# Cherokee Watershed Water Quality Project: Final Report

David L. Brown
Department of Geological and Environmental Sciences
CSU, Chico

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## Executive Summary

Stakeholder participants in the Cherokee Watershed Group have identified water quality as one of their top priorities. Existing water quality data is minimal, only available for isolated studies of individual physical and chemical constituents. Potential sources of non-point source water pollution in the Cherokee Watershed include historic hydraulic mining operations, current and proposed aggregate mining operations, urban runoff and individual sewage disposal (septic) systems in the headwaters, and chemical fertilizer and pesticide runoff. Funds from State Proposition 13 were received to develop a stakeholder involvement program and conduct a water quality monitoring program. The relevant water quality objectives addressed in this monitoring effort were: bacteria, biostimulatory substances (nutrients), selected chemical constituents (metals), dissolved oxygen, pH, pesticides (organophosphates), sediment, temperature, and toxicity. A bioassessment survey was also conducted.

Sampling of the main Cherokee Canal and four tributaries began in November 2003 and ended in December 2004. Monthly sampling occurred from December 2003 through June 2004 when flows effectively ended in the intermittent tributaries. Rain event-induced large runoff events were sampled in November 2003, January 2004, and December 2004. Sampling results showed relatively high fecal coliform bacteria in concentrations typical of local creeks. Nitrogen and phosphorus nutrients were low in concentration at background levels for the samples collected. Metals were generally found in trace concentrations. Mercury concentrations were comparable to similar local creeks under flow conditions between storms. Total mercury concentrations appear to increase during peak events, especially in Dry Creek. For large runoff events, 50%-90% of the mercury released is in the solid phase with sediment. Virtually no pesticides were detected for the one winter sample analyzed. General stream chemistry and

physical conditions were comparable to other streams in the region. Sediment and turbidity were closely linked to storm events as has been observed in the Cherokee Watershed. Survival toxicity was not observed, although some reproductive toxicity was noted. This finding was judged to not warrant immediate further testing by the analytical lab, as it was similar to other toxicity testing results in the region. Aquatic macroinvertebrate populations indicated reasonably healthy conditions for creeks in an agricultural environment. Two of the tributaries, Dry Creek and Clear Creek, had generally better bioassessment metrics (scores) than the Cherokee Canal, Cottonwood Creek, and Gold Run Creek.

Overall, observed water quality in the Cherokee water appears to be in generally good condition. Future monitoring should focus on mercury constituents, especially if future water quality goals are set for aquatic ecosystems in the Sacramento River Watershed. Monitoring of sediment and turbidity should be continued as potential sediment management and remediation activities proceed. Sampling for growing season pesticides should be performed at least on a reconnaissance basis. Bioassessment monitoring should be repeated with an emphasis on Cottonwood Creek, Gold Run Creek, and the Cherokee Canal. This overall water quality survey should be repeated on a periodic basis of three to five years, or as significant changes occur in the watershed.

## Introduction

Baseline data on water quality in nearly all of the Cherokee Watershed is virtually non-existent. Compliance with water quality standards for domestic use and instream flows is unknown. With the continued population growth in the upper and middle areas of the watershed, land use issues involving natural resources, and new business start ups and expansion, local stakeholders developed a plan to obtain baseline water quality data that can inform land and resource planning for the present and future.

In developing a watershed management effort, stakeholder participants in the Cherokee Watershed Group have identified water quality as one of their top priorities because the potential threats are diverse and extensive, and the existing data is minimal. Potential sources of non-point source water pollution in the Cherokee Watershed include historic hydraulic mining operations, pre-existing and proposed aggregate mining operations, proposed silica mining operations, urban runoff, individual sewage disposal (septic) systems, and chemical fertilizer and pesticide runoff. Funds from State Proposition 13 were received to develop a stakeholder involvement program and conduct a water quality monitoring program. The relevant water quality objectives addressed in this monitoring effort were: bacteria, biostimulatory substances (nutrients), selected chemical constituents (metals), dissolved oxygen, pH, pesticides (organophosphates), sediment, temperature, and toxicity.

## Review of Existing Data

Very few studies provide limited existing water quality data for the Cherokee Watershed. The following sources were searched and a brief summary of each result is listed below.

**California Department of Water Resources (DWR), Northern District: Water Quality Section.**

A phone interview with Jerry Boles, Head of the Water Quality Section, indicated that DWR has not collected any data for the Cherokee Watershed. Mr. Boles was not aware of any other sources or studies.

**Bradshaw, Ken. Spring 1998. Paradise Urban Watershed surface Water Quality. Unpublished data from class project. CSU, Chico.**

This project was a reconnaissance study of nutrient concentrations within and downstream of Paradise, California. The objective was to investigate whether the large population using on-site sewage disposal (septic) systems was causing elevated nitrate concentrations in small headwaters creeks. Surface water samples were collected from 13 stations on Dry Creek and 4 stations on Clear Creek in March and April 1998. Samples were analyzed using a Lachat Autoanalyzer. Nitrate concentrations never exceeded 3.0 mg/L in any of the samples obtained.

**Butte Creek Watershed Conservancy. Butte Creek Watershed Existing Conditions Report. Water Quality Chapter 5. [available on-line at: http://buttecreekwatershed.org/ecr/new/toc.htm]**

No direct monitoring data from Cherokee Watershed was reported in the Butte Creek Watershed Existing Conditions Report (Butte Creek Watershed Conservancy, 1998). The only references to monitoring include temperature monitoring at two stations on Butte Creek (below Western Canal and at Little Dry Creek Preserve) that were installed to detect the influences of the Cherokee Canal on Butte Creek water temperature.

**U.S. Geological Survey Water Quality Database available on-line at: http://waterdata.usgs.gov/nwis/qwdata**

Suspended and bedload sediment data was collected on Dry Creek near Nelson (USGS Station 11390210) for the period 1970 to 1974. On one sampling date in September 1988, general inorganic chemistry and trace metals were sampled on the main Cherokee Canal near Gridley Road above the Butte Sink (USGS Station 392126121523701). Of the metals above detection limits, the zinc concentration was the highest at 12 μg/L. Arsenic was present at 5.0 μg/L and mercury was at or below detection limits of 0.10 μg/L.

**Dileanis, P.D., K.P. Bennett, and J.L. Domalgalski, 2002. Occurrence and transport of diazinon in the Sacramento River, California, and selected tributaries during three winter storms, January-February 2000. Water Resources Investigations Report 02-4101. US Geological Survey in cooperation with California Department of Pesticide Regulation and Sacramento River Watershed Program. Sacrament, CA.**

As part of a larger study of diazinon occurrence in the Sacramento River Watershed, two storms were monitored in the main Cherokee Canal at Gridley Road. The January 2000 storm showed diazinon concentrations of 207 ng/L to 237 ng/L. During the two February 2000 storms, concentrations ranged from 65 ng/L to 78 ng/L and 111 ng/L to 126 ng/L, respectively.

