were later expanded to include testing for heavy metals and hardness, toxicity (a seven-day *Ceriodaphnia* survival test), Methylene Blue Active Substance (MBAS) test for possible sewage leakage, dissolved oxygen, and temperature.

In addition, the project habitat survey team deployed Stowaway® temperature recorders in pools within study reaches 2, 3, 4, and 5. These recorders were installed the first week in May, 2003, and retrieved in early October, except for the one above Oxford Street, which was inadvertently removed by workmen at the site in June.

Public outreach and education methods

CCWRAP's outreach and education effort operated at both creek-neighborhood and citywide levels. It worked to keep City of Berkeley officials posted regarding both the technical and community-organizing elements of the project -- and it was especially important that those whose homes abutted Codornices Creek understood fully the purpose of the stream survey, since the surveyors would be walking across their property, as well as the overall objectives of the project, since the landowners ultimately will be asked to participate directly in making their Codornices Creek properties more fish friendly.

The project took advantage of Berkeley's annual Earth Day celebration in April and its September Watershed Festival to showcase Codornices Creek protection and restoration efforts. Both events are held in Martin Luther King, Jr. Civic Center Park, where project staff and neighborhood volunteers helped create and staff a project table featuring panel displays of Codornices Creek photographs, brochures, and maps.

With the help of a property-owner database furnished by the City of Berkeley's Public Works Department, the project team prepared and mailed project information to each Codornices Creek property owner of record, together with an invitation to join the project team at a neighborhood briefing on the project.

Throughout the project term, the team's efforts to inform the community at large were specifically shared with key City offices, including the Council and the planning and public works departments.

Results: What Each Element of the Project Produced

Fish population assessment results

The fish trap captured steelhead/rainbow trout (*Oncorhynchus mykiss*), native threespine stickleback (*Gasterosteus aculeatus*), and California roach (*Hesperoleucus symmetricus*). Crayfish (most likely non-native Louisiana red-swamp crayfish, *Procambarus clarkii*) were also taken in significant numbers. The total number of each species trapped for each of the two years is shown in figures 3 and 4, below.

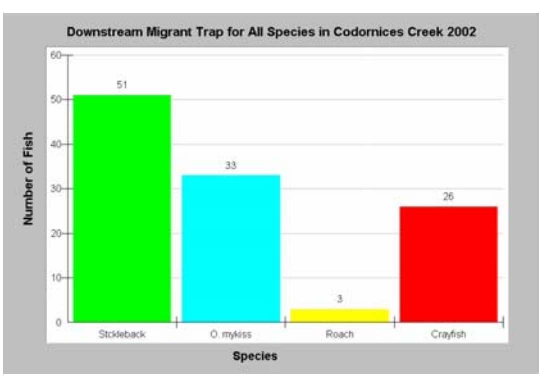

Figure 3. Fish trap results in 2002

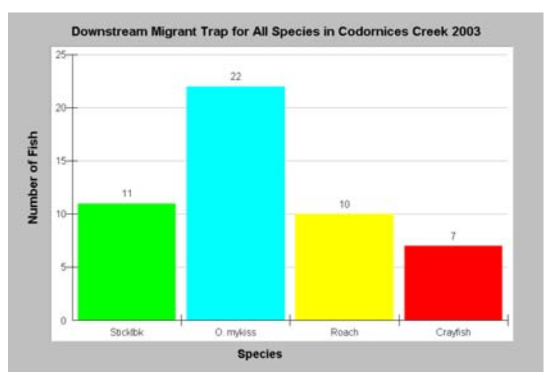

Figure 4. Fish trap results in 2003

The take of juvenile salmonids at the trap, by week, shown in Figure 5 below, generally mimics the temporal pattern of juvenile steelhead out-migration observed by fisheries professionals in other northern California coastal streams (Fukushima, 1998).

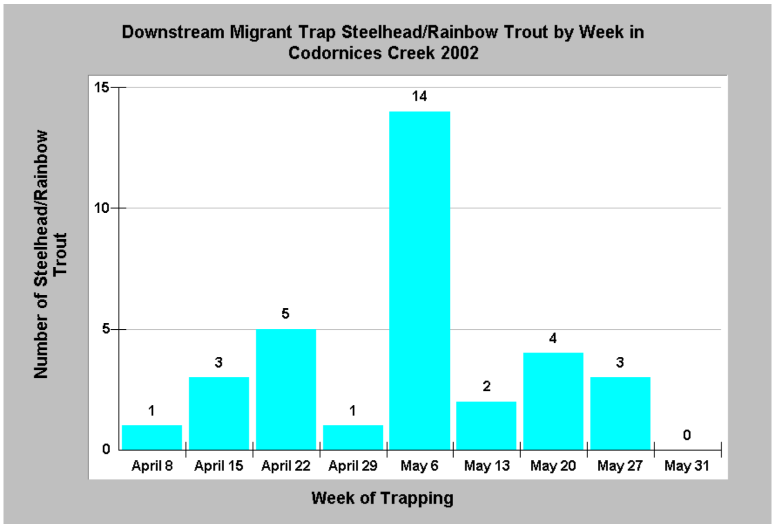

Figure 5. Number of juvenile salmonids trapped, by week, during 2002

Most of the salmonids recovered from the trap were less than 75 millimeters fork length, clearly young-of-the-year fish. The largest salmonid trapped in either year was 200 mm long, most likely a 3-year old fish. The prevalence of these young-of-the year salmonids moving downstream so soon after emergence from the gravel most likely indicates that these small fish are being forced from their home reaches due to Codornices Creek's currently limited rearing habitat.

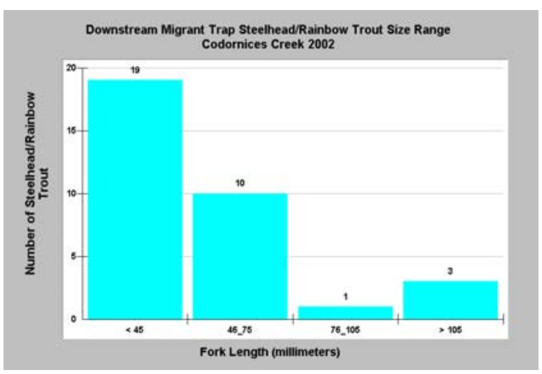

Figure 6. Size of salmonids from the trap in 2002.

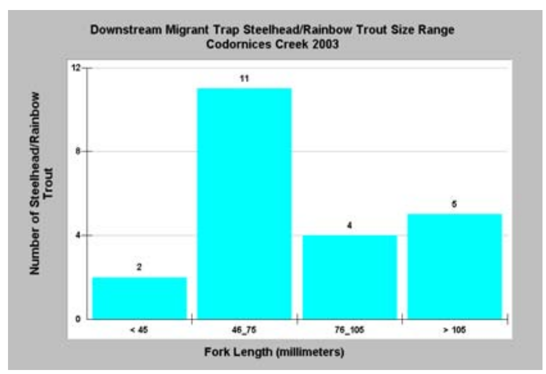

Figure 7. Size of salmonids from the trap in 2003

The likelihood of juvenile steelhead so small leaving their home-streams, surviving in the sea, and then returning successfully to spawn is extremely slim. In their seminal study of California coastal coho salmon and steelhead, Shapovalov and Taft found that 57 percent of the (marked) adult steelhead that returned to Waddell Creek in Santa Cruz County to spawn during their multi-year study period had left the stream as two-year-old fish, 30 percent had left as one-year-olds, and 12 percent as three-year-olds (Shapovalov, 1954). They observed only a single steelhead from all their study years that had left the stream before his first birthday and survived to return to Waddell Creek as an adult.

<u>Salmonid habitat assessment results</u>

The salmonid habitat survey team's most notable finding was that while juvenile salmonids were common all along Codornices Creek up to Albina Avenue, no salmonids whatsoever were observed in the stream above that point. The down-cut channel at the downstream end of the Albina Avenue culvert, together with the shallow depth of the scour pool there, appear to effectively stop the upstream migration of adult steelhead at that point. This and other steelhead barriers noted during survey are discussed in some detail in the next section and in Appendix A.

The percentage of stream habitat type by length – pools, flat-water, and riffles – for each of the five study reaches (figure 8, below) indicates that habitat for steelhead in Codornices Creek is presently limited. Pools, for example, make up only 20 percent of the length of the stream.

The California Department of Fish and Game suggests that pool enhancement projects be undertaken where primary pools comprise less than 40 percent of the total length of stream habitat (CDFG, 1998). In first and second order streams, a primary pool is defined as one having a maximum depth of at least two feet, which occupies at least half of the width of the low flow channel, and is as long as the low flow channel is wide.

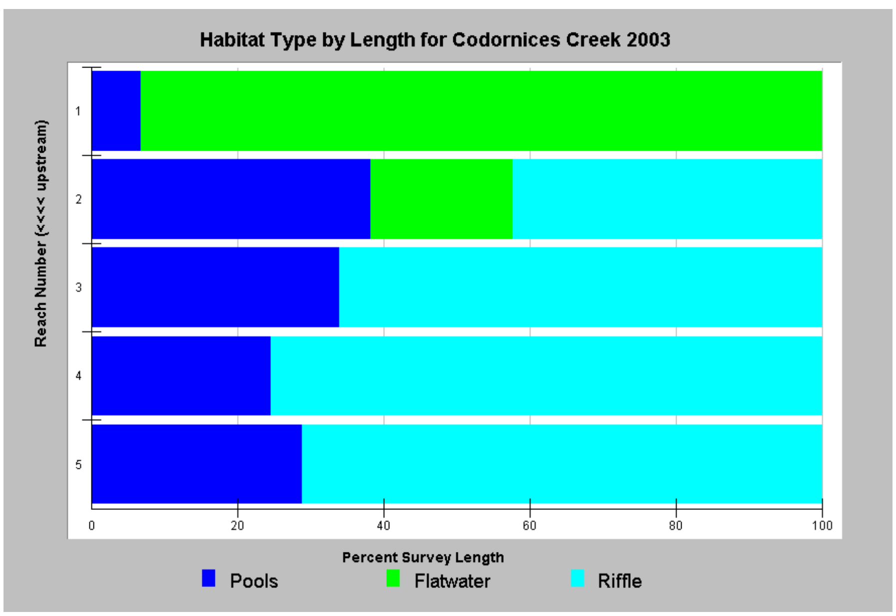

Figure 8. The percentage of stream habitat type by length for each of the Codornices Creek study reaches

Codornices Creek's pool-limited habitat, in combination with the survey team's observation that upstream salmonid migration appears to end abruptly at Albina Avenue, raises a number of questions from a steelhead restoration perspective. One clearly is: "How much pool habitat can be gained for steelhead by resolving the migration barriers up to, and including, the one which appears to be stopping steelhead altogether at Albina Avenue?"

As for the ability of Codornices Creek's gravels to support steelhead reproduction, Kondolf reported that the streambed particle sizes that are most suitable for supporting successful steelhead spawning, egg incubation, and fry emergence range in size from 10-45 mm (Kondolf, 1993). The median streambed particle size distribution indicates that while a number of Codornices Creek sites tested *below* Albina Avenue are unsuited to these critical steelhead life history stages, the sites tested *above* Albina are all uniformly suitable.

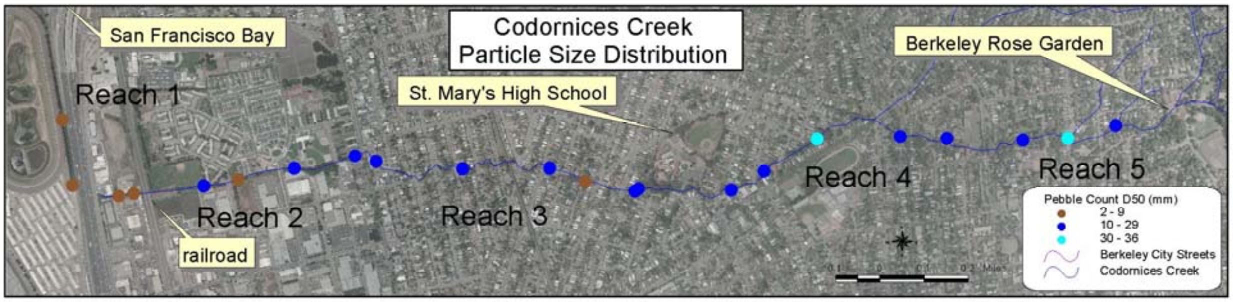

Figure 9. Codornices Creek pebble count sites showing suitable (blue) and unsuitable (brown) gravel areas.

As we noted above, the survey team recorded and geo-referenced streambank erosion sites. The failing hillside shown in figure 10, near St. Mary's High School, is contributing significant amounts of fine sediment into the stream and it clearly accounts for some of the unsuitability of Codornices Creek's streambed for steelhead reproduction below this point.

Figure 10. Sediment from the hillside is entering Codornices Creek near Albina Avenue

Returning to the discussion of pools and their importance to steelhead production, note the pool depth distribution for the survey reaches illustrated in figure 11, below.

