Chapter 4

A WATER QUALITY PROFILE OF BERKELEY'S CODORNICES CREEK

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Introduction

Today a visitor might find it hard to believe that nearly a dozen creeks run through the city of Berkeley. The majority of the creeks have been covered by the city with the advent of urbanization. There are two major creeks left in Berkeley that have portions open to the public in significant amounts. These are Strawberry and Codornices Creeks. Strawberry Creek is largely uncovered through the grounds at the University of California (see Thomas C. Frazier's paper on Strawberry Creek, this report, for more information). Codornices Creek (Spanish for quail) has more of its length uncovered than any other creek in Berkeley.

Codornices Creek is a permanent creek originating in the Berkeley Hills just below Grizzly Peak Boulevard (Figure 1). There are two major forks that meet to form the main stream. The southern fork is approximately 1.3 miles long, and the northern fork approximately 1.2 miles in length. These two branches meet at Josephine and Hopkins to form the main branch, which is approximately 2.5 miles long. Codornices Creek empties into the Bay just north of Golden Gate Fields. The creek as a whole represents some 6.5 miles of various stream environments with many sites of natural and exotic vegetation and wildlife.

Codornices Creek is unique to the Berkeley-Albany communities. It is the location for three of Berkeley's major parks: Codornices, the Rose Garden, and Live Oak Park. In addition, other non-park areas are visited frequently by residents, mainly children. These areas include the creek just south of St. Mary's High School (Albina and Hopkins, Berkeley), below BART between Key Route Boulevard and Masonic, and the area along the creek just south of the UC Village (between 10th and 5th Streets, Albany). These parks and non-park areas are cause for deep concern. The last set of water quality studies on Codornices Creek indicates that the creek was polluted heavily with fecal and coliform contamination (Berkeley, 1970; Grove, 1969). The purpose of this study is to analyze present water quality conditions in Codornices Creek for several reasons. The major concerns appear to be:

1. Codornices Creek may present a potential health hazard for children playing in the creek (from skin contact and/or oral ingestion).

2. Contamination of shellfish and marine fish near the mouth of Codornices Creek.
3. Preservation of the biota along the creek may be threatened if a major pollutant is released into the creek.
4. Identification of the major pollutant(s) and sources in order to suggest possible solutions in reducing these pollutants.
5. Construction of a park just south of the UC Village in Albany would be a great asset to the community if the water quality of Codornices Creek could be improved.

In determination of substances to test for in Codornices Creek, I followed parameters defined by organizations such as ABAG and the Regional Water Quality Control Board (RWQCB, 1975). These are:

1. Bacterial contamination
2. Sewage and oxygen-demanding waste
3. Toxic metals, pesticides
4. Nutrients (carbon, phosphorus, nitrogen)
5. Oil
6. Heat
7. Radiation

Results obtained concerning the water quality in Codornices Creek are shown in Table 1. Past results from two previous studies (Berkeley, 1970; Grove, 1969) are also shown in Table 1 to indicate the condition of the creek 14 years ago.

Methodology

Four major areas were used as collection sites along Codornices Creek in this 1983 survey. These are shown in Figure 1 as A, B, D, and E. Site A is the watershed area for the southern fork of Codornices Creek, located just below Fairlawn Road. Site B is at the bridge located in Codornices Park. Site C is at the Rose Garden (1969-70 testing site). Site D is located at Live Oak Park, and site E at 9th and Harrison in Albany. Site F is at the Eastshore Highway (1969-70 testing site). Samples were taken during a wet period (March 15, 1983) and a dry period (April 13, 1983, six days after the last rain) for both the bacteriological and pH tests. All other tests were performed on only one of these days.

Bacterial Survey (Coliforms) - All samples were collected in 250 ml sterile containers from the creek at the four testing siges (A, B, D, E). The 1983 samples were analyzed using the Most Probable Number (MPN) method as specified by Standard Methods (APHA, 1980).

Past History: Past studies on bacteria in Codornices Creek are from the efforts of John Grove (Grove, 1969) and the City of Berkeley (Berkeley, 1970).