**Giller, J.A. 1998. Hydrogeochemistry of the Cherokee Creek Watershed. Unpublished Master's Thesis. CSU, Chico.**

This study examined the distribution of major cations and anions in the geologic formations beneath the Cherokee Watershed. Groundwater samples were collected from 37 domestic wells and 2 springs. Surface water samples were collected from five locations along Dry Creek and four locations on Clear Creek in May and June 1998. Samples were analyzed using colorimetric method (Hach System). Nitrate concentrations decreased from the headwaters downstream in

both creeks. Concentrations of nitrates ranged from 0.4 mg/L to 3.5 mg/L in Dry Creek and 1.5 mg/L to 4.1 mg/L in Clear Creek.

**Sacramento River Watershed Program 2002-2003 Annual Monitoring Report. Available at:**

**http://www.sacriver.org/subcommittees/monitoring/documents/SRWP_AMR_FINAL_070904.pdf**

Mercury data from Dry Creek above the Cherokee Canal is summarized in the Year 5 report (SWRP, 2004). The specific sampling location is not given, but the station appears to be at the same location as the Dry Creek sampling site used in this investigation. Table 6 of the report indicates that seven samples were collected during the years 2001-2003 with a maximum mercury concentration of 62.7 ng/L. Six of the samples were below 50 ng/L, four samples were below 12 ng/L, and two samples were below 3.1 ng/L.

# Project Monitoring Results November 2003 - December 2004

## *Approach*

Beginning with the onset of Fall rain events in November 2003, monthly monitoring was conducted until mid-June 2004 when the major tributaries stopped flowing. Two rain storm sampling events also occurred. A third storm sampling event planned for the Spring of 2004 did not occur due to an early end to runoff-producing rain events. Instead, a final event sample was collected in late December 2004.

Initially, five monitoring sites were identified: four on tributary creeks and one site on the main Cherokee Canal at the Hwy 162 Bridge. The tributaries selected include: Dry Creek, Clear Creek, Cottonwood Creek, and Gold Run Creek. The main Cherokee Canal sampling site is located adjacent to the Department of Water Resources stream gage. With access to flow data, it is possible to make preliminary load estimates of any chemical constituents of concern. The tributaries sites are located immediately above their confluence with the Cherokee Canal. As such, samples from these sites provided composite concentrations of the analytical constituents to be monitored.

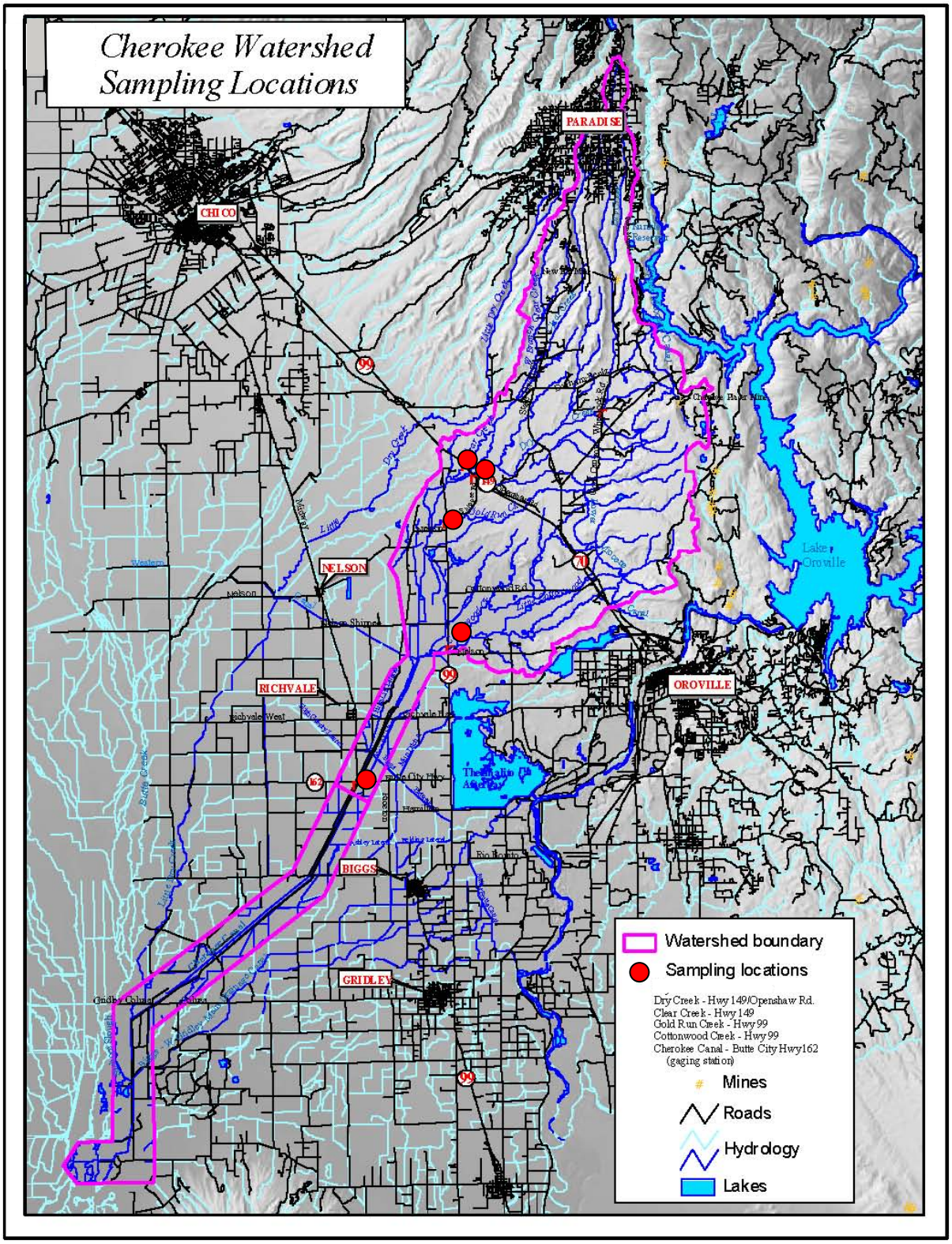
One additional tributary monitoring site was anticipated upstream of the tributary sites following preliminary sampling. This site would have been chosen had any of the tributaries shown elevated concentrations of the water quality constituents listed above. However, initial sampling showed all constituents to be quite low. After consultation with stakeholders, an upstream tributary sampling site was not monitored. The main channel and tributary site locations are listed on Table 1, and the locations of the sampling sites are shown on Figure 1.