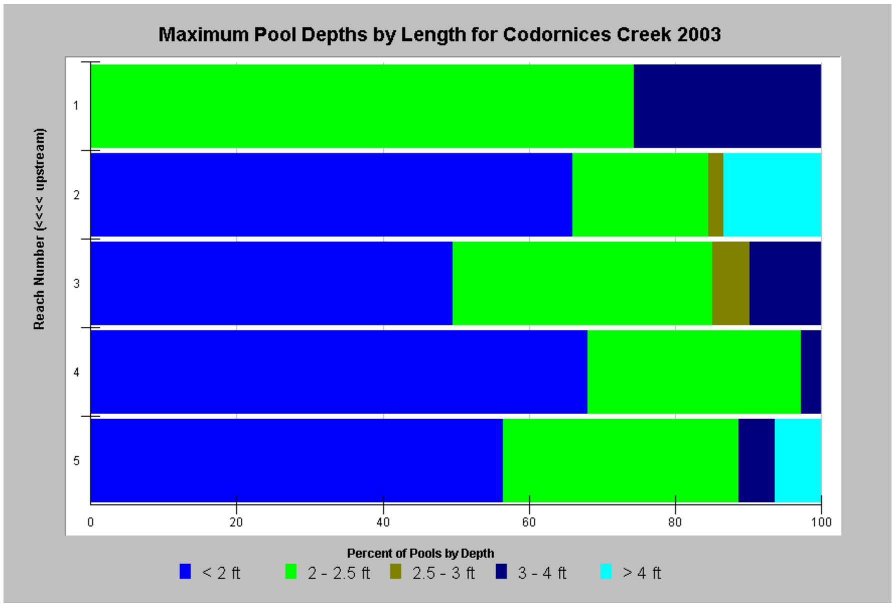

Figure 11. Distribution of pool depths determined from the 2003 Codornices Creek stream survey.

There are 159 pools in reaches 4 and 5, that is, above Albina Avenue. These pools have a combined volume of 14,500 cubic feet. In these two reaches alone there is 17,000 square feet of good quality spawning gravel, enough to support over 90 steelhead redds (spawning “nests”).

This quantity of potential steelhead spawning and rearing habitat is theoretically capable of producing 4,000 juvenile steelhead out-migrants and a sustainable spawning run of up to 400 adult steelhead – which would place Codornices Creek among the largest steelhead producing streams in the San Francisco Bay area.

Salmonid migration barrier and streambank erosion assessment results

FarWest Restoration Engineering personnel used the Fish X-ing© model to process the data collected by the habitat survey crew at the potential steelhead barrier sites. Of the 13 candidate barriers identified by the survey crew, four were found through use of the model to not represent barriers to steelhead migration.

The other nine candidate sites were found to either channel wintertime streamflow into velocities that are too great for reliable adult steelhead migration, or their scour pools below the culverts were found to be too shallow to allow adult steelhead to leap onto the culvert invert, or base flows during migration season were spread too thinly across the invert of the larger culverts – or some combination of these problems was found to exist.

Figure 12 illustrates a typical Codornices Creek steelhead migration barrier. Here, California Department of Fish and Game-trained CCWRAP habitat survey field leader Michelle Wallar measures the distance from the Albina Avenue culvert to the water surface elevation below, and the depth of the scour pour immediately below the culvert.

Adult steelhead could negotiate the jump shown here easily if the depth of the scour pool were equal to more like one-and-a-half times, rather than only one-half, the vertical distance from the stream's surface to the culvert's invert. Another fish passage issue at this site is the spreading of the flow across the relatively wide culvert invert, making the stream too shallow to support effective adult steelhead upstream swimming.

Figure 12. Down-cutting of streambeds below culverts has created most of Codornices Creek's fish barriers

For each of the problematic sites, including the major erosion site on the right streambank of Codornices Creek near Albina Avenue, FarWest Restoration Engineering has fashioned preliminary restoration recommendations (Appendix A).

At the time of this writing, UCC was negotiating with the Department of Water Resources for a modest grant with which to continue the engineering, and, importantly, the landowner consultations, needed to move the CCWRAP-identified preliminary barrier modification concepts toward acceptable, actionable construction projects. Construction funds for these and the other measures advanced in this Plan have been requested from the State of California's 2003 Consolidated Grant Program, the results of which will not be known until late spring, 2004.

The modest "bridge" grant sought from DWR will permit Codornices Creek restoration planning to maintain its momentum while UCC awaits word of its Consolidated Grant Program request.

Water quality assessment results

As noted earlier, the ability of Codornices Creek's water quality to sustain salmonids was tested in two general ways: water samples were collected and sent to certified laboratories for testing for urban pollution constituents, and water temperature data was collected by the project team using Stowaway recorders submerged in pools in study reaches 2 though 5.

Organophosphates

Water samples were taken at Live Oak Park and the BART crossing immediately after rainstorms beginning in November, 2001 and continuing through spring, 2003. On two occasions the samples contained diazinon levels higher than the 80 nanograms per liter (ng/l) the California Department of Fish and Game considers lethal to the zooplankton prey upon which juvenile salmonids depend. On another occasion a Live Oak Park, but not the BART sample exceeded that acute level. On three other occasions samples levels considered to cause chronic, but not acute toxicity were collected at both sites.

Testing for chlorpyrifos yielded levels below the method detection limits of 30 ng/l. One BART crossing sample was, however, slightly higher than DFG's chronic toxicity criterion of 20 ng/l. (See Appendix B for details of these and other Hydroikos Associates Codornices Creek water quality testing results.)

Hardness

The sensitivity of aquatic organisms to heavy metals is inversely related to the hardness of water, which is described as the sum of the calcium and magnesium ions. In considering the potential effect of heavy metals on aquatic organisms it is therefore necessary to also determine water hardness levels.

The Codornices Creek water samples, those that were tested for the other constituents as well, ranged in hardness from just over 50 milligrams per liter (i.e., expressed as the equivalent weight of calcium carbonate) to over 300 mg/l. Such relatively soft water is to be expected since surface runoff was dominating the groundwater contribution at the time that these samples were collected.

Heavy metals

Lead and zinc from the project samples never even came close to EPA's California Toxics Rule for aquatic life. Dissolved copper, however, exceeded the chronic criteria in three samples at the BART crossing and two at Live Oak Park. These results are discussed in some detail in Appendix B.

Toxicity tests

When water fleas, *Ceriodaphnia dubia*, were exposed to Codornices Creek water for seven days, they actually fared better – 100 percent survival and a higher reproductive rate for females – than they did in the laboratory's control water!

Rainbow trout survived at 100 percent in the Codornices Creek water (and in the laboratory's water as well, in this test).

MBAS

The Methylene Blue Active Substances (MBAS) tests to detect household detergents from sewage leakage were all negative, below the level of detection.

Water temperature

As reported in Appendix A, the Friends of Five Creeks (FFC) collected samples for turbidity, dissolved oxygen, and biochemical oxygen demand (BOD) analysis during the 1999 and 2000 water years. In 2001 they maintained a temperature recorder throughout the summer near the BART crossing. Figure 13 interprets FFC's 2001 temperature data in the Klamath Resource Information System, or KRIS, format. The KRIS program (see www.krisweb.com) has been used, through the courtesy of the non-profit Institute for Fisheries Resources (www.ifrfish.org), to capture, maintain, and interpret the data collected in this CCWRAP project.

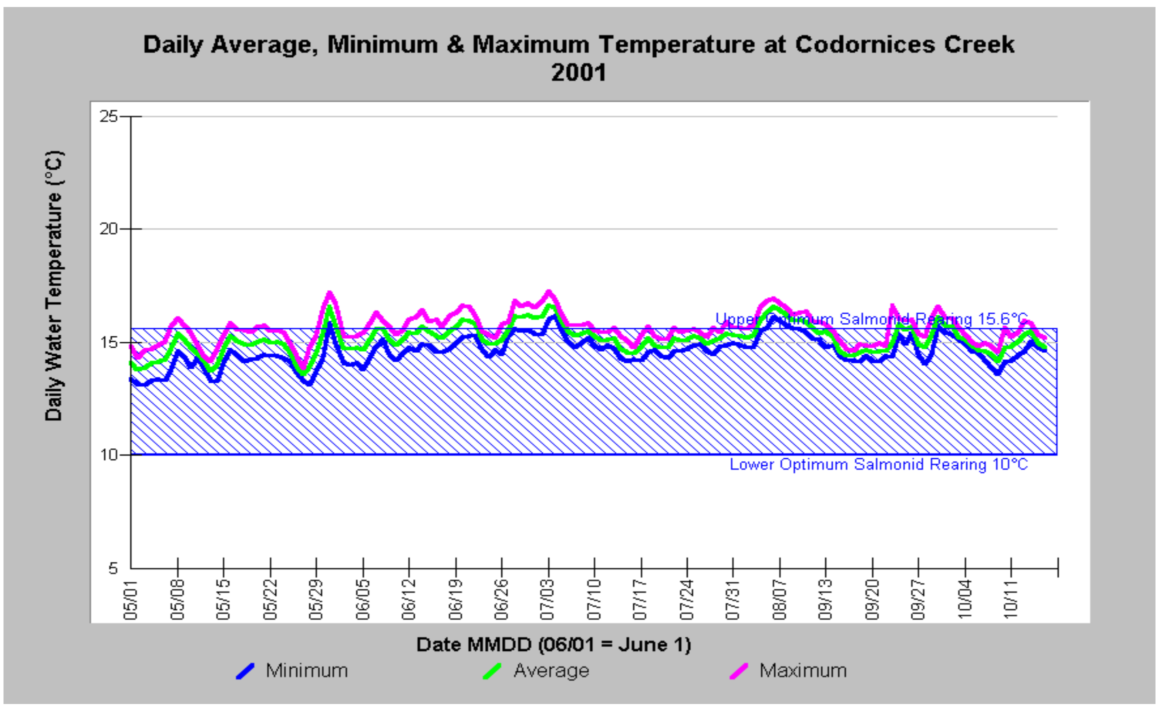

Figure 13. Friends of Five Creek's May-October, 2001 water temperature record

Figure 14, on the next page, shows the floating weekly average water temperatures, or MWAT, of five pools in Codornices Creek during the May-October, 2003 period -- plus those for the May-June record at the Oxford Street site. Water quality regulators and aquatic researchers believe that MWAT better describes the *duration* of high temperatures and their effects on aquatic organisms, including salmonids.

Figure 14's legend lists the 2003 temperature monitoring sites, from left to right, moving upstream.

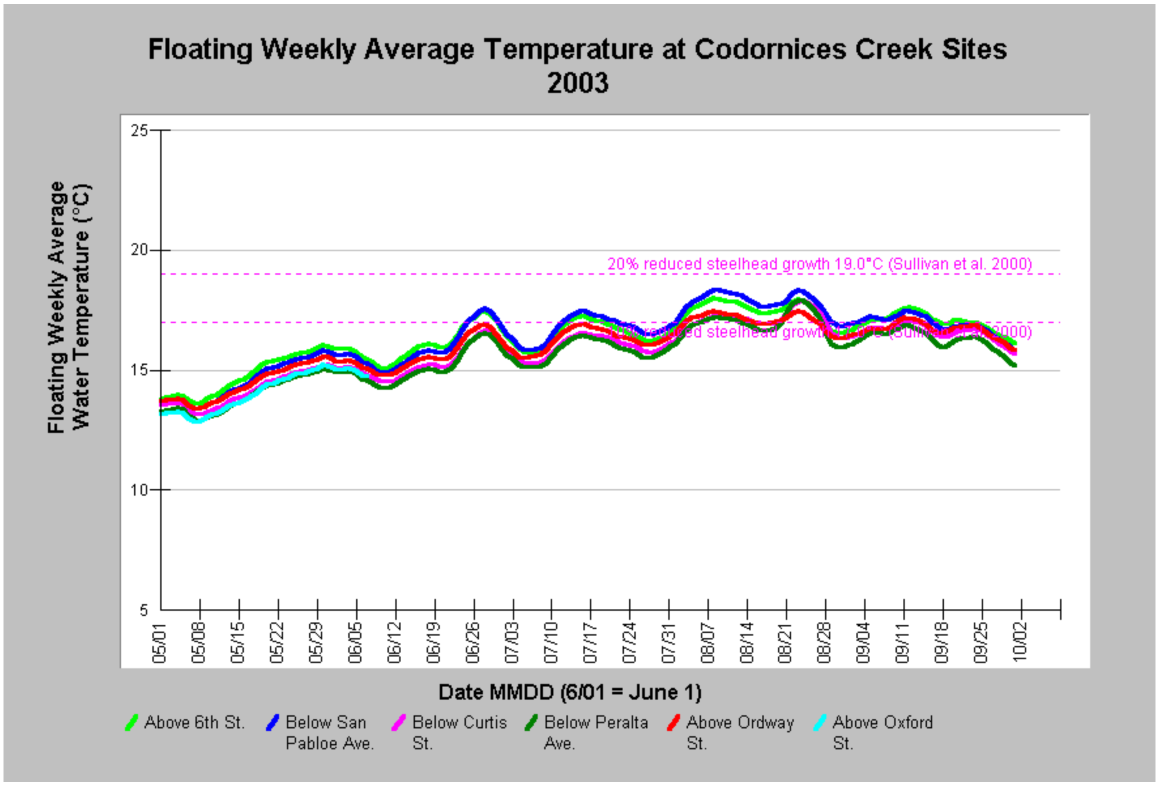

Figure 14. Floating weekly average water temperatures at six sites in Codornices Creek during 2003

A review of steelhead growth studies by Sullivan et al. determined that compared to the optimum temperatures range of 10-15.6°C, an MWAT of 17°C can diminish steelhead growth by 10 percent and an MWAT of 19°C can reduce growth by 20 percent (Sullivan, 2000).