Testing Sites		A	B	C	D	E	F
Bacteriological Survey: Coliforms (MPN/100ml)	10-20-69[a]			2,300	4,000	23,000	15,000
	2-3-70[b]		23,000	6,200	6,200	2,300	6,200
	3-9-70[b]		6,200	62,000	62,000	23,000	6,200
	3-15-83	24,000	24,000		3,500	5,400	
	4-13-83	16,000	18,000		9,000	6,000	
DO 3-15-83 (mg/l)		10.2	11		10.5	9.8	
BOD 10-20-69[a]				10			7
pH	3-15-83	7.8	7.6		7.4	7.8	
	4-12-83	8.3	8.1		8.4	8.5	
Heavy Metals 4-12-83 (mg/l)	Pb	.05	0		0	.08	
	Hg	.002	0		.006	.004	
	Cd	0	.007		.002	.004	
Nutrients 3-18-83 (mg/l)	NH_3	.06	.09		.09	.14	
	PO_4	.23	.30		.28	.42	
Turbidity (NTU) 4-12-83		1.0	0.8		1.5	1.2	
Conductivity (1000umho/cm) 4-83		0.7	0.7		0.7	0.68	
Distance (ml)		0	.68	.69	1.02	2.84	3.30

Table 1. Water quality data from Codornices Creek.

Source: a) Grove,1969. b) Berkeley, 1970. All others,this report.
Sites identified on Figure 1.

DO/BOD - The dissolved oxygen content was analyzed using a DO meter following methods in Standard Methods (APHA, 1980).

Past History: The Biochemical Oxygen Demand data (Table 1) are from John Grove's 1969 samples (Grove, 1969), which were tested by Engineering Science, Oakland.

pH - Both sets of samples were tested using a pH meter directly from the 1 liter plastic containers used in all the sampling except the bacterial survey.

Heavy Metals - These samples were collected during the dry period only and analyzed for lead, mercury, cadmium using a spectrophotometer (located in 20 Lewis, UCB) by methods of flame atomic absorption. The testing was done by myself and other Environmental Science students.

Nutrients - Four samples were collected during the wet period and tested for ammonia and phosphate by BC labs in Emeryville.

Turbidity and Conductivity - These samples were collected and tested using turbidity and conductivity meters as specified in Standard Methods (APHA, 1980).

Results

The results for the tests are shown in Table 1 and Figures 2 to 7.

Bacterial Survey - From Figure 2 we can see that coliform levels in all samples are much higher than allowed standards for recreational contact (2,000 MPN/100 ml, RWQCB, 1975). Samples taken in the wet period (3/15/83) show higher coliform counts than the samples tested for the dry period (4/13/83). Both the 1983 samples show a decrease in total coliforms below Codornices Park, as does the 2/3/70 sample, except for the Live Oak Park site. The 1969 and 3/9/70 samples indicate little contamination above Codornices Park, but heavy contamination below the Rose Garden and Live Oak Park. Contrary to this, both the 1983 samples indicate high coliform contamination upstream from Codornices Park.

DO/BOD - The dissolved oxygen data as seen in Figure 3 indicate that Codornices Creek is above the 5 mg/l minimum for dissolved oxygen content (RWQCB, 1975). There is a slight increase in dissolved oxygen below Codornices Park and a slight decrease below Live Oak Park. The results of the biochemical oxygen demand tests made in 10/20/69 show a decrease in BOD from the Rose Garden to the Eastshore Highway (Figure 3).

pH - On Figure 4 the results for wet and dry periods are graphed at each of the four locations tested. Samples from the dry period show higher pH values than the same sites during the wet period. The wet period (3/15/83) results show a decrease in pH below Codornices Park and an increase below Live Oak Park to the same value (7.8) as found at site A. Similar results are found in the dry period (4/13/83), with the highest recorded pH at 9th and Harrison (8.5). Standards for pH for San Francisco Bay are between 6.5 and 8.5 (RWQCB, 1975).