## *Sampling Schedule*

The sample collection frequency varies by location and the parameter to be tested, as summarized below in Table 2. Depending on the seasonal flow and precipitation conditions in the watershed, it was not possible to obtain some samples. This occurred during the summer when the tributary creeks went dry. The scheduled monthly sample events were conducted on the second Monday of each month.

For pesticides in water and chronic water column toxicity, sampling was episodic and was coordinated with scheduled basic water quality sampling events. Non-scheduled (i.e. "event-based") sample events were planned to coincide with conditions expected to result in higher pesticide concentrations (e.g. during seasonal pesticide applications, expected periods of agricultural runoff), or conditions that matched other monitoring efforts in the Sacramento River Watershed. Fish tissue sampling was conducted once annually in the Cherokee Canal as a composite sampling location. Bioassessment sampling and physical habitat assessment were conducted once for all sites monitored. The timing of the bioassessment sampling was during April 2004, when flow conditions permitted safe sample acquisition.

**Figure 1.** Monitoring Program Sampling Sites



## *Sampling Methods*

Water quality sampling activities conformed to the Project's Quality Assurance Project Plan (QAPP). The QAPP describes field protocols, sample handling and analysis, and other activities designed to ensure that high quality data is obtained from the water quality investigation. The following environmental monitoring elements were included in the Cherokee Watershed monitoring program:

- Priority metals
- General constituents in water (solids, alkalinity, hardness) in water
- Pesticides
- Mercury and chlorinated pesticides in fish tissue
- Toxicity in water
- Fecal coliform
- Nutrients (nitrogen, phosphorus)
- Benthic invertebrates (bioassessment monitoring)

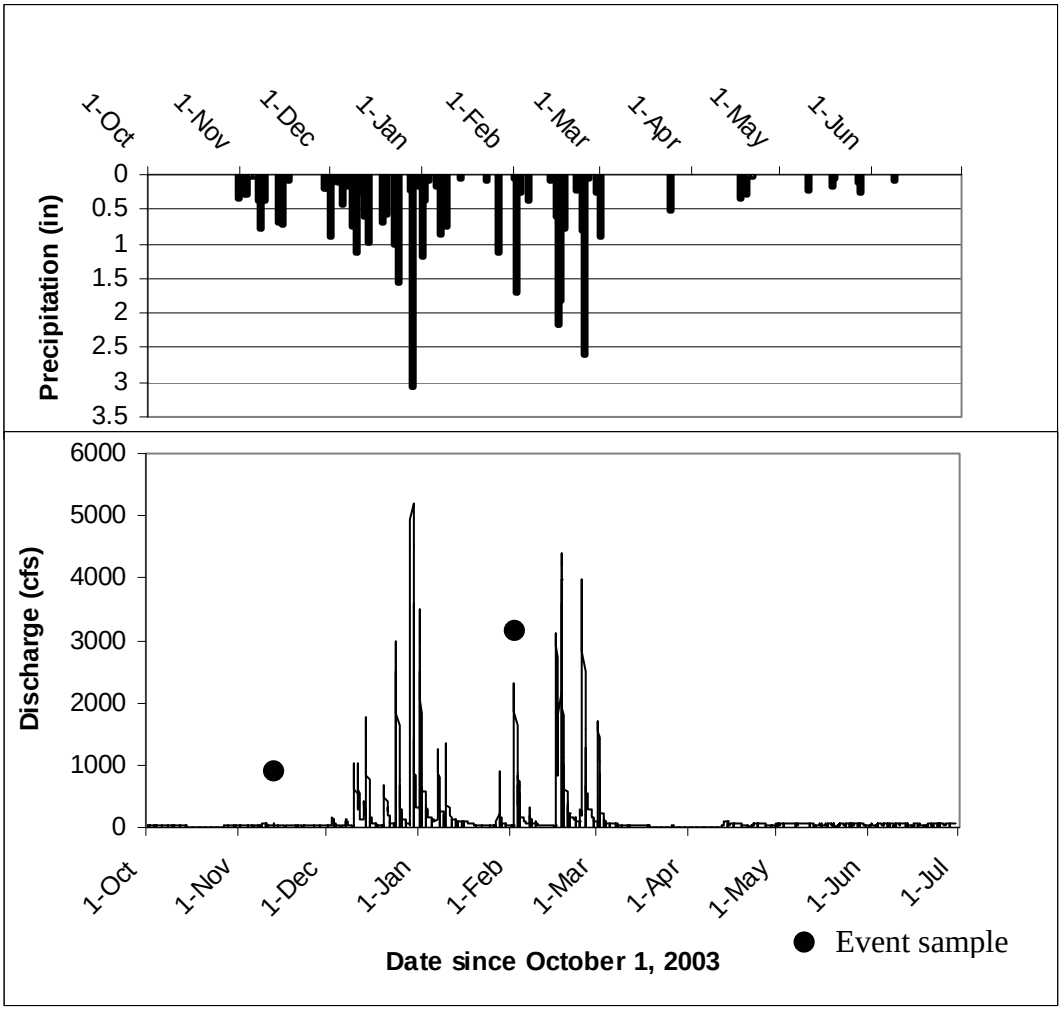
Specific individual parameters measured by the monitoring effort are listed in Table 3.

# Findings

## *Hydrologic Year Summary*

The overall rainfall pattern for the 2003-2004 monitoring period was near normal in the Sacramento River Watershed (CDEC, 2004). Small rainfall events (daily totals less than 1.0 inch) commenced at the end of October, and rain events with daily totals greater than 1.0 inches began to occur in mid-December. Significant rain events ended on March 1, 2004 (Figure 2) and the Spring season rainfall was below the long-term average. As noted earlier, the early end of significant runoff events prevented acquisition of the planned third runoff event sample. A third sampling event was conducted on December 30, 2004 at a discharge of approximately 2,300 cfs.

**Figure 2.** Precipitation and runoff patterns for the 2003-2004 monitoring period. Precipitation data from the Chico station (CHI) and discharge data from the gage on Cherokee Canal at the CWCC sampling location. Source: California Data Exchange Center)



## *Water Quality Sampling Results*

### Metals

Results from analysis of trace metals are presented on Table 4. Of the ten trace metals analyzed, cadmium, selenium, and silver were commonly near or below detection limits. Overall, the highest metals concentrations were detected in samples from the main Cherokee Canal (CWCC) sampling location. The number of samples for the year is small (less than nine) making it difficult to generalize trends between tributaries. The highest concentrations of four of the seven metals (mercury, arsenic, nickel, and copper) regularly detected, were observed in Dry Creek.