The data show that Codornices Creek warmed only slightly, about 1°C, as it flowed downstream from Oxford Street, near the top of study Reach 5, to 6th Street, in Reach 2. The maximum floating weekly average water temperatures (MWAT) exceeded 17°C in all sites, but it never exceeded 19°C at any site.

The CCWRAP project's 2003 Codornices Creek water temperature data compare favorably with that collected by the Friends of Five Creeks in 2001. Based upon these 2001 and 2003 data, summertime water temperatures in Codornices Creek would appear to be hospitable to steelhead.

Public outreach and education results

The project took advantage of Berkeley's annual Earth Day celebration in April and its September Watershed Festival to showcase Codornices Creek protection and restoration efforts. Both events are held in Berkeley's popular Martin Luther King, Jr. Civic Center Park, where project volunteers helped create and staff a project table featuring panel displays of Codornices Creek photographs, brochures, and maps. Through these events, the CCWRAP project was able to inform hundreds of fairgoers about plans for Codornices Creek's restoration at the 2002 and 2003 festivals.

With the help of the Berkeley Public Works Department's property-owner database, the project team prepared and mailed project information to each Codornices Creek property owner of record, together with an invitation to join the project team at a neighborhood briefing on the project. The meeting, held on the evening of January 23, 2003 at St. Mary's High School, was well attended. Almost without exception, the property owners at the meeting expressed enthusiasm for restoring steelhead to the creek.

Throughout the project term, the team's efforts to inform the community at large were shared equally with key City offices, including the Council and the planning and public works departments.

Figure 15. A fairgoer learns of plans for the Codornices Creek watershed's restoration at the Friends of Five Creeks and CCWRAP booth, Berkeley Watershed Festival, 2003

Recommendations: The Next Steps in Codornices Creek's Restoration

From the tasks, then, that were carried out in this *Codornices Creek Watershed Restoration Action Plan* project, the information that they yielded, and the analysis made of that information, we arrive at recommendations for the next-step actions needed to restore a sustainable steelhead population to the stream. The actions recommended here are *not* arranged in priority order, top to bottom. Rather, for the comfort of the readers, we have maintained the same structure – fish population, fish habitat, fish barriers, etc. – that we have used throughout the Plan thus far.

But let us be very clear: those steps necessary to eliminate barriers to the upstream migration of adult steelhead in winter, particularly that which now exists at the Albina Avenue culvert and the stabilization of streambank erosion sites, particularly those near Albina Avenue, are absolutely the highest Codornices Creek restoration actions recommended here.

<u>Fish population assessment recommendations</u>

Action 1. Upgrade the Codornices Creek fish population assessment information from its current qualitative level to a quantitative level, in order to provide a numerical baseline from which to evaluate the effectiveness of restoration actions.

Because the only completely secure site in which to install a downstream migrant trap on Codornices Creek turned out to be an impractical channel in which to operate the trap, the fish population assessment data gathered in the CCWRAP project was only qualitative, rather than quantitative. That is, we learned what kind of fish were in the stream, but, because flood flows overwhelmed the trap we could not quantify the number of fish in the total flow. We cannot say that there were “x” number of young-of-the-year salmonids in the stream in 2002 and “y” in 2003, and we still need such data if we are to quantify the benefits of the restoration project proposed here.

The next-step fish population assessment actions in Codornices Creek will likely involve sealing off test sections of the stream with block nets and then electro-fishing these sections, using the three-pass depletion method, to determine the total number of juvenile salmonids in each. These operations should be repeated during, and in the years following, the implementation of physical stream restoration actions.

Action 2. Determine whether the juvenile salmonids in Codornices Creek are, in fact, the progeny of sea-run steelhead.

Oncorhynchus mykiss demonstrates a great deal of flexibility in their life history. The progeny of resident rainbow trout can go to sea and become “steelhead”. The progeny of sea-run steelhead can, just as easily, settle down and become resident rainbow trout. Sea-run steelhead and resident rainbow trout can occupy the same stream (“sympatry”) and interbreed. This is why we usually refer to them as steelhead/rainbow trout.

This is understood by fisheries scientists, and would be of interest only to scientists and fishermen, perhaps, were it not for keen public interest in the State and federal endangered species acts, and the relationship between those acts and California’s program of ecosystem restoration in the San Francisco Bay-Delta watershed. Implementation of the endangered species acts led to the Bay-Delta restoration program (calwater.ca.gov); the Bay-Delta program provided the funding for this Plan. The program represents not only the means for bringing Bay-Delta salmonids back from the brink of extinction, but an opportunity to strengthen our knowledge of these species, so that we might improve our care of them.

As we proceed, now, to identify and implement the actions proposed in this Plan, it will serve both science and community curiosity to determine what mix of steelhead/rainbow trout we have in Codornices Creek. Are these juvenile salmonids in the project trap only the progeny of resident trout, as some have suggested? Or did their mothers migrate in from the sea? The answer can be found by analyzing the ratio of strontium to calcium in the fish's otolith ("earbone"), an established and affordable microchemistry technique easily available to the community as it goes forward, now, with Codornices Creek's restoration (Kalish, 1990).

<u>Salmonid habitat assessment recommendations</u>

Action 3. Select a sample of Codornices Creek pools, throughout study reaches 2-5, and monitor their depth over time in order to evaluate the effectiveness of restoration actions, particularly streambank stabilization.

The project habitat survey identified a number of streambank erosion sites (Figure 10 shows the most egregious). Sediment from these sites appears to be filling in pools, reducing the number of pools sufficiently deep to support juvenile steelhead summer survival.

Not only do the data suggest that steelhead habitat in Codornices Creek is "pool limited" (figures 8 and 11), but also that gravelly pool tail-outs downstream of Albina Avenue that might otherwise support steelhead spawning appear to be adversely impacted by fine sediment particles (Figure 9).

The V* ("V star", Lisle, 1991) method should be used to monitor the residual volume of a sample of Codornices Creek pools, particularly those downstream of major streambank stabilization projects, to determine whether the pools are recovering their original volume during flood flows and, thereby, increasing juvenile steelhead rearing habitat.

Action 4. Establish a benthic macro-invertebrate baseline with which to further evaluate Codornices Creek's health and the effectiveness of restoration actions over time.

A number of techniques for analyzing macro-invertebrate abundance levels, taxa richness, EPT taxa [the number of taxa found in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies)], EPT taxa composition and dominant taxa composition have been developed to determine and monitor stream health, much of them at the University of California's Berkeley campus. A selection of these techniques, undertaken by a U.C student in cooperation with restoration project staff, would strengthen the base for evaluating the effectiveness of Codornices Creek restoration over time.

<u>Salmonid migration barrier remediation and streambank erosion control recommendations</u>

Action 5. Determine the hydraulic capacity of each culvert identified as a steelhead-stopper and determine the level, if any, to which the proposed barrier remediation action will impact the ability of the culvert to pass flood flows.

Action 6. Based on the culvert hydraulic analysis results, refine barrier remediation design concepts sufficiently to review with the City and adjacent landowners.

Action 7. Refine streambank stabilization projects sufficiently to review with City and adjacent landowners.

The primary purpose of the proposed state Department of Water Resources grant augmentation discussed earlier is to enable the next-step engineering tasks described above, together with the necessary landowner outreach. Streamside landowners have been working for generations to constrain Codornices Creek – in the Berkeley "Flats" to make real estate from wetlands, and, upstream, to protect what real estate they have from gnawing flood flows. In a classical demonstration of the force of nature, each human constraint appears to have increased the force of the creek on its banks and bed.

Landowners, including the City, will require timely, professionally-reliable information concerning the changes to banks and streambed proposed to aid Codornices Creek steelhead restoration. The restoration project team is committed to furnishing landowners the information that they need to become full and confident partners in the restoration actions.

Water quality assessment and protection recommendations

Action 8. Cooperate with the San Francisco Bay Regional Water Quality Control Board staff in the installation and maintenance of an automated water sample on Codornices Creek, one that can take samples periodically during storms events.

The water samples collected for this Plan project were admittedly "grab" samples, collected just as quickly after rainstorms as the project team could get to the established sampling sites. The SFB RWQCB staff has planned, for some time now, through its surface water ambient monitoring program (SWAMP) to install an automatic water sampler, one capable of gathering and analyzing water samples throughout and between Codornices Creek storm events.

State funding cut-backs made uncertain the level of SWAMP effort that the SFB RWQCB staff can reasonably accomplish. The Codornices Creek restoration team should work closely with SFB RWQCB's SWAMP team to optimize the ability of the latter to monitor Codornices Creek water quality.

Action 9. Develop a "Pesticides Watch" plan, in consultation with the SFB RWQCB staff, and periodically gather Codornices Creek water samples for analysis for pesticides.

Pesticides are so ubiquitous in our society, and they are so deleterious to the growth and survival of juvenile salmonids, that an ongoing Codornices Creek restoration program merits an ongoing "Pesticides Watch" effort. As noted in Appendix B, the pesticide of preference, diazinon, for which the CCWRAP project sampled and tested, is fast giving way in Alameda County to synthetic pyrethrins, or pyrethroids. While these chemicals are easier on humans and their mammalian pets, they are more toxic to insects, including those upon which juvenile salmonids prey, than organophosphates like diazinon.

A plan for monitoring these pesticides should be developed in consultation with the staff of the San Francisco Bay Regional Water Quality Control Board.

Public outreach and education recommendations

Action 10. Identify funding for, and intensify public outreach and education efforts in support of, the "Codornices Creek Watershed Restoration Action Program" (CCWRAP-2) program.

We report here the results of the CALFED-funded Codornices Creek Watershed Restoration Action Plan – "CCWRAP-1". As the restoration planning team moves into the next set of tasks, including those refining the barrier remediation and streambank stabilization work, Codornices Creek restoration is moving from a preliminary planning stage to an action stage, the Codornices Creek Watershed Restoration Action Program – "CCWRAP-2". Here is where the role of public outreach and education moves from clearly beneficial to absolutely critical.

The factors that limit the ability of adult steelhead to reach all of Codornices Creek's potential spawning habitat, and the factors that limit the opportunity of juvenile steelhead to grow successfully in Codornices Creek, are related to the nature of the built environment – the culverts beneath the City's streets, backyard revetments to confine flood flows, the removal of streamside vegetation for either flood control or aesthetics. To restore Codornices Creek to conditions capable of hosting a sustainable steelhead population will require that some of this built environment be modified. This, then, is where steelhead restoration advocates will need to be accessible to the City and creek-side landowners, alike. They will need to be informed, articulate – and patient. Change does not come easily.

It is the position of the restoration planning team that changes to the built environment along Codornices Creek can be made in aesthetically-pleasing ways without endangering property, and that the restoration of a sustainable steelhead population to Codornices Creek, one able to use the stream habitat from the Bay to the Berkeley Rose Garden, will become a source of substantial – and warranted – civic pride for the Berkeley community in the 21st century.

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FarWest
RESTORATION
ENGINEERING

September 2, 2003

Bill Kier
Kier Associates
207 Second St., Ste. B
Sausalito, CA 94965

Subject: Preliminary Fish Passage Culvert Assessment, Codornices Creek Culverts, Berkeley/Albany, California

Dear Bill:

I am pleased to submit this preliminary fish passage assessment of culverts along Codornices Creek along the Berkeley/Albany border. This analysis is a first cut assessment of the 13 culverts identified by Kier Associates as potential fish passage barriers. In addition, Mr. Fran Borcalli of Wood-Rodgers Consultants assisted in the development of cost estimates for culvert retrofits and recommendations for the repair of two erosion areas specified by Kier Associates.

I appreciate the opportunity to provide these services to Kier Associates. Please do not hesitate to call me at (510) 865-2840 with any questions or comments.

Sincerely,

Roger Leventhal, P.E.
Principal Engineer

538 Santa Clara Ave
Alameda, CA 94501
(510) 865-2840 ph

Preliminary Fish Passage Culvert Assessment

Codornices Creek Berkeley/Albany, California

September 2, 2003

Prepared by

FarWest Restoration Engineering
538 Santa Clara Avenue
Alameda, California 94501

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CODORNICES CREEK
PRELIMINARY FISH PASSAGE CULVERT ASSESSMENT

1.0 Introduction

1.1 OVERVIEW

Codornices Creek is a perennial stream that flows from the hills east of San Francisco Bay. The approximately 1.5 square mile watershed extends from the headwaters in the Berkeley Hills and drains ultimately to the San Francisco Bay. Elevations within the basin range from sea level at the outlet near Golden Gate Fields race track to approximately 1,340 feet at the summit of Grizzly Peak (USGS, 1959).

Codornices Creek is one of the most open creeks in this area of San Francisco Bay and represents an important opportunity to restore a viable anadromous fish run along the Bay. Along the lower reaches of the creek between the railroad tracks and San Pablo Avenue, there are plans to implement a significant creek restoration project scheduled to begin in 2004 (WRI 2001). This work will involve the removal of culverts at 5th and 10th and eventually 6th Streets along Lower Codornices Creek below San Pablo Avenue.