Heavy Metals

A graph of the heavy metals tested (Figure 5) shows some lead and mercury above Codornices Park, but no cadmium. The cadmium level rises at Codornices Park but decreases until Live Oak Park. The lead and mercury values increase significantly at Live Oak Park, with lead increasing at 9th and

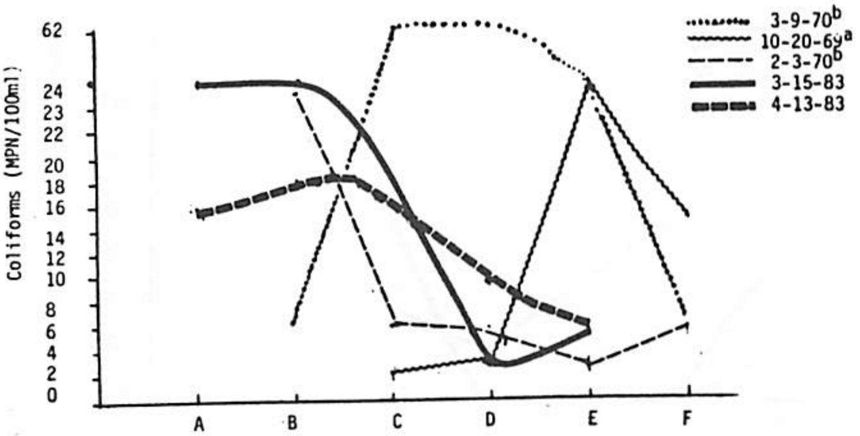

Figure 2. Results of Coliform Analyses for Codornices Creek.

Source: Sites identified on Figure 1. a)Grove, 1969 b) Berkeley, 1970
All others, this report.

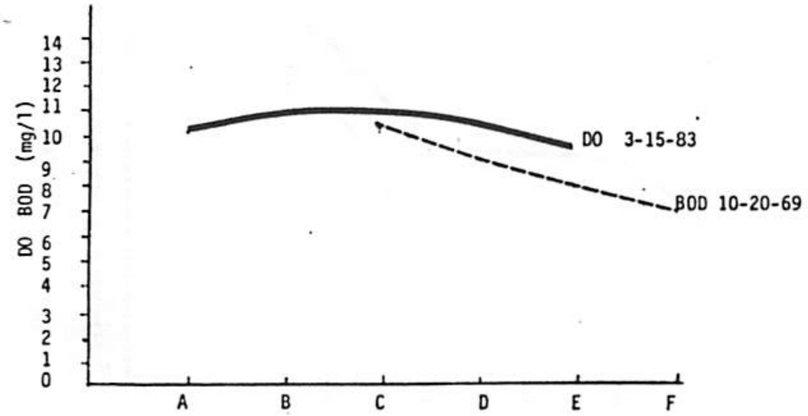

Figure 3. Graph of DO and BOD.

Source: DO, this report. BOD, Grove,1969. Sites identified on Figure 1.

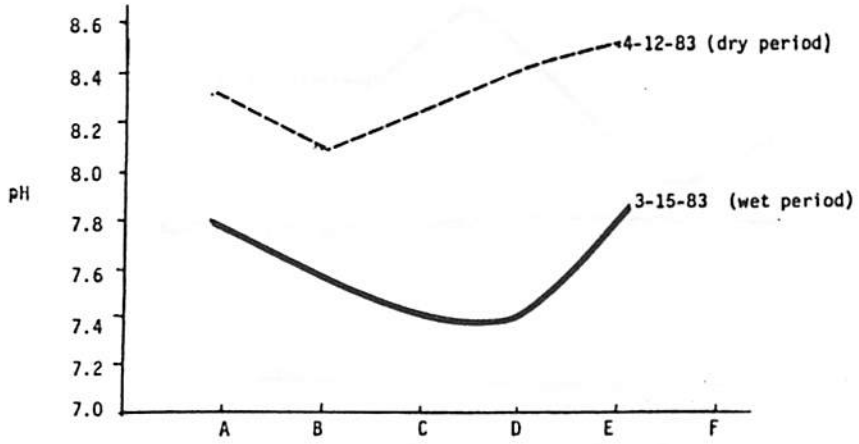

Figure 4. Graph of pH levels.

Source: This report. Sites identified on Figure 1.