Of the two storm events sampled, the highest concentrations of metals in the main canal and the four tributaries occurred during the storm event sampled on February 3, 2004. The first storm event sampled on November 16, 2003 did not produce a detectable "first flush" of metals. This is likely due to the fact that the peak discharge from the watershed was only 41 cfs at the Cherokee Canal gaging station. In contrast, the peak discharge during the February 3 event was over 2,250 cfs.

Of the trace metals, mercury has received the most attention as a priority pollutant in the Sacramento River watershed (SRWP, 2004). During the 2003-2004 runoff season, the peak concentrations of total mercury were detected in the Cherokee Canal during two February high discharge events at 17.9 ng/L and 15.4 ng/L, respectively (Table 4). All other samples contained detectable concentrations of total mercury below 8.0 ng/L. The runoff event sampled on December 30, 2004 produced the highest mercury concentrations observed in Cherokee Canal (26.5 ng/L), Dry Creek (279 ng/L), and Gold Run Creek (7.82 ng/L). The February 3, 2003 event sample total mercury concentration was 7.97 ng/L for a comparable magnitude runoff

event. This finding suggests that mercury loads increase during storm events with sediment releases, but the magnitude of the loading can be highly variable between events.

Another attribute of the storm event metals concentration data was the distribution of metals between the dissolved and solid phases. Table 5 shows the percentage of metals in solution for the two storm events. With increased discharge, the dissolved fraction was a smaller percentage of the total concentration. It should be noted that approximately 97% of the total mercury in the Dry Creek sample for December 30, 2004 was in the solid phase (Table 5). Analytical reports are presented in Appendix A.

## General Constituents

General constituents detected in monthly and event samples are summarized on Table 6. Hardness results ranged from 22 mg/L to 93 mg/L. However, with the exception of the April 12, 2004 monthly sample, all but one of the values were below 60 mg/L indicating "soft" water. Alkalinity values ranged from 27 mg/L to 82 mg/L. Total dissolved solids (TDS) ranged from 39 mg/L to 139 mg/L. Total suspended solids ranged from less than 2 mg/L (detection limits) to 55 mg/L, with the highest values always occurring at the Cherokee Canal sampling site. The February 3 event samples TSS reached their highest concentrations (Table 6) at all locations. Analytical reports are presented in Appendix B.

## Nutrients and Pathogens

Nutrients were analyzed for event samples collected on November 16, 2003 and February 3, 2004. Results are summarized on Table 7. Nitrate (and nitrite) concentrations ranged from less than 0.05 mg/L to 0.38 mg/L. Concentrations of orthophosphate ranged from

below detection limits (0.01 mg/L) to 0.05 mg/L. The low concentrations in all samples suggest that these are background levels.

Fecal coliform was measured at the Cherokee Canal sampling site for both storm events. The November 3 sample contained 300 Most Probable Number (MPN) per 100 milliliters (ml) and the February 16 sample contained more than 1,600 MPN/100 ml. Analytical reports are presented in Appendix B.

## Pesticides

Only one triazine pesticide (simazine) was detected in the pesticide sample collected on February 27, 2004. Simazine, a chemical herbicide used in agriculture and along roadways, was detected at 0.16 μg/L (detection limit 0.1 μg/L). A scan of 37 organophosphate (OP) pesticides including diazinon did not detect any of these compounds. Likewise none of the 25 carbamate pesticides tested was detected. A listing of all pesticides tested is presented on the analytical reports included in Appendix C.

## Aquatic Toxicity

Aquatic toxicity samples were collected on February 27, 2004 along with the pesticide sample. Pacific EcoRisk performed a "short-term" chronic toxicity analysis of a water sample from the Cherokee Canal sampling site. Survival and reproduction tests showed that there was no toxicity to the test organism *Ceriodaphnia dubia* at 100% of the ambient canal water. However, there was a toxic effect of the ambient canal water on *Ceriodaphnia* reproduction. Reproductive success of the test population was reduced by approximately 64% compared with the control population. Similar reproductive toxicity effects lacking apparent causes have been noted periodically throughout the Sacramento River watershed (S. Clark, Pacific EcoRisk,

personal communication). No follow-up testing was conducted since survival toxicity was not detected. The toxicity analytical report is presented in Appendix D.

## Fish Tissue

Department of Fish and Game (DFG) analyses of fish samples from the Cherokee Canal (CWCC) sampling site showed a mean wet weight mercury concentration of 0.10 μg/g (mg/kg). This value is at the lower end of the range of 0.04 mg/kg to 0.48 mg/kg observed at comparable locations on nearby Sacramento River tributaries (SRWP, 2004). Laboratory analytical reports are presented in Appendix E.

## Bioassessment

Over the past two decades, federal and state agencies have developed monitoring protocols for measuring the integrity of stream biological communities. This approach has been termed bioassessment, and can effectively assess a broader range of effects of point and nonpoint source pollutants. Bioassessment protocols include surveys of indicator species as well as evaluation of the physical aquatic habitat (channel conditions, sediment size, etc.). Target aquatic organisms used in bioassessments emphasize benthic macroinvertebrates, which are bottom-dwelling, macroscopic aquatic animals lacking backbones. These organisms include aquatic insects, crayfish, snails, clams and worms. In a given stream, the number of individual taxonomic categories can include a very large number of genera. Thus, most bioassessment protocols employ various indicator organisms and multi-species groups of organisms to characterize water quality conditions and disturbance effects.

These methods also provide an effective means of evaluating the effects of habitat alteration and discharges of non-chemical substances such as sediment. Finally, bioassessment

surveys integrate the effects of water quality conditions over longer time periods, and have been used to characterize the overall "health" of surface waters.

Benthic macroinvertebrate samples were collected at the five water quality sampling sites on April 7, 2004. Three samples were collected at each sampling site by California Department of Fish and Game personnel using a D-shaped kick net with a 0.02-inch (0.5-mm) mesh. Sample collection and handling methods followed California Stream Bioassessment Procedures (CSBP) (DFG, 2003). The CSBP is the California State adaptation of the national Rapid Bioassessment Protocols developed by the U.S. Environmental Protection Agency (Barbour et al., 1999). A macroinvertebrate taxonomic list was generated, and a standard set of biological metrics was calculated (Appendix F).

Summary metrics are presented on Table 8. There were 55 taxa collected (Appendix F). Based on the biological metrics and taxa list, Clear Creek and Dry Creek appear to have the highest biotic condition. The main Cherokee Canal site was intermediate, and the biotic condition was diminished in Cottonwood Creek and Gold Run Creek. However, there is some variation for individual metrics. The DFG has determined several metrics to best differentiate the extent of disturbance or water quality impairment. These are Cumulative Taxa, Percent Dominant Taxon, Sensitive EPT Index (%), Shannon Diversity Index, Percent Intolerant Taxa, and Percent Scrapers (grazers). The results for these metrics are described below.