An important part of analyzing the potential for a viable run of anadromous salmonids is to hydraulically evaluate barriers to fish passage. The most common barriers are culverts under road crossings. Culverts that can hinder or stop upstream fish passage are often located on smaller streams, such as Codornices Creek, that may contain important habitat reaches. Kier Associates and the Urban Creeks Council (UCC) are preparing a separate report evaluating the existing habitat for fish along Codornices Creek (Kier 2003 in preparation).

1.2 SCOPE OF WORK

Kier Associates in coordination with the Urban Creeks Council (UCC) is conducting an assessment of fish habitat along the entire Codornices Creek watershed. As part of their work, Kier Associates has identified 13 culverts and two erosion areas as potentially impacting fish passage and habitat.

FarWest Restoration Engineering (FRE) was retained by Kier Associates to analyze 13 existing culverts along Codornices Creek that were identified as potentially impacting fish passage from the Bay to the headwaters. For this work, FRE used FishXing (version 2.1) to hydraulically analyze fish passage under various flow conditions.

The primary objectives of the study were the following:

- Evaluate the impacts of the culverts on both juvenile and adult salmonids under both low and high fish passage flow conditions.
- Make recommendations for improvements to culverts identified as having fish passage issues and concerns.
- Provide preliminary cost-estimates for recommended improvements.
- Provide sketches and recommendations for the repair of two eroded areas identified by Kier Associates as impacting fish habitat within the creek.

This report is a preliminary assessment of fish passage through existing culverts within the creek. Due to budget and schedule constraints the analysis was limited and focused in scope. As described within, we have made recommendations for additional analysis during subsequent project phases to provide additional analysis for the culverts along this creek and to further refine the cost estimates.

The typical fish passage barriers created by culverts include the following:

- Elevated flow velocities in the culvert
- Flow depth is too shallow in the culvert for fish passage
- Too great a distance between the downstream pool and the culvert outlet to allow for fish to leap
- Excessive debris accumulation
- Excessive turbulence and velocities at the culvert inlet due to constriction of flows.

Definitions of barrier types and potential impacts.

Barrier Category	Definition	Potential Impacts
Temporal	Impassable to all fish some of the time	Delay in movement beyond the barrier for some period of time
Partial	Impassable to some fish at all times	Exclusion of certain species and life stages from portions of a watershed
Total	Impassable to all fish at all times	Exclusion of all species from portions of a watershed

Culverts that form even partial barriers may cause problems because even if culverts are eventually negotiated, excess energy expended by fish may result in their death prior to spawning or reductions in viability of eggs and offspring. Migrating fish concentrated in pools and stream reaches below road crossings are also more vulnerable to predation by a variety of avian and mammalian species, as well as poaching by humans. Culverts which impede adult passage limit the distribution of spawning, often resulting in under seeded headwaters and superimposition of redds in lower stream reaches.

The goal of the analysis is to evaluate which culverts form either temporary or permanent hydraulic barriers and at what times of the year. For example, certain culverts may form barriers at critical times of the fish passage lifecycle, and therefore result in excessive energy loss and fish mortality.

2.0 Project Work Activities

2.1 FIELD SURVEYS

Field surveys of the culverts were conducted by Kier Associates on June 17-18, 2003. These surveys determined the relative inlet and outlet elevations of the culverts, as well as the culvert materials and condition, i.e. degree of sediment build-up.

FRE performed additional field assessments in July 2003 to determine tailwater conditions for development of a tailwater rating curve. These field assessments involved identification of the tailwater control section location, an approximate estimation of the control section invert elevation and a trapezoidal approximation of the tailwater control section. Downstream tailwater control surveys were not performed and should be included during final analysis.

Table 1 shows a summary table of the field data collected for each the selected culverts to be evaluated.

2.2 HYDROLOGY AND FLOW ESTIMATES

Fish passage assessments require development of the upper and lower fish passage flows through the culvert. For salmonids, we have used the fish passage parameters shown in Table 2 (from Ross Taylor and Associates, 2003) and summarized below.

To determine fish passage flows, we evaluated two different data sources:. 1) the short period of record stream gauge data for Codornices Creek and an analysis of stream gauge data from southern Alameda County performed for Stonybrook Creek.

2.2.1 Codornices Creek Stream Gauge

There is no long term stream gauge record for Codornices Creek. The Friends of Five Creeks and Balance Hydrologics maintained a small stream gauge located under the BART tracks that collected data from October 2000 through September 2001. Figure 2 of the report "Water Quality in Codornices Creek" (Coats, July 15, 2003) shows the hydrograph of this gauge during the recording period.

FRE prepared a flow-duration curve of the dataset for the period of record, however, the period of record is much too short (only one year) to be statistically significant. The approximate passage flows produced from the Balance data are shown in table 1 below.

2.2.2 Southern Alameda County Data

As a preliminary estimate of fish passage flows, we have also utilized data developed for the Stonybrook Creek Fish Passage Assessment (Michael Love, 2001) a tributary to Alameda Creek in Alameda County. A regional flow duration curve was developed based upon data developed from several stream gauges in this area. The mean annual precipitation (MAP) and type of coastal watershed in the area of analysis is approximately the same as Codornices Creek, and therefore, this data should be appropriate for developing fish passage flows at Codornices Creek. A regional flow duration curve for this area of Alameda County should be developed under final design. The regional flow duration curve provides a discharge (in cfs) per square mile of drainage area. For the Codornices Creek analysis, an average drainage area of 1.2 square miles was used, which is the watershed drainage area above San Pablo Avenue. Note that stream gauge data is normally only available on larger creeks, therefore the regional flow duration flows are biased to larger creeks and may not be exactly applicable to smaller streams like Codornices Creek.

Table 1: Summary of Flow Passage Flows

Passage Flows	Adult Rainbow Trout (200 mm)	Juvenile Salmonids (80 mm)		Calculated Flows from Existing Stream Gage Data (note 1)	Calculated Flows from Southern Alameda County Data (based on a 1.2 sq mile drainage area)
Minimum passage flow (*use larger of two flows)*	50% exceedance flow or 3 cfs	95% exceedance flow or 1 cfs		50% exceedance flow = 0.22 cfs; 95% exceedance flow = 0.08 cfs	50% exceedance flow = 0.2 cfs; 95% exceedance flow = 0.01 cfs
Maximum passage flow	1% exceedance flow	10% exceedance flow		1 % exceedance flow = 15.5cfs 10% exceedance flow = 1.14 cfs	1 % exceedance flow = 18 cfs 10% exceedance flow = 2.88 cfs

Note 1: Data record is too short to be statistically valid.
Values for southern Alameda County were used in this analysis except for low passage flows where the default "use larger of …" values were used.

Even given the differences in the data sets, the calculated values between both methods are fairly close. Given the longer period of record for the southern Alameda County analysis, these values were used in the hydraulic analysis for the maximum passage flows and the default values for minimum passage flows were used.

Previous estimates of flood flows within the creek (PWA 1997) indicate the 100-year flood event is approximately 1,000 cfs. However, this is likely a high estimate and assumes that flood flows are unimpeded in the watershed.

3.0 Fish Passage Culvert Assessment

3.1 GENERAL

For each of the 12 culverts identified by Kier Associates, a culvert analysis was performed using the Fish-Xing software developed by San Dimas Technology and Development Center and Michael Love Associates (the existing culvert at 10th street was removed from the passage analysis because it is proposed to be replaced by a bridge in 2004). Table 2 shows a summary of the fish passage results based upon the barrier codes from the model. For each culvert indicating passage problems, a recommended restoration alternative along with a preliminary cost estimate for implementation has been included.

We used the program default values for fish swimming abilities and passage criteria for juvenile and adult rainbow trout (as specified by Kier Associates) were based upon a size of 80 mm and 200 mm, respectively. Preliminary solutions for culverts identified as having potential fish passage problems are described in subsequent sections.

Field topographic surveys of the downstream tailwater control slope were not conducted, and therefore, we have assumed a downstream tailwater control slope of 0.5 percent. Note that the results of the fish passage analysis are not very sensitive to this parameter, and different assumed slopes from 0.25% to 1% did not change the results significantly.

Many of the culverts along Codornices Creek are relatively large, often 6 ft by 6 ft arch culverts, which conveys flood flows but produces insufficient depth of flow for fish passage at many of these culverts. Note that low flow depth is the easiest barrier for fish to migrate and as such is often ranked as the least concern of all the fish passage codes, especially given the uncertainties in the passage flows (as opposed to other physical barriers such as a perched culvert). Most of the culverts appear to be relatively old.

As described under the proposed engineering solutions, baffles or other tailwater control solutions will be required to raise the water depth within the culverts to create passage conditions. However, while these types of engineered solutions may improve fish passage, culvert efficiency to transport flood flows may be reduced. This is a problem which should be evaluated during final analysis and design.

3.1.1 Culvert Retrofiting/Restoration options

For each culvert showing passage issues, we have developed a preliminary recommendation for approaches to address the issue. Given that flow depths (and associated higher velocities) are the primary issue in most of the culverts, typical solutions to raising depths within culverts include the following:

- **Culvert Baffles.** Culvert baffles raise water levels by adding roughness to the culvert and providing resting places for fish, which is especially important within long culverts. There are several types of baffles and construction materials range from wood to steel. Baffles do increase maintenance costs for culverts since they require cleaning and debris removal to maintain function. Baffles also can greatly reduce the hydraulic capacity of the culvert for flood protection and therefore should be used as little as possible. The California Department of Fish and Game guidance documents discourage the use of baffles on culvert retrofits (CDFG 2002).

- **Back Flooding Weirs**. This approach involves installing rock or log weirs across the channel downstream of the culvert outlet to raise tailwater elevations and provide additional backwater to facilitate fish passage.
- **Step-Pool Construction.** For conditions where there is a perched culvert and greater than three feet of grade change is required, a step-pool channel morphology can be constructed in a series of rock steps alternating with pool to reduce the required leaping distance and elevation change.
- **Concrete or Gabion Sills**. A more engineered approach is to install a concrete or gabion sill in the channel with a low flow notch down the center of the channel to raise grades and tailwater elevations. This approach may be more permanent than solutions involving rock and logs but it is not as natural and will likely be more difficult to permit.

For each of these approaches, the hydraulic capacity of the culvert to convey flood flows will have been reduced. During final design, the impacts on flood control of installing any structures to aid fish passage will need to be evaluated.

For this project, we have selected different restoration approaches on a preliminary basis and applied them to those culverts indicating fish passage issues. In addition, a preliminary order of magnitude cost estimate has been provided. Both the method and cost estimate are preliminary and are intended to allow for project evaluation. Detailed designs and cost estimates should be performed during the next phase of the project.

3.2 8TH STREET CULVERT

The culvert at 8th street is unusual because the upstream entrance is through a hole cut through the side of the culvert. For the culvert analysis, the inlet head loss values were increased to the maximum to account for increased entrance head loss. The existing outlet apron for 8th street is a long (approximately 75 feet) asphalt concrete section that is impassible for fish because of low flow depths and velocities. As part of the proposed restoration plan for Lower Codornices Creek prepared by the Waterways Restoration Institute (WRI) and FRE, this outlet condition will be restored to a more natural creek geometry will alleviate this condition and improve fish passage for this culvert.

3.2.1 Results for Juvenile Salmonid Fish Passage

Under existing conditions, the downstream concrete apron from 8th street has much too low a depth of flow to allow for fish passage. Under low flow conditions, the barrier codes for this culvert (summarized in Table 2) show that depth and exhaustion from prolonged velocities inhibit fish passage for juveniles. Approaches to increasing depths within the culvert under these conditions will be described under section 3.2.3 below.

3.2.2 Results for Adult Resident Trout Fish Passage

The results for the adult rainbow trout (size of 200 mm) are similar to those for the juvenile trout passage. The depth of flow, especially, along the existing apron is too shallow to allow for fish passage. Low flow depth of flow and higher than acceptable velocities form a potential barrier to fish passage.

3.2.3 Preliminary Culvert Retrofit/Restoration Options

Approaches to raising flow depths within the culvert for fish passage include installation of baffles, or raising tailwater depths by installing outlet weirs or modifying downstream flow conditions. For this culvert, we have assumed that the downstream tailwater conditions will be modified to provide additional stream roughness (hence raise water levels) under the proposed restoration plan to be implemented in 2004/2005. This work will include regrading of the channel bottom, and the reintroduction of vegetation (hence roughness) into the channel, which will raise water elevations.

3.3 SAN PABLO AVENUE CULVERT

The San Pablo Avenue Culvert is a major culvert along Codornices Creek and forms a potential barrier to fish passage along the creek. The length of the culvert is approximately 254 feet. It has an outlet scour pool of approximately four feet at the outlet of the culvert. As part of the proposed restoration plan prepared by the Waterways Restoration Institute (WRI 2001) and FRE, this outlet condition will be restored to a natural creek geometry with the construction of a step-pool system at the outlet.

3.3.1 Results for Juvenile Salmonid Fish Passage

The results for the San Pablo culvert for passage of juvenile fish passage indicate a barrier for excessive leap height at the outlet and low flow depth. In addition, the length of the culvert presents passage problems due to fish exhaustion. The perched culvert and culvert length are significant barriers that will have to be addressed during final design.