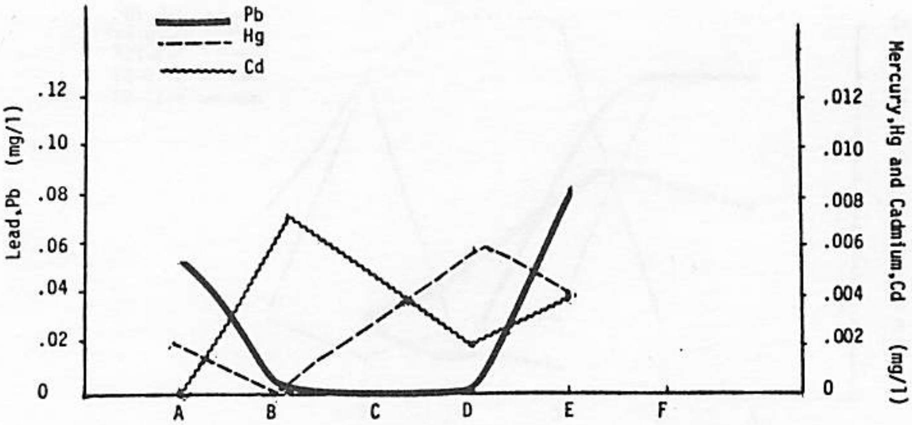

Figure 5. Graph of Heavy Metals, Pb,Hg, and Cd.

Source: This report. Sites identified on Figure 1.

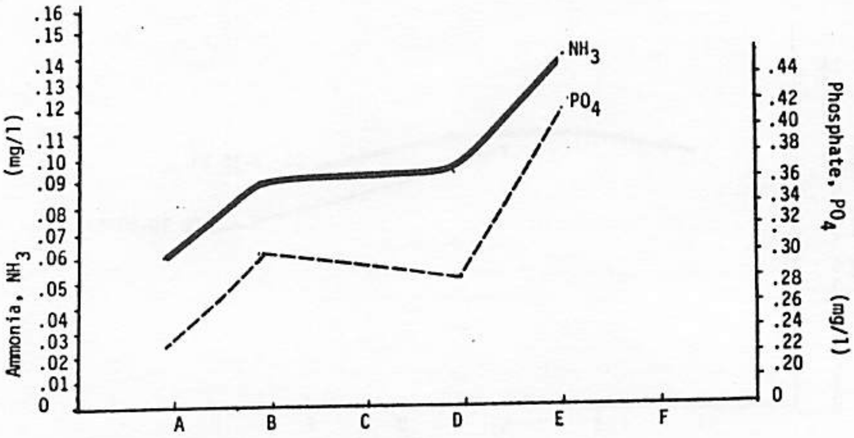

Figure 6. Graph of nutrients, PO_4,and NH_3.

Source: This report. Sites identified on Figure 1.

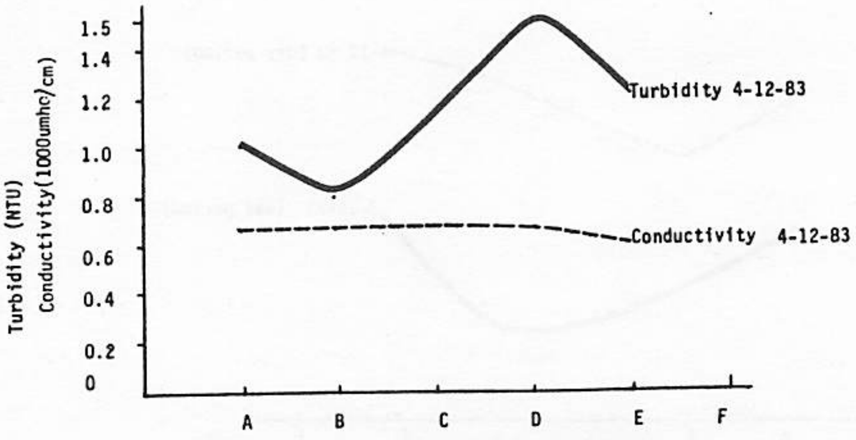

Figure 7. Graph of Turbidity and Conductivity.