The Cumulative Taxa metrics reflect the biological diversity (based on number of taxonomic groups described) of each tributary, and the number generally decreases in response to disturbances. Dry Creek had the highest cumulative taxa (35), the Cherokee Canal had 21 taxa, Clear Creek had 18 taxa, and the other two tributaries had 16 taxa. The Percent Dominant Taxa for Dry Creek and Clear Creek were 50 and 38, respectively. The Cherokee Canal had 69

percent, and Cottonwood Creek and Gold Run Creek had 61 and 45 percent, respectively. This metric represents the percent composition of the single most abundant taxon and increases in response to disturbances.

The EPT taxa metrics consider the number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) insect orders. Overall, these three orders contain numerous taxa that are sensitive to pollution stresses and other forms of disturbance. The Sensitive EPT Index (%) determines the percent composition of mayfly, stonefly, and caddisfly larvae low tolerance values for the three taxa combined. The Sensitive EPT Index will decrease in response to disturbances, and the data showed 50% (Clear Creek), 21% (Dry Creek), 3% (Cherokee Canal), and zero in the other two tributaries. Results of this measurement support the conclusion that the Clear Creek and Dry Creek tributaries appear to be healthier than the other sampling sites.

The Shannon Diversity Index is a general ecological measure of diversity that incorporates taxa richness and evenness, and the index decreases with response to disturbance. Evenness is a measure of how similar the abundances of different taxa are. This measure was highest in Clear Creek at 1.8. Both Dry Creek and Gold Run Creek had an index of 1.7. The Cherokee Canal and Cottonwood Creek had the lowest index of 1.2.

The Percent Intolerant Taxa metric represents the percentage of organisms in the sample observed to be highly intolerant to habitat or water quality impairment. These taxa have low tolerance values (t-values of 0, 1, or 2 out 3 maximum). This measure decreases in response to disturbance. The Clear Creek site had the highest value of 50% indicating the presence of a relatively large number of intolerant taxa. Dry Creek had an intermediate value of 20%, and other three sites were very low (Cherokee Canal at 2%) or zero.

Organisms termed “scrapers” are benthic macroinvertebrates that graze upon periphyton, the algal and cyanobacterial communities that cover streambeds. The grazer communities in healthy streams are dominated by insects that are intolerant of disturbance. Grazers in degraded aquatic systems are dominated by non-insect taxa, which are relatively tolerant of pollutants. The Percent Scrapers metric is the percentage of overall organisms that function in this capacity. For this metric, Cottonwood Creek and Gold Run Creek had the highest percentages, at 18% and 19%, respectively. Clear Creek had the next highest percentage at 16%, while both the Cherokee Canal and Dry Creek were very low at 1%.

Overall, the biological metrics indicate that the Clear Creek site seemed to be the healthiest drainage relative to the other sites. Dry Creek had the second best metrics overall. Metrics were generally low at the Cherokee Canal and quite low in most of the metrics except for Percent Scrapers. Additional sampling should be performed in the future to detect changes in the health of the tributaries and main canal. Sampling should be conducted to consider potential seasonal habitat differences, although intermittent flow conditions will limit sampling in the four tributaries. With additional sampling, the apparent lower health rating of Cottonwood Creek and Gold Run Creek may prove significant and may warrant upstream sampling.

## Field Parameters

Field water quality data are presented on Table 9. Stream temperatures ranged from a low of 7.5$^{o}$ C on the February 3, 2004 event sample to a high of 28.8$^{o}$ C on the June 14, 2004 monthly sample. Overall pH values remained near neutral (7.0), with most values slightly above 7.0 in Clear Creek, Dry Creek, and Cottonwood Creek. Stream pH ranged from a low of 5.2 on January 12, 2004 at Gold Run Creek to a high of 8.0 in Clear Creek on November 16, 2003 during the first runoff event. Dissolved Oxygen (DO) ranged from a low of 6.5 mg/L in

Cottonwood Creek in April 2004 to a high of 12.4 mg/L in the Cherokee Canal in February 2004. Electrical Conductivity was generally lowest during runoff events, and ranged from a low of 30 μS/cm in Cherokee Canal in November 2003 to a high of 178 μS/cm in Clear Creek in February 2004. Turbidity values generally followed the trend of Total Suspended Solids (Table 6) and ranged from a low of 1 NTU in Clear Creek in June 2004 to a high of greater than 50.0 NTU during the December 30, 2003 event sample in Dry Creek. Periodic instrument problems occurred on several sampling dates.

## Water Quality Goals for Cherokee Watershed

The Regional Water Quality Control Board Basin set water quality objectives in the Water Quality Control Plan (Basin Plan) for the Sacramento River and its major tributaries (SWRCB, 1998). No beneficial uses specific to the Cherokee Watershed have been published to date. For the purposes of this study, beneficial uses for Cherokee Watershed are assumed to be consistent with those for the larger Butte Creek watershed, including: agriculture, contact recreation, aquatic habitat, and wildlife habitat. Relevant water quality criteria are summarized in Table 10. The Basin Plan for Upper Butte Creek (above Chico) also includes municipal and domestic water supplies, power generation, and coldwater spawning habitat for anadromous fish species. These uses are interpreted as not being applicable to the Cherokee Watershed given its lower elevation position relative to Butte Creek. Groundwater wells are the dominant water supply source in the middle and upper Cherokee Watershed. No significant hydropower projects exist in the watershed, and the steep channels and intermittent flow conditions of the tributaries preclude the existence of significant spawning habitat.

### Metals

Overall metal concentrations were observed to be at trace concentrations, and appear to be well below the more stringent drinking water standards. Arsenic concentrations (total and dissolved) were highest in the Cherokee Canal, but never exceeded 0.5 μg/L compared with the water quality criteria of 10 μg/L. Total and dissolved cadmium were generally below detection limits, and the samples with detectable concentrations were an order of magnitude below the criteria of 0.22 μg/L. The highest chromium concentrations (~3.3 μg/L) were likewise well below the criteria of 50 μg/L.

Copper concentrations were closer to water quality criteria (10 μg/L), but were still generally less than 5 μg/L. Lead concentrations were always less than 1.0 μg/L compared with the criteria of 15 μg/L (dissolved). Nickel concentrations were similar to copper (less than 5 μg/L), compared with the water quality criteria of a dissolved concentration of 100 μg/L. Selenium and silver were frequently below detection limits, and far below their criteria of 50 μg/L and 10 μg/L, respectively. Zinc concentrations were similar to those of copper and nickel, generally less than 5 μg/L compared with a dissolved concentration criteria of 100 μg/L.