3.3.2 Results for Adult Salmonid Fish Passage

The results for passage of adult salmonids are similar to those for the juvenile fish with the primary barrier to fish passage being the low flow depth and excessive leap at the outlet.

3.3.3 Preliminary Restoration Alternatives

The outlet scour pool, approximately four feet deep, will be filled and the channel bottom regraded through construction of a series of step-pools to raise the creek invert to the bottom of the culvert invert. Given the length of the San Pablo culvert, a series of fish baffles would be installed within the culvert to provide increased depth and resting areas for fish passage within the culvert.

3.4 KAINS STREET CULVERT

The Kains Culvert was modeled as a 6 ft by 6 ft circular culvert with a length of approximately 98 ft and a slope of 0.2 percent. The creeks slopes at a grade of approximately two percent uniformly from the downstream outlet with no significant outlet scour pool. The downstream cross-section of the creek is a concrete trapezoidal channel.

3.4.1 Results for Juvenile Salmonid Fish Passage

Results for the 1 cfs and 2 cfs model runs for passage of juvenile salmonids indicate the culvert is a barrier to fish passage due to insufficient flow depth. There is no reported depth barrier at 3 cfs, which indicates that flow depths are almost suitable for fish passage.

3.4.2 Results for Adult Salmonid Fish Passage

The analysis results for adult fish passage indicate a depth barrier at 3 cfs, no barrier at 11 cfs and an excessive velocity barrier at 18 cfs. A review of the results indicates that raising water levels in the culvert by increasing downstream grades should make this culvert passable.

3.4.3 Preliminary Restoration Alternatives

We propose to construct a downstream grade control consisting of a combination of logs and rock to raise the water levels within the culvert. We will locate the backwater control at a location of a riffle section downstream of the culvert and we will design to increase water level by a few inches.

3.5 STANNAGE STREET CULVERT

The Stannage Street Culvert was modeled as a 6 ft by 6 ft arch culvert with a slope of 1.10 percent. The length of the culvert is approximately 122 feet and it is on private property. The tailwater control section begins at approximately 20 feet from the culvert outlet and consists of a riffle section in between a trapezoidal channel section. There is no significant scour pool at the culvert outlet.

3.5.1 Results for Juvenile Salmonid Fish Passage

The results for all of the juvenile passage flow analyses (1 cfs, 2 cfs and 3 cfs) indicate that the flow depth within the culvert ranges from 0.13 ft to 0.25 ft which is below the 0.3 ft flow passage depth minimum. Therefore, the Fish-Xing model shows the culvert as depth limited for juvenile salmonid passage.

3.5.2 Results for Adult Salmonid Fish Passage

Hydraulic modeling results for adult fish passage for 3, 11 and 18 cfs indicate a depth barrier at 3 cfs and a velocity barrier at 18 cfs. Neither of these barrier codes are too difficult to solve, and we recommend raising the tailwater elevation to increase flow depths and reduce velocities. The calculated depths are within 0.1 to 0.2 of the required depths.

3.5.3 Preliminary Restoration Alternatives

We recommend regrading of the downstream tailwater control section by building up the control elevation with rock boulders. An increase of greater than three inches should allow for sufficient depths for fish passage.

3.6 CORNELL STREET CULVERT

The Cornell Culvert was modeled as a 6 ft by 5 ft arch culvert that is sunken (i.e. sediment buildup) about 0.8 ft. The length of the culvert is approximately 106 feet at a slope, based upon field elevations, of -0.33%, a negative slope indicating that the outlet is higher than the inlet. Since Fish-Xing will not allow for negative culvert slopes, for the passage modeling we set the culvert at a flat slope. This is no appreciable scour pool at the culvert outlet. Access to the culvert is through private property.

3.6.1 Results for Juvenile Salmonid Fish Passage

Results for the Cornell Street culvert indicate that the culvert depth may be too shallow for much of the distance in the culvert under the very low passage flowrate of 1 cfs. However, the model indicated the culvert did not pose a hydraulic barrier under the 2 cfs and 3 cfs conditions. Given the uncertainties in the passage flows and tailwater conditions, we believe this culvert does not pose a barrier for juvenile fish and we shall reconfirm the result in final analysis and design.

3.6.2 Results for Adult Salmonid Fish Passage

Results for adult fish passage are similar to those for juvenile fish passage, and the culvert does not appear to form a barrier

3.6.3 Preliminary Restoration Alternatives

No modifications to this culvert are recommended at this time.

3.7 TALBOT STREET CULVERT

The Talbot Street culvert was modeled as a 6 ft by 6 ft arch culvert with a concrete bottom at grade. The length of the culvert is approximately 144 feet and it is at a slope of approximately 0.01 percent. There is no significant scour pool at the culvert outlet.

3.7.1 Results for Juvenile Salmonid Fish Passage

Hydraulic modeling of flow passage for juvenile salmonids indicates that the Talbot Street culvert does not pose a hydraulic barrier for fish passage, therefore, no additional engineering modifications are required.

3.7.2 Results for Adult Salmonid Fish Passage

Hydraulic modeling of flow passage for adult salmonids indicates that the Talbot Street culvert does not pose a hydraulic barrier for fish passage, therefore, no additional engineering modifications are required.

3.7.3 Preliminary Restoration Alternatives

No work is recommended at this culvert.

3.8 EVELYN STREET CULVERT

The Evelyn Street Culvert was modeled as a 6 ft by 6 ft arch culvert with a concrete bottom at grade. The length of the culvert is approximately 112 feet and it is at a slope of approximately 2 percent. This is no appreciable scour pool at the outlet.

3.8.1 Results for Juvenile Salmonid Fish Passage

Fish passage results for the Evelyn Culvert indicate that the shallow depth is a barrier for migration of juvenile salmonids under flow passage conditions.

Under the 2 and 3 cfs conditions, the fish exhausted at burst speed, indicating higher then wanted velocities due to the shallow culvert flow depth and culvert slope.

3.8.2 Results for Adult Salmonid Fish Passage

The modeling results for adult fish passage show depth barriers at 3 and 11 cfs and a fish exhaustion barrier at 11 and 18 cfs. Deeper flow depths would assist fish passage.

3.8.3 Preliminary Restoration Alternatives

We recommend constructing boulder rock weirs at the downstream tailwater control section to raise water levels through the culvert. Depths are within a few inches of an appropriate depth, therefore, downstream grade control should increase the pass-ability of the culvert for fish.

3.9 MASONIC STREET CULVERT

The culvert under Masonic Street was modeled as a 6 ft by 6 ft arch approximately 100 feet long at a slope of 2.5 %. There is a small outlet pool with a depth of approximately 6 inches at the outlet of the culvert. The bottom of the culvert is relatively smooth concrete that will be difficult for fish to pass.

3.9.1 Results for Juvenile Salmonid Fish Passage

The results for the Masonic Street culvert are similar to those of previous culverts, like that at Evelyn Street. Under all three passage flow conditions, the flow depth is slightly too low, approximately 0.1 to 0.2 ft, within the culvert to allow for juvenile fish passage.

3.9.2 Results for Adult Salmonid Fish Passage

Results for passage of adult fish show a depth barrier at 3 and 11 cfs. However, the depth barrier at 11 cfs is only 0.03 ft, which is within the error limits of preliminary modeling and likely does not require significant modifications to meet passage requirements. The fish exhaustion barrier at 18 cfs is for a velocity of 4.5 ft/sec, which is only slightly higher than the requirement of 3.9 fps.

3.9.3 Preliminary Restoration Alternatives

Given the uncertainties in the modeling, this culvert likely does not pose a significant barrier to fish passage. However, minor modification of the tailwater control section, to increase water depths by a few inches should allow this culvert to pass the F-Xing hydraulic analysis. In addition, the upstream section of the culvert is smooth concrete which may impede fish passage. Construction of a low flow passage channel or fish baffles is recommended to aid fish passage through the upstream culvert section.

3.10 SANTA FE STREET CULVERT

The Santa Fe culvert was modeled as a 6 ft by 6 ft arch culvert that is sunken (embedded) at a depth of one foot. The culvert length is 178 feet at a slope of 0.37 percent. There is a small pool with a maximum depth of approximately one foot at the culvert outlet.

Tailwater elevations for this culvert were based upon the rating curve for the stream gauge provided by Balance Hydrologics. The streamgauge data was not referenced to any datum and the location of the gauge could not be located in the field, therefore, it was assumed that the zero elevation of the gauge was equal to the outlet culvert elevation. This may overestimate the tailwater depth and should be confirmed during final design.

3.10.1 Results for Juvenile Salmonid Fish Passage

The modeling results indicate that the culvert forms a depth barrier for juvenile fish passage under the 1 cfs and 2 cfs flow conditions and not at the 3 cfs flow condition. Given the uncertainties in the rating curve elevation, it is likely that flow depths in this culvert are too low for fish passage and should be raised to allow for improved passage.

3.10.2 Results for Adult Salmonid Fish Passage

The modeling shows no fish passage barrier for this culvert under the selected flow conditions.

3.10.3 Preliminary Restoration Alternatives

No work is recommended at this culvert.

3.11 CURTIS STREET CULVERT

The Curtis Street Culvert was modeled as a 6 ft by 3 ft arch culvert sunken approximately one foot of depth. The length of the culvert is approximately 64 feet. This culvert is submerged to within a few inches of the top of the pipe and discharges into a 3 foot scour pool which submerges the outlet.

3.11.1 Results for Juvenile Salmonid Fish Passage

Fish-Xing was unable to calculate flows since the outlet of the culvert was submerged. Given this condition, this culvert forms no barrier to fish passage. Therefore, no additional modifications are required.

3.11.2 Results for Adult Salmonid Fish Passage

Fish-Xing was unable to calculate flows since the outlet of the culvert was submerged. Given this condition, this culvert forms no barrier to fish passage. Therefore, no additional modifications are required.

3.11.3 Preliminary Restoration Alternatives

Given the submerged flow conditions of this culvert, it does not appear to pose a barrier to flow passage.

3.12 NEILSON STREET CULVERT

The culvert under Neilson Street was modeled as a 6 ft by 6 ft arch culvert at a slope of 1.1 percent and a length of 252 ft. There is a small outlet scour pool of approximately 6 inches depth.

3.12.1 Results for Juvenile Salmonid Fish Passage

Similar to the other culverts along the creek, the calculated depth of flow within this culvert is too low to allow for juvenile fish passage.

3.12.2 Results for Adult Salmonid Fish Passage

The modeling showed a depth limitation at the low flow analysis of 3 cfs, no barrier at 11 cfs and a fish exhaustion barrier at 18 cfs. The exhaustion barrier is due to slightly elevated velocities (approx 4.7 fps) elevated over the allowable velocity of 3.9 fps. Within the error margin of this modeling, these differences are small and may not be accurate.

3.12.3 Preliminary Restoration Alternatives

Modifications to the downstream tailwater section to raise downstream water levels and flow depths in the culvert should remove the hydraulic barrier to fish passage. We recommend installation of a boulder or log grade control section to raise the flow depths.

3.13 PERALTA STREET CULVERT

The Peralta Culvert was modeled as a 6 ft by 6 ft arch culvert filled with approximately one foot of sediment. The length of the culvert is long at approximately 474 feet. It has a slope of 1.65 percent. There is an outlet pool approximately 1.5 feet deep.

3.13.1 Results for Juvenile Salmonid Fish Passage

The results for this culvert also indicate too shallow a flow depth for juvenile fish passage under all flow conditions. In addition, the analysis indicated that the fish became exhausted at prolonged speed indicating that the culvert is too long.

3.13.2 Results for Adult Salmonid Fish Passage

The culvert forms a depth barrier to passage at 3 and 11 cfs flows because calculated flow depths are slightly below the required depth (at 11 cfs the calculated flow depth is only 0.06 ft below the desired depth). Calculated velocity at 18 cfs is 4.07 fps which is only slightly greater than the desired velocity of 3.9 fps. Given the uncertainties in modeling, these differences are not significant.

3.13.3 Preliminary Restoration Alternatives

Given the length of the Peralta culvert, baffles may be useful to provide higher depth and lower velocity resting areas for fish passage. We also recommend installing downstream tailwater structures with boulder or log weirs to raise the backwater depth through the culvert.

4.0 Conceptual Solutions - St. Marys High Schools Area

Kier Associates identified three problem areas for Codornices Creek around the St. Marys High School Area. The creek through this reach flows through a bridge under Albina Street, which is the entrance to St. Marys High School. No field measurements of the bridge were provided. The solutions discussed below are conceptual and no hydraulic or engineering analysis was performed for this report.

The three problem areas are as follows (locations shown on figure 1):

- A bank erosion area located on the right bank just downstream of the bridge.
- The concrete bottom of the bridge forms an approximate four foot jump barrier to fish passage, and it likely causes a low flow depth barrier to fish passage.
- Several hundred feet upstream of the bridge, Codornices Creek becomes a concrete bottom rectangular channel approximately 6-8feet wide. This section would likely present impassible flow depth and velocities to fish passage.

Conceptual solutions for each of these three areas as discussed below.

4.1 DOWNSTREAM BANK EROSION AREA

Kier Associates has shown that the erosion area along the right bank of the creek just downstream of the bridge may be a significant source of fine grained sediment into the creek and may impact fish habitat. Visual inspection of the area shows that much of the erosion is due to runoff from the adjacent roadway channeling down the slope. Figure 3 is a sketch of the existing problem area along with possible restoration solutions. At this point, we do not recommend massive regrading of the bank slope. We propose to install a runoff control along the roadway, along with a native revegetation effort along the slope.