Source: This report. Sites identified on Figure 1.

Harrison. At 9th and Harrison the lead concentrations are above the allowed standards (0.2 mg/l maximum daily, RWQCB, 1982).

PO_4/NH_3: In Figure 6 the PO_4 and NH_3 values have been graphed. This figure shows that both PO_4 and NH_3 values increase below site A to site B (Codornices Park). They then decrease until below Live Oak Park, where they both increase dramatically at 9th and Harrison (site E). Both of these values are above the allowed standards at site E. The maximum allowed PO_4 concentration has been set at 0.01 mg/l (Stoker and Seager, 1976). The maximum allowed un-ionized ammonia concentrations are 0.4 mg/l as N (RWQCB, 1982).

Turbidity/Conductivity

Figure 7 shows that the turbidity values decrease below the southern watershed area (site A) and increase to the maximum recorded value at Live Oak Park. The conductivity values stay constant at the first three testing sites with only a slight decrease at site E. Turbidity values for inland water should not exceed 10 JTV by 10% (RWQCB, 1975). The standards for conductivity have been set between 0.5 and 2.0 umhos/cm (APHA, 1980).

Discussion

Bacterial Survey - The most common bacteria are those from the coliform group, which originate in the intestine or feces of humans and animals, and nonfecal forms from fibrous and vegetable organic substances (McKee and Wolf, 1963). These bacterial contaminants enter the creek by surface runoff, leaky sewer pipes, and direct animal contamination.

Direct examination or analysis of water for the presence of each specific pathogen that may be present in the water (such as cholera, ameobic dysentery, infectious hepatitis, typhoid, and so on) is both slow and expensive for routine purposes; therefore only coliforms are tested as indicators of possible pathogens (Spiro and Stiglian, 1980).

The concentration of coliforms is dependent upon several factors, including exposure to sunlight, degree of dilution, and the physical, chemical, and biological characteristics of the receiving stream (McKee and Wolf, 1963). From the results in Figure 2 and Table 1 we can conclude that the bacterial levels are indeed higher during the wet period (3/15/83) as compared to the dry period (4/13/83). This can be accounted for by the higher amounts of storm runoff entering the creek carrying bacterial pollutants. The high coliform counts measured above Codornices Park in 1983 indicate that bacterial contamination may be coming from the older sewage systems in this area. The reduced coliforms in 1983 below Codornices Park indicate that little contamination has entered the creek (except a slight increase between Live Oak Park and 9th and Harrison), and the original coliforms have been diluted or destroyed by physical, chemical, and/or biological conditions present. This is a good sign until we get to the point where Codornices Creek enters the Bay. The coliforms at this point have been reported at levels above 240,000 MPN/100 ml from contaminants originating from Golden Gate Fields (see Neila Imaly's paper, this report, for more information). Even higher results have been reported coming from the storm drains south of Golden Gate Fields (see Teresa Simonitch's paper, this report). Clearly these areas represent the major bacterial pollutants for both Codornices Creek and the Bay.

The coliform results from past and present studies indicate that without a doubt Codornices Creek is polluted and has been for at least 14 years.

DO/BOD - The amount of dissolved oxygen in Codornices Creek is dependent upon the amount of surface contact with the oxygen in the atmosphere, aquatic plants and animals (mainly bacteria), and temperature (Stoker and Seager, 1976). As the temperature increases, the amount of oxygen decreases. Since in all the samples tested DO is above 5 mg/l, we can safely conclude that DO is not one of the creek's major problems. Indeed, there are numerous fish (sculpin, spined stickleback, and mosquito fish) present in the creek. Algae, while numerous along the creek, are not overpowering the creek's natural ecosystem of checks and balances (Boggan, 1982).