Mercury concentrations were in the parts per trillion range, and were thus more than two orders of magnitude below the dissolved criteria of 2 μg/L for drinking water. Three of the highest concentrations observed in the Cherokee Canal during rain events (26.5 ng/L, 17.9 ng/L and 15.4 ng/L) were below the 50 ng/L recommended criteria based on the California Toxics Rule (USEPA, 2000). The total mercury concentration in Dry Creek on December 30, 2004 (279 ng/L) did exceed this standard. However, the 50 ng/l concentration is also a drinking water criteria. To date, the State of California has not adopted mercury criteria specifically for aquatic habitats.

## General Constituents

Of the general constituents tested, total suspended solids (TSS) are one of the chief water quality concerns in the Cherokee Watershed. Both suspended and bedload sediment are ongoing management concerns in the operation of the Cherokee Canal. Suspended sediment loads, as reflected by TSS, increase during rain event runoff (Table 6). Although the Basin Plan does not list specific sediment or TSS limits for Butte Creek, the aquatic habitat uses of lower Butte Creek are at risk of impairment with elevated sediment loading from Cherokee Watershed. The highest

tributary concentrations of TSS were observed in Clear Creek and Gold Run Creek. These are also two of the smallest tributaries in terms of flow production. Ambient (non-event) releases of TSS occur in Dry Creek and Cottonwood Creek.

## Nutrients and Pathogens

Nutrient concentrations were low for the two samples collected (Table 7). The Basin Plan does not list specific concentration limits for non-consumptive uses (Table 10). The sampling results from a citizen's water quality monitoring program conducted over the same time frame should be reviewed to determine if nutrient concentrations are higher during non-event flow conditions.

Only two rain event samples were collected for pathogen analysis (Table 7) and this limited sampling schedule does not directly relate to the Basin Plan minimum sample size (five samples over 30 days). Both of the fecal coliform concentrations are at or above the Basin Plan limits for contact recreation. However, contact recreation during the winter months in the Cherokee Watershed appears to be highly unlikely. During the hot weather of summer months, contact recreation is likely to be constrained by the limited public access to the Cherokee Canal and very limited flows in the tributaries.

## Pesticides

Pesticides were essentially non-detectable, and thus the general Basin Plan goals appear to be satisfied for the Cherokee Watershed above the Highway 162 Bridge.

## Field Parameters

Observed conditions of temperature, pH, dissolved oxygen, and electrical conductivity generally appear to fall within the specific limits set for certain drainages throughout the

Sacramento River Watershed. However, no specific limits have been set for the Butte Creek watershed.

## Turbidity

Basin water quality criteria set an objective that peak turbidity not increase more than 20% over background turbidity levels. Averaging periods required to determine background levels are not specified, but it seems unlikely that the single winter runoff season of monthly samples plus two events suffice. Basin guidelines allow exceptions for winter runoff events. Suspended sediment is a major turbidity constituent in the Cherokee Watershed and various State and Federal agencies are engaged in sediment discharge management. Monitoring of turbidity and suspended sediment is likely to continue as a part of ongoing management of the Cherokee Canal. The variability of the turbidity values observed requires additional monitoring before a full assessment can be made of whether or not basin guidelines are being met.

## Analysis of Historic Monitoring and Water Quality Data

Historic data is extremely sparse, and thus trends are largely speculation until future data is gathered. It is interesting to note that previous diazinon concentrations observed in the Cherokee Canal (Dileanis et al., 2002) did not recur during this study. Diazinon use has been in decline over the past decade (DPR, 2001), and this may be reflected in the current findings. Mercury concentrations in sampling over the past four years (SRWP, 2004) coupled with the results of this study suggest that continued monitoring for mercury is warranted.

## Summary of Current Water Quality Conditions

Overall water quality conditions in the Cherokee Watershed appear to be in compliance with regional goals (CRWQCB, 2004). Sampling results showed relatively high fecal coliform bacteria in concentrations typical of local creeks. Nitrogen and phosphorus nutrients were low in concentration (at background levels) for the samples collected. Metals were generally found in trace concentrations. Mercury concentrations were comparable to similar local creeks. Virtually no pesticides were detected for the one winter sample collected. General stream chemistry and physical conditions were comparable to other streams in the region. Sediment and turbidity were closely linked to storm events as has been previously observed in the Cherokee Watershed. Survival toxicity was not observed, although some reproductive toxicity was noted. This again was judged by the analytical lab to be similar to other toxicity testing results in the region. Aquatic macroinvertebrate populations indicated reasonably healthy conditions for creeks in an agricultural environment. Two of the tributaries, Dry Creek and Clear Creek, had generally better bioassessment metrics (scores) than the Cherokee Canal, Cottonwood Creek, and Gold Run Creek.

Of the findings from this investigation, the observed mercury concentrations would seem to be the priority for follow-up monitoring. Mercury concentrations were well below drinking water standards, but they do raise potential concerns for the aquatic environment. The 2002-2003 Annual Monitoring Report of the Sacramento River Watershed Program (SWRP, 2004) summarizes several federal mercury thresholds for wildlife protection. These criteria include 0.91 ng/L for total mercury and 0.641 ng/L for dissolved mercury. Observed mercury concentrations at all sampling locations exceeded these thresholds in the majority of samples. For comparison purposes, total mercury concentrations in the three runoff event samples collected from the Cherokee Canal during this investigation (15-27 ng/L) appear to be similar to those of Big Chico Creek and Little Chico Creek, whose maximum total mercury concentrations were less than 10.1 ng/L and 27.4 ng/L, respectively (SWRP, 2004).

The relevance of published wildlife mercury concentration thresholds to aquatic systems in the Cherokee Watershed is unknown at presence. The extent that wildlife populations use the Cherokee Canal or its tributaries is also unknown. Stakeholders and agency personnel may want to consider these findings for determining monitoring priorities as mercury regulations continue to evolve.

## Recommendations

Future monitoring should focus on mercury constituents, especially if future water quality goals are set for aquatic ecosystems in the Sacramento River Watershed. Monitoring of sediment and turbidity should be continued as potential sediment management and remediation activities proceed. Sampling for growing season pesticides should be performed at least on a reconnaissance basis. Bioassessment monitoring should be expanded to develop an Index of Biological Integrity (IBI) for the Cherokee Watershed. An IBI represents a set of quantitative

tools that provide an integrative and readily understandable procedure for measuring the biological health of streams. The Southern Coastal California IBI (Ode et al., 2003) would be an appropriate candidate for developing an index for the Cherokee Watershed. This process would take 2-3 years, and consist of data collection, development of appropriate statistical analyses, and testing (L. Memmott, Butte County, personal communication).