4.2 ALBINA STREET BRIDGE

The Albina Street bridge has a concrete bottom structure that appears to have increased flow velocities and caused a downstream scour pool. The outlet to the bridge is perched approximately 3-4 feet above the downstream pool invert. Figure 4 shows a conceptual profile drawing through the bridge. Figure 5 is a conceptual sketch of possible restoration alternatives in plan view of the bridge with step-pools and the upstream rectangular concrete section.
Conceptual restoration options include construction of a series of step-pools to connect to the downstream existing tailwater control section to reduce the jump height to one foot or less.

Restoration of the concrete bridge bottom is more difficult. A low flow channel may be notched into the bottom concrete to provide a fish passageway, but this type of notch channel is difficult to maintain. In addition, the structural integrity of the bridge could be compromised; therefore, no alterations to the concrete bottom should be performed without review by a qualified structural engineer.

Therefore, we tentatively propose a baffle system be installed along the bridge channel bottom to provide flow depths and velocities suitable for fish passage.

4.3 UPSTREAM RECTANGULAR CONCRETE SECTION

Upstream of the Albina street bridge is a rectangular concrete section of approximately 300-500 linear feet. The concrete channel in this area may provide structural support for the retaining walls that are adjacent to the creek along both sides. Figure 5 shows a conceptual section of part of this reach retrofitted with fish baffles. The immobile concrete bottom does not allow for development of pool and riffle habitat and causes excessive velocities those likely form barriers to fish passage. There is also a jump step of approximately three feet into the concrete section that would require regrading to reduce the jump to less than one foot in height.

We have shown solutions that may work within the existing right of way. Ideally, the best solution would be to acquire additional right of way and construct the appropriate bankfull channel planform, profile and section.

Given the uncertainties over the role of the concrete channel in providing structural support to existing retaining walls, we propose installing fish baffles within the channel to provide for suitable depth and velocity for fish passage.

5.0 Recommended Next Steps

We recommend that the following steps be implemented for this project:

- Conduct minor additional field surveys to better determine tailwater control sections and slope and to confirm Fish-Xing modeling results.
- Determine the hydraulic capacity of each culvert for passage of flood flows and determine whether the recommended restoration alternatives may impact flood protection.
- Develop final designs and cost estimates for restoration/retrofit alternatives.

6.0 References/Bibliography

Documents used during preparation of this plan include the following:

1. California Department of Fish and Game (CDFG), Culvert Criteria for Fish Passage, May 2002.
2. Kier Associates. 2003. Codornices Creek Watershed Restoration Action Plan, prepared for the Urban Creeks Council and the California Bay Delta Authority Watershed Program. CA Dept. Wat. Res. Contract 4600001722. Sausalito, CA
3. Michael Love and Associates, Stonybrook Creek Fish Passage Assessment, April 6, 2001.
4. Philip Williams and Associates, Codornices Creek Flooding Analysis, October 13, 1997.
5. Ross Taylor and Associates, 2003, Marin County Stream Crossing Inventory and Fish Passage Evaluation. Prepared for Marin Department of Public Works.
6. Waterways Restoration Institute, Draft Codornices Creek Preliminary Restoration Plan, May 15, 2001.

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WATER QUALITY IN CODORNICES CREEK

Report for the Urban Creeks Council

By

Robert Coats

July 15, 2003

WATER QUALITY IN CODORNICES CREEK

Introduction

The Urban Creeks Council proposes to restore the habitat for steelhead in Codornices Creek. For successful restoration, it is essential that the quality of the water in the creek be satisfactory for all life stage of steelhead–migration, spawning, incubation and rearing. Water quality must also be satisfactory for organisms–such as aquatic invertebrates–that help support a viable population of steelhead. The purpose of this study is to measure and document some of the water quality parameters in Codornices Creek that are known to be problematic in urban creeks. If the creek is polluted beyond remediation, efforts aimed at restoring the physical habitat will be misspent. If, however, water quality problems in the creek are tractable, then some effort to improve water quality as part of the overall restoration effort is justified. The parameters chosen for this study are the organophosphate pesticide diazinon, and the metals copper, nickel, lead and zinc. Initial samples were also analyzed for chlorpyrifos. Based on existing information, we also consider other water quality parameters or issues–dissolved oxygen and septic sewage inflow–and how they might be addressed.

Background

Diazinon

Diazinon has been identified as a cause of toxicity to zooplankton in runoff, both in urbanized streams in the Bay Area, and in agricultural areas of the Central Valley. The problem was first identified in the Designed Urban Stormwater Treatment (Dust) marsh in Fremont (Katznelson and Mumley, 1997). Since then, diazinon toxicity has been identified in numerous urban streams in the Bay Area, and elsewhere in the U.S. (Lee, et al., 1999; Johnson, 2000). According to figure from the California Department of Pesticide Regulation, over 85,000 pounds of diazinon were used in the Bay Area in 1999; of this, about 60 percent was used for structural pest control, 27 percent in agriculture, and the remainder for landscape maintenance (Regional Board Staff, 2000). The problem is considered by the California State Water Resources Control Board to be sufficiently serious that the agency has added 35 urban creeks in the Bay Area to the "303(d)" list as "water quality impaired" due to diazinon. Although Codornices Creek is not listed specifically, the Board staff considers that diazinon "potentially impairs the habitat-related beneficial uses of all Bay Area urban creeks".

Not all zooplankton are equally sensitive to diazinon. *Ceriodaphnia* (the commonly-used test organism) and *Mysidopsis*, and the amphipod *Gammarus* are especially sensitive. The LC_{50} for *Ceriodaphnia* is 450 nanograms per liter (ng/l). Other zooplankton are less sensitive. On the basis of the available data on toxicity, the

California Department of Fish and Game has developed water quality criteria for diazinon of 80 ng/l for acute (one hour) exposure, and 50 ng/l for chronic (four day) exposure (Siepmann and Finlayson, 2000). The US EPA has been developing water quality criteria for diazinon since the late 1980s but has still not adopted them.

Although diazinon is not lethal to salmonids at the concentrations likely to occur in urban runoff, sublethal effects can occur at low concentrations. Scholz et al. found that a concentration of 1.0 µg/l was sufficient to inhibit an olefactory-mediated alarm response (essential for avoiding predators), and 10.0 µg/l disrupted homing behavior. Since olefactoy detection of pheromones is essential to breeding in salmon (Moore and Waring, 1996), it seems likely that diazinon could disrupt that function as well.

Chlorpyrifos

Chlorpyrifos, like diazinon, is an organophosphate insecticide. It is the active ingredient in Dursban, and is used in flea powder and flea shampoos. Although it is not used outdoors in amounts comparable to diazinon, it is much more toxic to zooplankton. The EPA freshwater acute (1 hour) criterion is 70 ng/l, and the chronic (4-day) criterion is 41 ng/l. The CDF&G suggested criteria are lower, however—the suggested freshwater criterion is 20 ng/l (Lee, et al., 1999).

Metals

Trace amounts of metals frequently occur in runoff from urbanized areas, in concentrations that are biologically significant. The Santa Clara Valley Loads Assessment Report (Woodward-Clyde Consultants, 1991) reported that (for metals) the most frequent wet weather exceedences of water quality criteria were for copper, lead and zinc. Copper in urban runoff originates from brake linings, and from architectural use of copper (Boulanger and Nikolaidis, 2003). Zinc may originate from galvanized steel, including culverts, and lead from old housepaints.

The sensitivity of aquatic organisms to copper, zinc and lead (among other metals) is inversely related to water hardness (hardness is the sum of Ca and Mg ions, typically expressed as an equivalent weight of calcium carbonate, in mg/l). The relationship is recognized in the criteria for these metals adopted in the California Toxics Rule (CTR) (40 CFR Part 131, May 18 2000). The formulas for deriving the criteria for dissolved metals from hardness are complex, but can be empirically approximated with simply quadratic equations.

Unidentified Sources of Toxicity

The lethality of urban runoff to coho salmon has recently been recognized in the Seattle area. Otherwise healthy fish are reported to become disoriented, roll to their sides, and sometimes "skitter across the top of the water in a final, desperate burst of energy" before dying (Stiffler and McClure, 2003). In one study, 88 percent of the coho entering a stream died from apparent toxicity before spawning. The National Marine Fisheries

Service Ecotoxicology Laboratory is currently trying to identify the cause of the problem. It may be that multiple agents—pesticides, polycyclic aromatic hydrocarbons (PAHs), heavy metals etc—have a synergistic effect, causing damage at levels that would not be lethal for any of them alone. The acute and lethal toxicity of urban runoff in Codornices Creek has not been observed, but clearly more needs to be known about the acute and chronic effects of urban runoff on salmonids.

Hydrology of Codornices Creek

Codornices Creek drains an urban watershed, and much of the watershed is paved. Runoff is routed from streets, driveways and roofs drains via storm sewers to the creek. As a result, runoff in the creek responds very rapidly to rainfall, and the creek is very "flashy". Figure 1, the runoff hydrograph for January 25, 2001, illustrates the flashy character of the creek. Discharge rose from 0.6 to 10 cfs between 13:00 and 14:00, and then rose from 10 cfs to 150 cfs by 14:30. By 02:00 on the 26th, it had dropped back down to 1.0 cfs. The rapid change in the hydrograph suggests that juvenile trout would have to find shelter quickly during the rising of a flood, and would be at risk of stranding as the discharge falls at the end of a storm. It also creates a difficult sampling problem, since many water quality constituents of interest change with discharge. To adequately characterize the water quality in the creek--especially transient water quality problems--would require an automated sampler capable of collecting samples at frequent intervals.

Figure 1. Discharge at BART Crossing, Jan. 25-26 2001

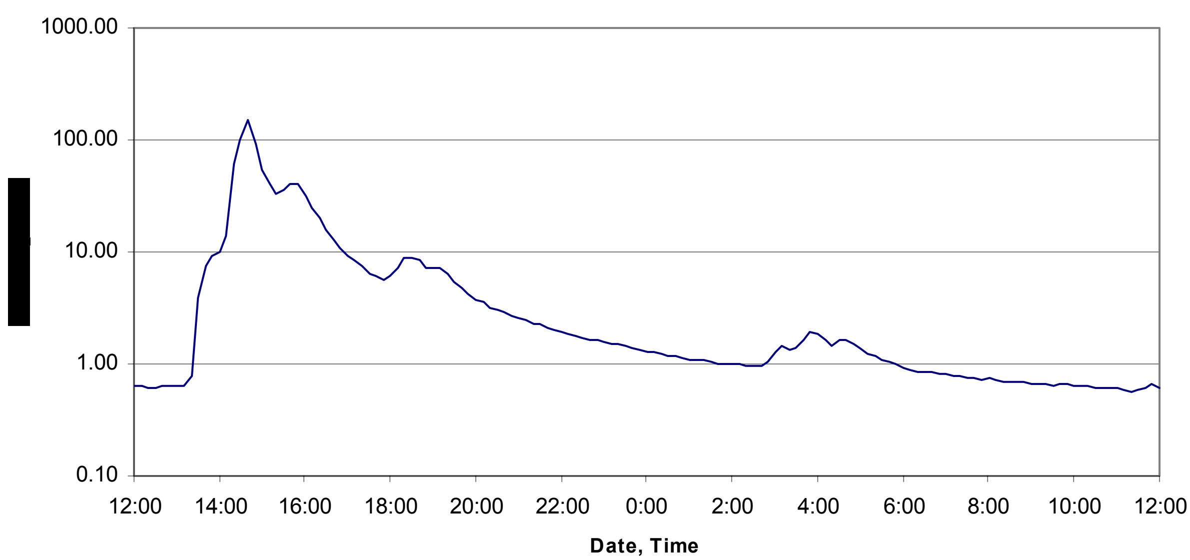
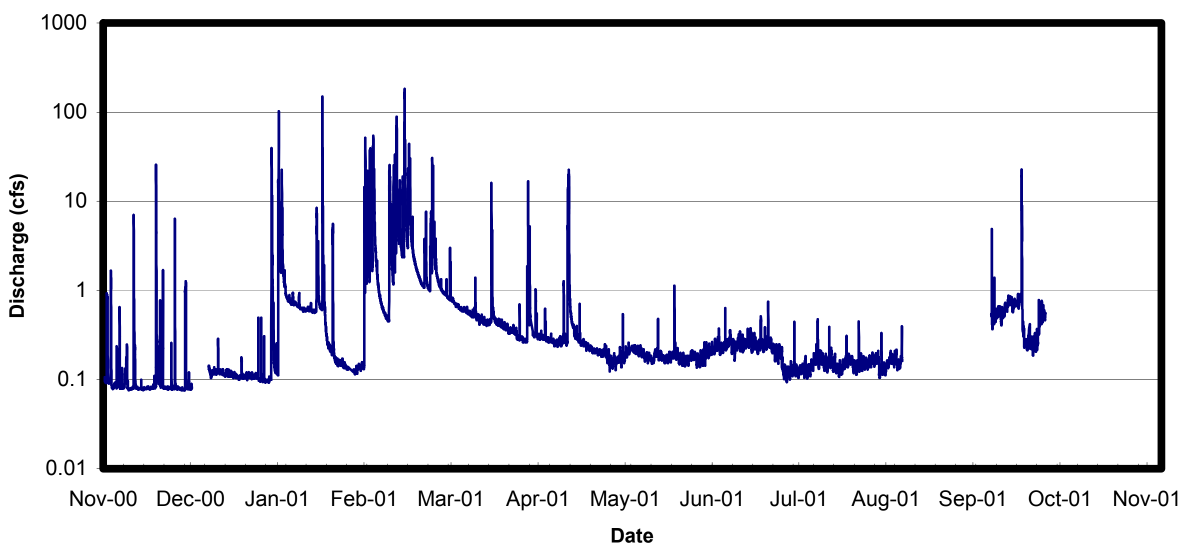


Figure 2 shows the runoff hydrograph for most of the 2001 water year. Note that most of the time the discharge is less than 1.0 cfs, but that it sometimes exceeds 100 cfs.[1] The hydrograph also shows some curious spikes in discharge during the summer months. This is probably caused by so-called "nuisance flow" associated with landscape irrigation, washing of cars, or leaks in water supply pipes.