The BOD results from 10/20/69 (Grove, 1969) indicate that although these values are significantly above one (one or less indicates a healthy creek), there was a significant decrease in the BOD values that indicates at that time Codornices Creek was substantially self-purifying although polluted (Grove, 1969). Some more recent BOD tests are needed in addition to the DO data in this report to help clarify this point in more detail.

pH - Optimum growth for most types of aquatic organisms, such as algae and plankton, takes place at a pH between 6.5 and 8.4. pH values above 8.4 destroy algae and plankton (McKee and Wolf, 1963). pH values below 6.0 can result in excessive corrosion of plumbing systems, piers, and related structures (Stoker and Seager, 1976). The pH levels seen in Table 1 and Figure 4 are lower during the wet periods due to the effects caused by the slightly acidic rain. During the dry period the pH values were above 8.0, indicating basic conditions. This is caused by increased concentration of hydroxide ions by the addition of bases, such as sodium hydroxide, calcium carbonate, magnesium carbonate, ammonia, and so on (Stoker and Seager, 1976).

All the values of pH tested indicate that Codornices Creek is not suffering from too low or too high pH (except 9th and Harrison, where values are 8.5).

Lead - The majority of lead comes from the atmosphere (leaded gasoline, industries) and from surface runoff. Most of the lead that enters Codornices Creek is probably from surface runoff via storm drains. There are between 80-100 storm drains that lead directly into Codornices Creek. The majority of them are located between sites D and E (between Live Oak Park and 9th and Harrison, Figure 1).

As seen in FIgure 4 the highest levels are between sites D and E, indicating that the storm drains are a significant factor. The major problem with high concentrations of lead, as well as the other two metals tested, is that they can be a major health hazard when incorporated into organisms. In higher animals and humans high levels can affect the central nervous system (Stoker and Seager, 1976).

Mercury - When mercury is discharged or released into water it is not readily bio-available because of the strong bonds it forms with hydroxide, sulfide, carbonate, and organic matter (Spiro and Stigliani, 1980). Mercury, like lead, is largely found with decreasing pH, and is not a problem associated with Codornices Creek.

One problem, however, is that oxygen is probably the element which has the greatest impact for increasing the availability of metals, since metals are released when the sediments that contain these metals are oxidized (Spiro and Stigliani, 1980).

Because of the significant levels of oxygen (DO, Figure 3) this could be a problem to the biota of Codornices Creek if the concentration of these metals were much higher.

Cadmium - Cadmium, because of its chemical similarity to zinc, is readily taken up by plants (Spiro and Stigliani, 1980). The highest values for cadmium were recorded at Codornices Park. This value decreases by the time we get to 9th and Harrison (Figure 5).

PO_4/NH_3 - The major nutrients for plants are the elements carbon, nitrogen, and phosphorus. Carbon is the element required in the largest amounts (Spiro and Stigliani, 1980). CO_2 from the atmosphere is utilized directly by algae and aquatic plants, and bacterial decomposition of organic matter. Under normal conditions, it appears that CO_2 (carbon) is available in sufficient quantities to prevent carbon from being a limiting nutrient (Stoker and Seager, 1976; Spiro and Stigliani, 1980).

Nitrogen may gain access to water in solution as the result of nitrogen fixation, absorption from the air, ammonia from rainfall or runoff, organic nitrogen from decomposing plants and animals, land drainage including seepage and runoff, and wastes and waste effluents. In solution, the element may exist as organic nitrogen, nitrite or nitrate ion, or ammonium ion (Mackenthan, 1965; Spiro and Stigliani, 1980). Ammonia is a plant nutrient and can be toxic to fish and other aquatic life if high enough levels are present (McKee and Wolf, 1963; Spiro and Stigliani, 1980). Increased levels of ammonia decrease the ability of fish to combine oxygen with hemoglobin and the fish suffocates. Unpolluted rivers and creeks generally have ammonia concentrations less than 0.2 mg/l as N-nitrogen with little problem of toxicity (McKee and Wolf, 1963).

As seen in Figure 6, the ammonia levels in Codornices Creek increase from .06 - .14 mg/l. This is probably due to sewage contamination, especially between Live Oak Park and 9th and Harrison.

Phosphorus occurs naturally in rocks and soils as calcium phosphate ($Ca_3(PO_4)_2$). In natural waters with normal range pH such as Codornices Creek, phosphorus exists as $CaHPO_4$ (Mackenthan, 1965).