The current water quality survey should be repeated on a periodic basis of three to five years; and as major changes occur in the watershed. These changes may include significant expansion of surface mining; increased urbanization; major flood events that trigger significant channel alterations; flow alterations related to surface water or groundwater management; or extended drought conditions.

# References

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**Table 1.** Sampling site locations

| Site | Location | UTM coordinates |
|---|---|---|
| Cherokee Canal | At the Hwy 162 Bridge | 10 608095E 4368919N |
| Dry Creek | Old bridge parallel to Hwy 149 | 10 614133E 4384877N |
| Clear Creek | Bridge on Hwy 149 | 10 613600E 4385414N |
| Gold Run Creek | At the Hwy 99 Bridge | 10 612702E 4382461N |
| Cottonwood Creek | Private bridge on the Starkey property upstream from Hwy 99 | 10 614434E 4377799N |

NOTE: All UTM coordinates are based on the NAD 27 datum.

**Table 2.** Summary of Sampling Sites, Frequency, and Parameters

| | | Station | |
|---|---|---|---|
| **Pollutant type** | **Sampling schedule** | **Tributaries** | **Canal** |
| Trace metals | Monthly | x | x |
| | Event | x | x |
| General Constituents | Monthly | x | x |
| | Event | x | x |
| Pesticides | Episodic (once) | | x |
| Aquatic Toxicity | Episodic (once) | | x |
| Fish Tissue | Episodic (once) | | x |
| Fecal coliform | Episodic (twice) | x | x |
| Nutrients | Episodic (twice) | x | x |
| Bioassessment | Spring 2004 (once) | x | x |

**Table 3.** Parameters Measured for the Cherokee Water Quality Program

| Chemical and Physical Water Quality Parameters | |
|---|---|
| **Trace Metals** | **General Constituents** |
| (Filtered and unfiltered) | Alkalinity |
| Arsenic | Hardness |
| Cadmium | Total Suspended Solids |
| Chromium | Total Dissolved Solids |
| Copper | |
| Lead | **Field Parameters** |
| Mercury | Temperature |
| Nickel | pH |
| Selenium | Dissolved Oxygen |
| Silver | Electrical conductivity |
| Zinc | |
| **Nutrients** | **Pesticides** |
| Nitrate (+nitrite) | Organophosphorus Pesticides |
| Ortho-phosphate | Carbamate Pesticides |
| | Triazine Pesticides |

| Aquatic Toxicity | |
|---|---|
| *Ceriodaphnia* reproduction | *Ceriodaphnia* mortality |

| | |
|---|---|
| **Fish Tissue** | **Bioassessment** |
| Mercury | *Benthic Invertebrates* |
| Chlorinated pesticides | Community abundance and diversity metrics |
| **Pathogens** | *Physical Habitat* |
| Fecal coliform | Measures of habitat quality |

**Table 4.** Results from metals analyses

| | | CWCC | CWCLR | | CWDC | | CWGRC | CWCWC |
|---|---|---|---|---|---|---|---|---|
| | | Cherokee | Clear | | Dry | | Gold Run | Cottonwood |
| Trace Metal | units | Canal | Creek | | Creek | | Creek | Creek |
| **Mercury** | | | | | | | | |
| 16-Nov-03 total | ng/L ppt | 3.43 | 2.39 | | 1.90 | | 0.48 | ns |
| 16-Nov-03 dissolved | ng/L ppt | 1.39 | 1.78 | | 1.67 | | 0.31 | ns |
| 8-Dec-03 total | ng/L ppt | 4.60 | 3.34 | | 3.24 | | 1.11 | 2.31 |
| 12-Jan-04 total | ng/L ppt | 5.47 | 1.25 | | 5.02 | | 1.66 | 1.84 |
| 3-Feb-04 total | ng/L ppt | 17.9 | 3.77 | | 7.97 | | 5.14 | 3.94 |
| 3-Feb-04 dissolved | ng/L ppt | 3.31 | 1.91 | | 3.47 | | 1.83 | 2.47 |
| 9-Feb-04 total | ng/L ppt | 5.14 | 1.08 | | 7.44 | | 1.15 | 1.53 |
| 27-Feb-04 total | ng/L ppt | 15.4 | ns | | ns | | ns | ns |
| 8-Mar-04 total | ng/L ppt | 4.40 | 0.74 | | 5.57 | | 1.16 | 1.14 |
| 12-Apr-04 total | ng/L ppt | 3.62 | 0.70 | | 2.49 | | 1.48 | 1.04 |
| 10-May-04 total | ng/L ppt | 5.88 | 0.87 | | 1.79 | | dry | dry |
| 14-Jun-04 total | ng/L ppt | 2.23 | 0.61 | | 2.17 | | dry | dry |
| 30-Dec-04 total | ng/L ppt | 26.5 | ns | | 279 | | 7.82 | ns |
| 30-Dec-04 dissolved | ng/L ppt | 4.68 | ns | | 8.26 | | 3.49 | ns |
| **Arsenic** | | | | | | | | |
| 16-Nov-03 total | ug/L ppb | 0.463 | 0.291 | | 0.300 | | 0.095 | ns |
| 16-Nov-03 dissolved | ug/L ppb | 0.459 | 0.300 | * | 0.310 | * | 0.086 | ns |
| 8-Dec-03 total | ug/L ppb | 0.436 | 0.140 | | 0.223 | | 0.134 | 0.237 |
| 12-Jan-04 total | ug/L ppb | 0.437 | 0.220 | | 0.239 | | 0.134 | 0.158 |
| 3-Feb-04 total | ug/L ppb | 0.250 | 0.180 | | 0.182 | | 0.163 | 0.106 |
| 3-Feb-04 dissolved | ug/L ppb | 0.146 | 0.157 | | 0.164 | | 0.062 | 0.092 |
| 9-Feb-04 total | ug/L ppb | 0.401 | 0.112 | | 0.164 | | 0.079 | 0.093 |
| 8-Mar-04 total | ug/L ppb | 0.379 | 0.111 | | 0.245 | | 0.139 | 0.168 |
| 12-Apr-04 total | ug/L ppb | 0.240 | 0.135 | | 0.174 | | 0.126 | 0.170 |
| 10-May-04 total | ug/L ppb | 0.377 | 0.145 | | 0.276 | | dry | dry |
| 14-Jun-04 total | ug/L ppb | 0.441 | 0.131 | | 0.501 | | dry | dry |
| 30-Dec-04 total | ug/L ppb | 0.417 | ns | | 0.354 | | 0.239 | ns |
| 30-Dec-04 dissolved | ug/L ppb | 0.236 | ns | | 0.196 | | 0.110 | ns |