Figure 2. Estimated Discharge, Codornices Creek at BART, WY 2001



Methods

Samples were collected at two sites on Codornices Creek: Live Oak Park (LOP) just upstream of the Walnut St. bridge, and at the BART crossing, between Masonic and Santa Fe. Collection was timed to catch storm runoff, although runoff peaks sometimes preceded sample collection. Samples for organophosphates were collected in laboratory-provided clean glass bottles and shipped on ice in a cooler to AQUA-Science in Davis, for next-day delivery. Samples for metals analysis were collected in double-bagged individually-labeled nalgene bottles using latex gloves, and shipped in a cooler for overnight delivery to Frontier Geosciences in Seattle.

Organophosphates were analyzed by enzyme-linked immunosorbent assay (ELISA) (Sullivan and Goh, 2000). Method detection limits (MDLs) are 30 nanograms per liter (ng/l) for both diazinon and chlorpyrifos. Initially the analysis included both diazinon and chlorpyrifos, but the results showed that the latter was typically below the MDL and

[1] Data for Figures 1 and 2 are from the Friends of Five Creeks; Gustavo Porras and Ed Ballman measured discharge, temperature, and conductivity at the BART crossing, and reduced the data.

the MDL itself is greater than the suggested chronic criterion for chlorpyrifos. At that point, chlorpyrifos was dropped, and the metals were added to the analysis list.

Dissolved metals were analyzed by inductively-coupled plasma-mass spectrometry (ICP-MS). MDLs are 0.05 µg/l for copper and zinc, and 0.01 µg/l for lead. In most cases, samples for metals are filtered through an acid-rinsed 40 µm filter before they are acidified for storage and later analysis. The samples from May 19, 2002, however, were not filtered prior to analysis, so the concentrations represent total recoverable rather than dissolved metals. The total recoverable concentrations were converted to estimates of dissolved concentration using data from the Santa Clara Co. stormwater program (Woodward-Clyde Consultants, 1991).

Since the aquatic life criteria for some heavy metals depend on the hardness of the matrix water, samples were also collected for hardness. These samples were stored unrefrigerated, and analyzed using a LaMotte test kit, generally within a few days of sample collection.

On April 1 2003, within 24 hrs of a small storm, a sample was collected at the BART crossing for toxicity tests at AQUA-Science laboratory in Davis. A 7-day Chronic Survival and Reproduction test was run with *Ceriodaphnia dubia* and a 96-hr Acute Survival Test was run with juvenile rainbow trout. In the latter test, the water was changed after about 48 hrs. Both tests were run with undiluted creek water.

Residents along Codornices Creek have reported occasional odors indicative of raw sewage. If confirmed, this would be a serious problem for salmonids, especially at low flow, when the sewage could cause low dissolved oxygen concentrations. To identify possible inflow of domestic waste, 11 samples were collected from the creek on April 9th, from Golden Gate Fields to Spruce St., during a period of relatively low flow. The samples were sent in a cooler on the day they were collected to Brelje & Race Laboratories in Santa Rosa, and analyzed for Methylene Blue Active Substances (MBAS). This is a sensitive test for the presence of household detergent, and is used to identify point-sources of sewage effluent.

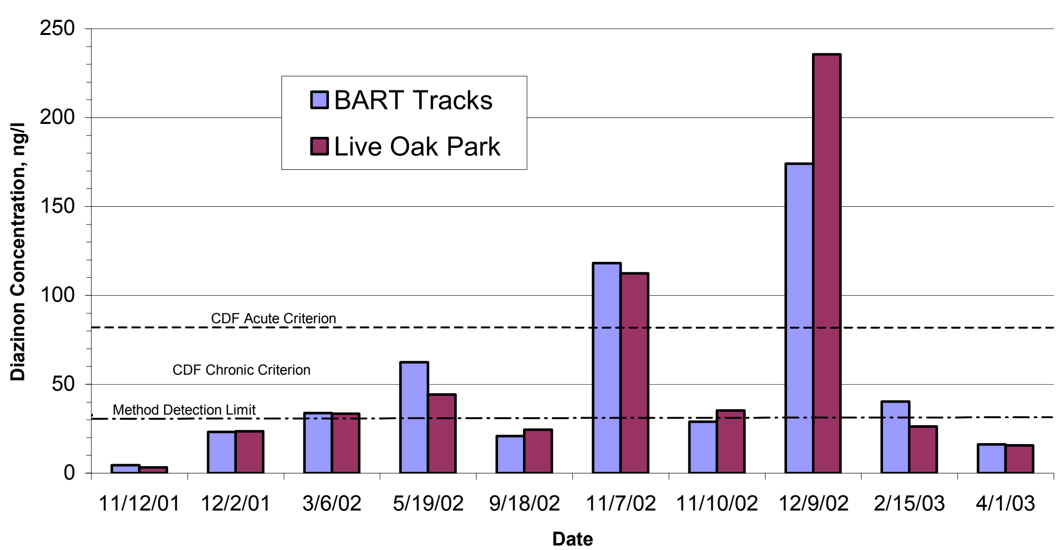
A staff gage with a stage data logger (maintained by volunteers Ed Ballman and Gustavo Porras) is located at the BART crossing. The staff is read when samples are collected, so that stage can be converted to discharge. Temperature and conductivity are also recorded by the data logger.

Results

<u>Organophosphates</u>

Figure 3 shows the concentrations of diazinon in the samples. On two occasions, samples at both Live Oak Park and the BART crossing exceeded the CDF acute criterion of 80 ng/l. and on one occasion the Live Oak Park sample but not the BART crossing sample exceeded the acute criterion. Three samples (one from Live Oak Park and two from the BART crossing) exceeded the chronic criterion but not the acute criterion.

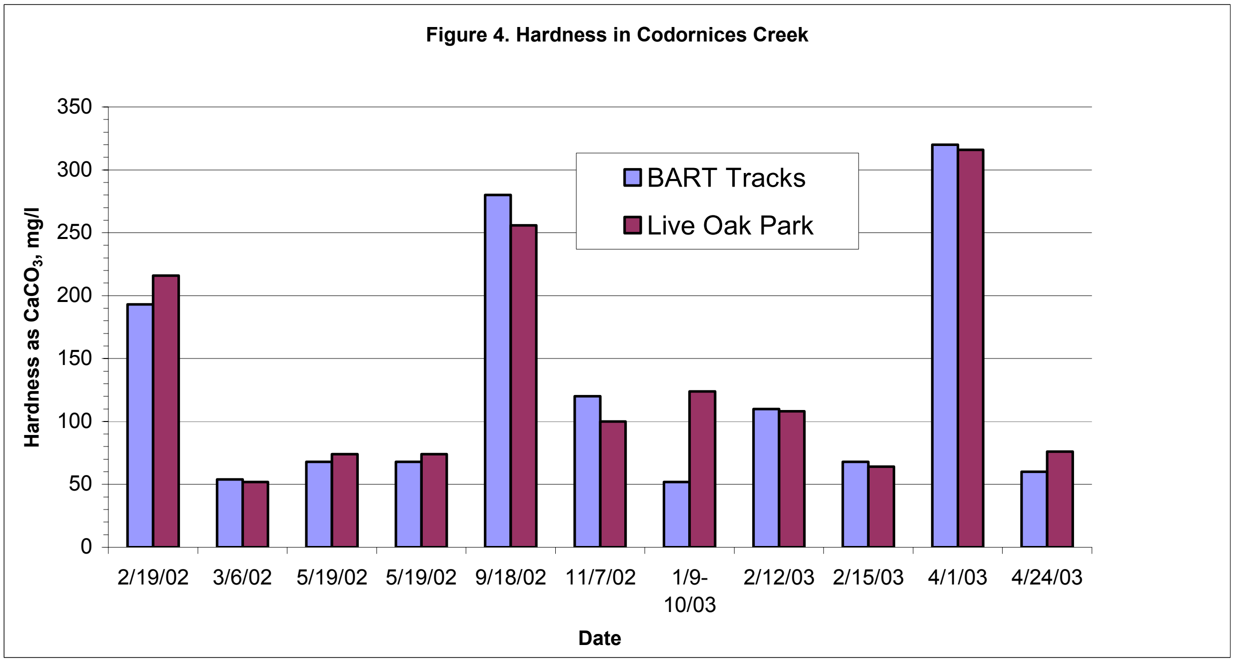
Figure 3. Diazinon in Codornices Creek



All four of the chlorpyrifos samples were less than the MDL of 30 ng/l, although one of them (BART crossing, 11/15/01) was reported as just over the CDF chronic criterion of 20 ng/l.

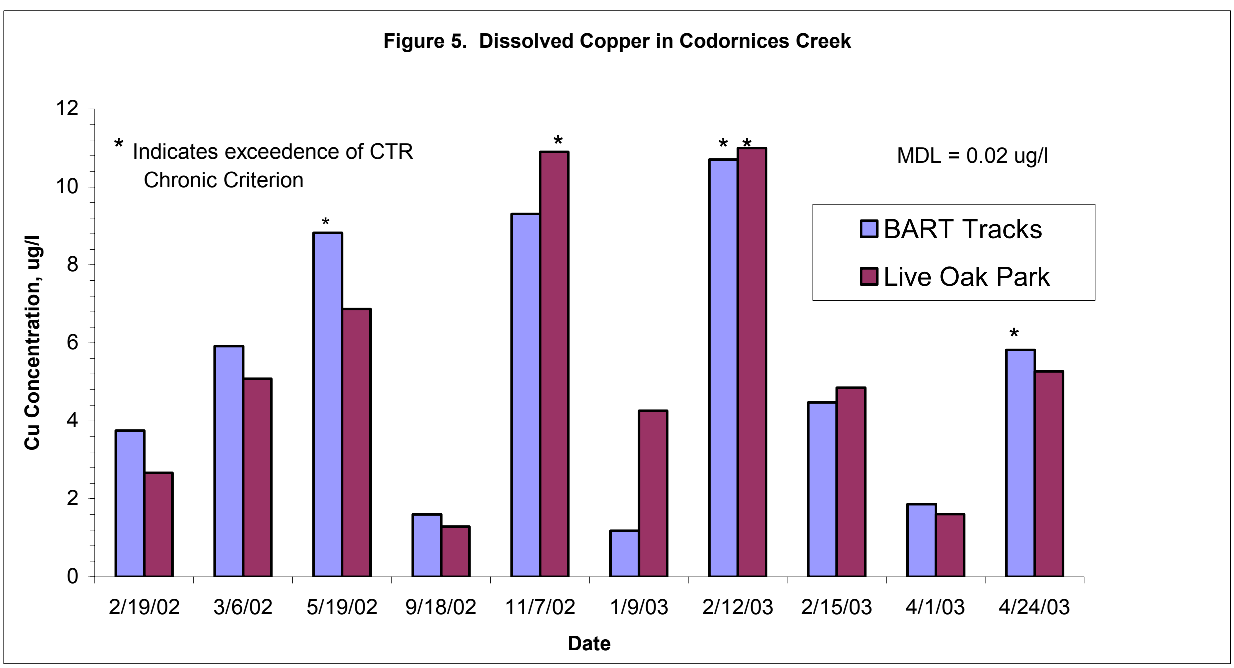
Hardness

Figure 4 shows the hardness in samples collected at the same time that samples were collected for heavy metals. Hardness varied from just over 50 mg/l to over 300 mg/l. As expected there is not much difference between the hardness at the two sampling sites on a given day (in January 2003, a sample was collected at BART crossing on the 9^{th} and at LOP on the 10^{th}). In general, hardness is inversely related to discharge, reflecting the relative contributions to the stream of surface runoff and groundwater.



Heavy Metals

The concentrations of dissolved lead and zinc never came close to the CTR chronic criteria for aquatic life. Dissolved copper, however, did exceed the chronic criteria in 3 samples at the BART crossing, and 2 samples at LOP. Figure 5 shows the results for copper. The acute criteria for aquatic life were not exceeded in any of the samples.



Some heavy metals data are also available from the 1993-94 San Francisco Bay Area Stormwater Runoff Monitoring study (Woodward-Clyde Consultants, 1996). The exact location on Codornices Creek is unknown. Neither discharge nor hardness were reported, so individual sample concentrations are hard to interpret in terms of hydrologic conditions and water quality criteria.