The element is necessary in biological life processes, and is converted into organic phosphate in the biomass. (Inorganic phosphorus of 0.01 mg/l is the maximum concentration that can be permitted without the danger of supporting undesirable growth. Higher levels than this can bring about unwanted algal growth) (Stoker and Seager, 1976).

As seen in Figure 6 the phosphate levels increase downstream from site D (Live Oak Park). Walking along the creek, one sees evidence of large amounts of algal growth, especially below San Pablo Avenue (Figure 1). THis increased algal growth may be one of the factors why there are such large fish populations in this area, as compared to other areas along the creek (personal observations).

Turbidity/Conductivity - Turbidity in water is caused by suspended matter, such as clay, silt, finely-divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms (APHA, 1980). Conductivity is the ability of an aqueous solution to carry an electric current. A good conductivity indicates the presence of ions such as inorganic acids, bases and salts. Organic compounds that do not dissociate in aqueous solution are poor conductors (APHA, 1980). As seen in Figure 7, Codornices Creek has very low turbidity and conductivity values. These results are consistent with visual observations along Codornices Creek. Even during the rainy seasons Codornices Creek appears relatively clear. During non-rainy seasons the water in Codornices Creek appears clean and sparkling. The conductivity values seen in Table 1 and Figure 7 are within the allowed values for freshly distilled water, 0.5-2.0 umhos/cm (APHA, 1980).

In conclusion, Codornices Creek does not appear to be suffering from large amounts of sediment or ions (salts, acids, or bases). However, since these results are from only one day, much more testing needs to be done, especially during periods of high storm runoff, to provide a more detailed conclusion.

Summary

The major contaminants in Codornices Creek appear to be high coliforms, lead and nutrients PO_4 and NH_3. There may be significant levels of other harmful substances not tested, such as pesticides, herbicides, oil and so on. Certainly this report has only touched the surface of the many pollutants that may be present in Codornices Creek. However, the pollutants that this study was able to identify, both past and current, are reasons for concern. Codornices Creek is polluted and has been for some time. If Codornices Creek is to be "cleaned up," there are certain procedures that will need to be followed in the future:

1. Increase public awareness. This could be done by mail, billboards or whatever means available. If effective, this program would reduce litter into the creek, both organic and inorganic.
2. Increase the frequency of storm drain cleaning and street sweeping. Presently, the storm drains are cleaned once a year. A more frequent cleaning program would help reduce litter and flooding. Street sweeping

around Berkeley is done only on major routes and is greatly hampered by parked cars along the streets. A regulation needs to be passed so that these parked cars could be removed prior to a large storm.

3. A separate storm drain system. The major pollutants that enter Codornices Creek are introduced through the storm drains. Ideally, a separate storm drain system would reduce much of the pollutants. Realistically, the costs involved are tremendous; therefore, as an alternate plan, the installation of sand-gravel filters at the major storm drains would be effective.
4. More complete testing done on a more routine basis. This would help narrow down the major sources of pollutants and give us a much better picture of how Codornices Creek is doing.
5. Putting up warning signs in the non-park areas. These areas appear to be used frequently by children who play in and along the creek. The Cities of Berkeley and Albany, or concerned groups such as "Friends of the Creeks," need to do something about this soon. The coliforms are dangerously high, especially where the creek enters the Bay. People fishing and looking for shellfish can be seen almost every weekend right near where Codornices Creek enters the Bay.
6. Replanting of natural vegetation. Certain areas along the creek are barren. The largest tract is between 5th Street and the Eastshore Highway. This area was recently uncovered back in November, 1982 (Catz, 1983). This would be an excellent area for a park. Another area for a park is along Codornices Creek just south of the UC Village. Any sites considered for parks, however, should be considered potential health hazards as long as Codornices Creek remains polluted.

I think many would agree that the hope is someday to be able to clean up Codornices Creek. This stream is an invaluable resource for both Berkeley and Albany, besides the fact that it marks the borders separating these two cities. Codornices Creek provides an atmosphere of much scenic and recreational enjoyment to both communities, and therefore deserves more attention than it has been receiving. The pollution problems associated with Codornices Creek can be solved by the people who really care and want to protect their natural resources.

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