Table 1 shows the results from the Woodward-Clyde study. For most of the samples, some of the constituents were below the Method Detection Limit (MDL). For those samples, the value included in the average is the square root of a random number between 0 and 1, multiplied by the MDL. This is a close approximation of assigning a random number from a log-normal distribution between the MDL and a concentration of essentially 0. Note that the average dissolved copper concentration reported by Woodward-Clyde (4.2 ug/l) is very close to the average found in this study (5.4 ug/l).

Table 1. Average concentrations of dissolved metals in Codornices Creek, April 1986-April 1987

	Conc., ug/l	Sta.Dev., ug/l	number of samples	number of samples>MDL
Arsenic	1.46	1.00	11	8
Cadmium	0.13	0.10	16	3
Chromium	1.10	0.76	11	4
Copper	4.17	3.18	16	14
Lead	1.77	1.68	16	10
Mercury	0.15	0.11	11	2
Nickel	3.17	3.17	11	10
Selenium	---	---	---	0
Silver	---	---	---	0
Zinc	15.42	18.66	16	12

Note: for calculating averages and standard deviations, samples reported as ND were replaced by sqrt(rand())*MDL

Toxicity

The 7-day *Ceriodaphnia* test showed 100 percent survival in undiluted water from Codornices Creek. The percent survival in the control tank was actually lower (90 percent) than in water from Codornices Creek. The reproductive rate was also higher in the creek water (43.0 neonates/female) than in the control (37.7 neonates/female).

The rainbow trout acute survival test showed 100 percent survival after 96 hrs, in both treatment and control.

MBAS

The test for Methylene Blue Active Substances was negative (below the level of detection) for all samples. If there is a problem with sewage contamination of the creek, it is a sporadic one, since no detectable household detergents were present in the creek at the time of sampling.

Dissolved Oxygen

The concentration of dissolved oxygen (DO) in the creek is determined by temperature, the rate of chemical and biological uptake, the rate of reaeration, and the rate of production by algae in the creek. DO was not measured directly in this study, but Friends of Five Creeks have provided some data. Table 2 shows the temperature , turbidity, DO and biochemical oxygen demand (BOD) in samples from WY 1999 an WY 2000. The sample from 2/5/00, with discharge of 3.5 cfs, had a relatively high turbidity (40 jtu), and a significant BOD (3.8 mg/l), but the DO at the time of sampling was 9.8 mg/l. This suggests that the during storm events, when the stream contains a lot of available organic carbon or other reduced substances, the rate of reaeration due to turbulent flow exceeds the rate of oxygen uptake. DO is more likely to be a problem at low flow, when the temperatures are warmer, and turbulent reaeration is less. Note that at low flow (in July 1999) the DO dropped to 8.2 mg/l, or 81.3 percent of saturation. The lowest DO value as both concentration (7.2 mg/l) and percent saturation (68.6) was recorded was during low-flow in mid-October 1999, at 2nd St.

Table 2. Water quality data from Friends of Five Creeks.

Date/Time	Site	Measured Discharge	Water Temp	pH	Turbidity	Dissolved Oxygen	Percent Sat.	5-day Dissolved Oxygen	Biological Oxygen Demand
(mm/dd/yr)		(cfs)	(^{o} C)		(jtu)	(ppm)		(ppm)	(ppm)
11/6/98	BART crossing	---	---	7.5	5-200	---		---	---
11/7/98	BART crossing	---	13	6.5	80	9.4	89.2	---	---
12/5/98	BART crossing	0.8	9.5	8	1.3	10.4	91.0	---	---
1/9/99	BART crossing	0.19	8.5	8	0.0	---	---	---	---
2/6/99	BART crossing	2.01	10.1	7.5	20.0	10.7	95.0	---	---
3/9/99	BART crossing	1.08	10.5	7.5	0.0	11.0	98.6	---	---
4/10/99	BART crossing	1.0	10.0	7	0.0	10.4	92.1	3.2	7.2
5/1/99	BART crossing	1.2	12.5	7	2.5	9.4	88.2	---	---
6/5/99	BART crossing	0.9	13.0	7.0-7.5	5-10	---	---	---	---
7/10/99	BART crossing	0.46	15.1	8	0.0	8.6	85.4	---	---
8/7/99	BART crossing	0.32	15.0	7.5	5.0	8.2	81.3	---	---
9/4/99	BART crossing	0.24	14.5	8	1.2	8.8	86.3	---	---
10/9/99	BART crossing	---	15.1	6.3	---	7.5	74.5	5.8	1.7
10/12/99	BART crossing	---	---	7.7	<5	8.7		---	---
11/6/99	BART crossing	0.10	14.1	7.5-8.0	---	8.6	83.6	8.3	0.3

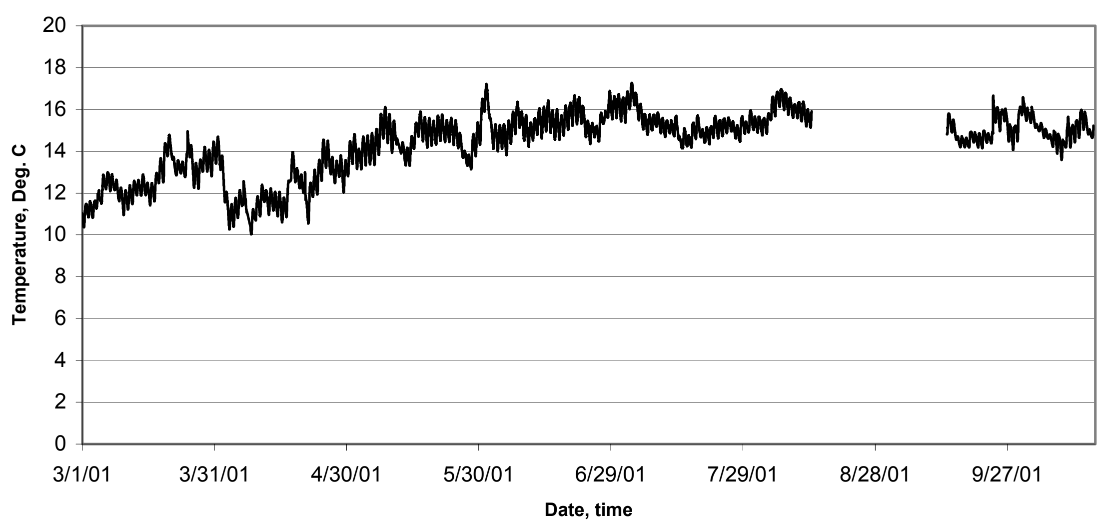
12/11/99	BART crossing	---	9.9	7.5	<5	9.8	86.6	9.3	0.5
1/8/00	BART crossing	0.15	10.0	7.9	0.0	8.6	76.2	9.5	n/a
2/5/00	BART crossing	3.46	12.0	8.2	40.0	9.8	90.9	6.0	3.8
3/11/00	BART crossing	2	13.0	8.9	0.0	7.8	74.0	8.2	n/a
4/1/00	BART crossing	0.69	13.0	7.5	0.0	8.1	76.8	---	---
10/11/99	LOP	---	14.0	8.0	<5	9.4	91.2	9.0	0.4
10/13/99	9th St.	---	16.5	7.3	<5	10	104.4	---	---
10/18/99	2nd St.	---	13.2	8	<5	7.2	68.6	---	---
10/19/99	6th St.	---	16.0	---	---	---		---	---

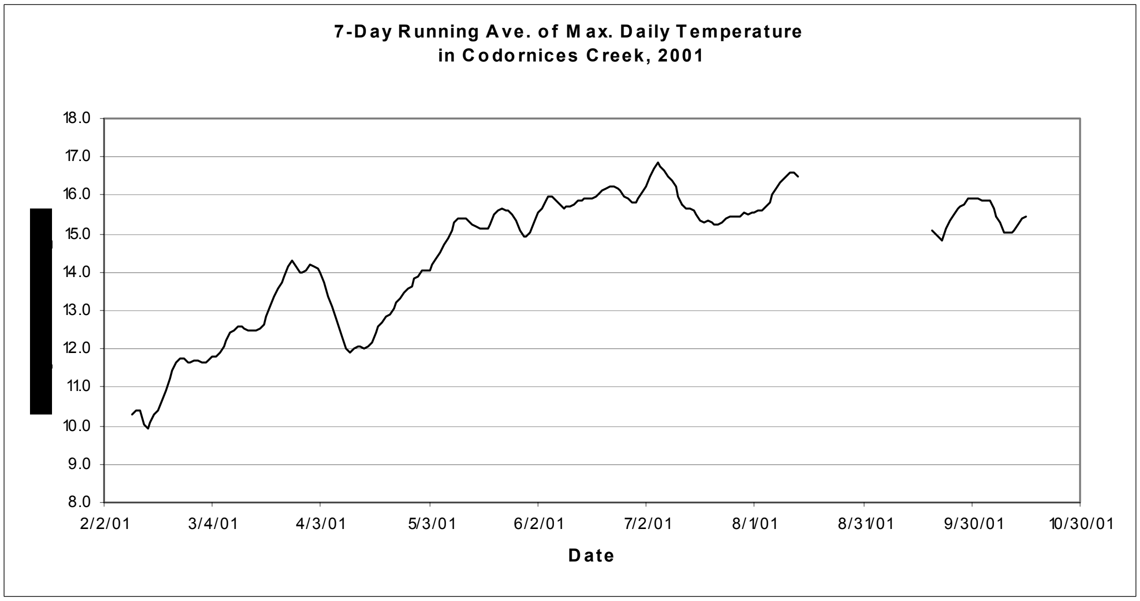
<u>Temperature</u>

Figure 6 shows the temperature record in Codornices Creek for March-October 2001, recorded at the BART crossing. The Urban Creeks Council consultants are currently collecting additional temperature data. These data were used to calculate the running 7-day average of maximum daily temperature (Figure 7).

The U.S. EPA defines a criteria called the Maximum Weekly Average Temperature (MWAT) as "the mathematical mean of multiple, equally spaced, daily temperatures over a 7-day consecutive period" (U.S. EPA, 1977). The maximum value of the running 7-day average of the 10-minute values (which seems to be what EPA means by “MWAT”) is 16.4 deg. C. The maximum temperature recorded in 2001 was 17.3 degrees. The biology report on Codornices Creek discusses the significance of these temperature statistics.

Figure 6. Temperature in Codornices Creek at BART Crossing, 2001





Discussion and Recommendations

Sampling for diazinon in Codornices Creek has shown that both the chronic and acute water quality criteria recommended by the California Dept. of Fish and game are exceeded occasionally. The exceedences, however, are below any concentration at which physiological effects on salmonids have been shown. Effects on aquatic insects and zooplankton are possible, but these effects are likely to be of short duration.

Sampling for copper, zinc and lead has shown that only dissolved copper concentrations exceed the chronic criterion, but do not exceed the acute criterion. As with diazinon, any effects on aquatic organisms are likely to be transient. Toxicity tests on a sample of creek water from early April showed that the sample tested caused no mortality of either rainbow trout or *Ceriodaphnia.*

No evidence of sewage contamination was found in a synoptic survey for household detergents.

To say that sampling was able to identify only sporadic water quality problems, however, does not mean that severe problems never exist. Given the flashy nature of the watershed, and the unpredictability of human behavior, it is likely that water quality in Codornices Creek is occasionally degraded by runoff from the urbanized watershed. The recent experience with fish kills in the Seattle area suggests that attention should continue to be focused on water quality problems in any urban creeks that are managed for salmonid habitat.

In order to address the existing and potential water quality problems in Codornices Creek, we have the following recommendations. Some of the recommendations could be implemented by the City, or a regional agency, and some by neighborhood groups or citizen volunteers.

1. Water quality monitoring of the creek should continue, incorporating the use of automated samplers that can collect samples periodically during a storm event. Analysis should include some of the common known water quality problems in urban runoff, such as volatile organic carbon, oil and grease, and polycyclic aromatic hydrocarbons (PAHs). Sampling should also attempt to characterize the water quality during the flow spikes of late summer.

2. A program of citizen education will continue to play an important role in maintaining water quality in the creek. Stenciling of storm drains has already probably helped raise the awareness level. Dissemination of information of alternatives to garden pesticides is also important. It is likely that diazinon will be replaced by pyrethroid insecticides, which are relatively non-toxic to mammals, but highly toxic to aquatic crustaceans and insects. Pyrethroids are already the dominant insecticide in structural pest control in Alameda County. Unfortunately, the quantitative methods for measuring low concentrations of the pyrethroid insecticides are poorly developed.

3. The city should evaluate the possibility of installing “fossil filters” in drop inlets that drain to Codornices Creek. These filters are very effective in removing hydrocarbons from stormwater. They do require periodic maintenance and replacement. Citizen volunteers could play a role in maintaining them in some individual neighborhoods. Detailed information on fossil filters is included in an Appendix to this report.

This study has shown that copper and diazinon occasionally exceed water quality criteria in Codornices Creek. The frequency and duration of these exceedences, however, are not severe enough to prevent a population of rainbow trout/steelhead from thriving in reaches of the creek that have otherwise suitable habitat. Continued focus on water quality issues should be a part of ongoing efforts to restore and enhance salmonid habitat in the creek.

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