**Table 4.** Results from metals analyses (cont.)

| | | CWCC | CWCLR | CWDC | CWGRC | CWCWC |
|---|---|---|---|---|---|---|
| | | Cherokee | Clear | Dry | Gold Run | Cottonwood |
| Trace Metal | units | Canal | Creek | Creek | Creek | Creek |
| **Chromium** | | | | | | |
| 16-Nov-03 total | ug/L ppb | 1.08 | 1.39 | 0.23 | 0.21 | ns |
| 16-Nov-03 dissolved | ug/L ppb | 0.34 | 0.36 | 0.21 | 0.07 | ns |
| 8-Dec-03 total | ug/L ppb | 0.94 | 0.13 | 0.52 | 0.25 | 1.16 |
| 12-Jan-04 total | ug/L ppb | 0.6 | ND <0.07 | 0.33 | 0.28 | 0.11 |
| 3-Feb-04 total | ug/L ppb | 3.55 | 3.43 | 2.65 | 1.22 | 0.83 |
| 3-Feb-04 dissolved | ug/L ppb | 0.44 | 0.51 | 0.47 | 0.24 | 0.21 |
| 9-Feb-04 total | ug/L ppb | 2.17 | 0.89 | 0.94 | 0.50 | 0.40 |
| 8-Mar-04 total | ug/L ppb | 2.29 | 0.54 | 4.16 | 0.60 | 0.20 |
| 12-Apr-04 total | ug/L ppb | 1.21 | 0.60 | 0.32 | 0.66 | 0.21 |
| 10-May-04 total | ug/L ppb | 2.83 | 0.59 | 0.34 | dry | dry |
| 14-Jun-04 total | ug/L ppb | 0.72 | ND <0.07 | ND <0.07 | dry | dry |
| 30-Dec-04 total | ug/L ppb | 12.7 | ns | 34.2 | 4.36 | ns |
| 30-Dec-04 dissolved | ug/L ppb | 0.69 | ns | 0.74 | 0.61 | ns |
| **Nickel** | | | | | | |
| 16-Nov-03 total | ug/L ppb | 3.52 | 2.19 | 1.25 | 0.56 | ns |
| 16-Nov-03 dissolved | ug/L ppb | 2.67 | 1.29 | 1.09 | 0.43 | ns |
| 8-Dec-03 total | ug/L ppb | 4.42 | 0.71 | 1.77 | 0.66 | 2.48 |
| 12-Jan-04 total | ug/L ppb | 3.00 | 0.80 | 1.87 | 0.76 | 0.67 |
| 3-Feb-04 total | ug/L ppb | 5.33 | 3.57 | 4.93 | 1.66 | 1.21 |
| 3-Feb-04 dissolved | ug/L ppb | 2.07 | 1.20 | 2.12 | 0.83 | 0.73 |
| 9-Feb-04 total | ug/L ppb | 3.31 | 1.16 | 2.14 | 0.65 | 0.75 |
| 8-Mar-04 total | ug/L ppb | 2.91 | 0.88 | 3.85 | 0.73 | 0.64 |
| 12-Apr-04 total | ug/L ppb | 2.21 | 0.95 | 1.09 | 0.89 | 1.73 |
| 10-May-04 total | ug/L ppb | 3.46 | 1.20 | 1.09 | dry | dry |
| 14-Jun-04 total | ug/L ppb | 1.54 | 0.58 | 0.76 | dry | dry |
| 30-Dec-04 total | ug/L ppb | 12.20 | ns | 38.74 | 3.78 | ns |
| 30-Dec-04 dissolved | ug/L ppb | 2.82 | ns | 4.57 | 1.33 | ns |

**Table 4.** Results from metals analyses (cont.)

| | | CWCC | CWCLR | CWDC | CWGRC | CWCWC |
|---|---|---|---|---|---|---|
| | | Cherokee | Clear | Dry | Gold Run | Cottonwood |
| Trace Metal | units | Canal | Creek | Creek | Creek | Creek |
| **Copper** | | | | | | |
| 16-Nov-03 total | ug/L ppb | 4.46 | 2.52 | 1.11 | 0.62 | ns |
| 16-Nov-03 dissolved | ug/L ppb | 3.11 | 1.96 | 0.81 | 0.47 | ns |
| 8-Dec-03 total | ug/L ppb | 4.16 | 1.70 | 1.51 | 1.17 | 2.95 |
| 12-Jan-04 total | ug/L ppb | 3.86 | 0.99 | 1.31 | 1.23 | 1.25 |
| 3-Feb-04 total | ug/L ppb | 5.06 | 2.92 | 3.13 | 2.76 | 1.75 |
| 3-Feb-04 dissolved | ug/L ppb | 2.17 | 1.45 | 1.38 | 1.30 | 1.19 |
| 9-Feb-04 total | ug/L ppb | 4.04 | 1.08 | 1.32 | 0.93 | 1.19 |
| 8-Mar-04 total | ug/L ppb | 2.51 | 0.82 | 1.99 | 0.92 | 1.13 |
| 12-Apr-04 total | ug/L ppb | 2.10 | 0.94 | 0.96 | 1.22 | 2.02 |
| 10-May-04 total | ug/L ppb | 3.34 | 0.83 | 0.92 | dry | dry |
| 14-Jun-04 total | ug/L ppb | 1.78 | 0.68 | 0.9 | dry | dry |
| 30-Dec-04 total | ug/L ppb | 8.62 | ns | 22.4 | 4.07 | ns |
| 30-Dec-04 dissolved | ug/L ppb | 3.34 | ns | 3.75 | 2.27 | ns |
| **Zinc** | | | | | | |
| 16-Nov-03 total | ug/L ppb | 2.56 | 2.06 | ND <0.10 | 0.19 | ns |
| 16-Nov-03 dissolved | ug/L ppb | 0.91 | 0.58 | ND <0.10 | ND <0.10 | ns |
| 8-Dec-03 total | ug/L ppb | 2.17 | 0.57 | 0.60 | 0.56 | 1.49 |
| 12-Jan-04 total | ug/L ppb | 2.47 | 0.53 | 0.79 | 0.94 | 0.66 |
| 3-Feb-04 total | ug/L ppb | 5.84 | 3.84 | 3.05 | 3.35 | 1.72 |
| 3-Feb-04 dissolved | ug/L ppb | 0.60 | 0.65 | 0.39 | 0.48 | 0.59 |
| 9-Feb-04 total | ug/L ppb | 3.33 | 0.77 | 0.88 | 0.71 | 0.61 |
| 8-Mar-04 total | ug/L ppb | 2.33 | 1.16 | 2.18 | 0.95 | 0.73 |
| 12-Apr-04 total | ug/L ppb | 1.81 | 0.80 | 0.50 | 1.34 | 0.81 |
| 10-May-04 total | ug/L ppb | 3.17 | 0.48 | 0.58 | dry | dry |
| 14-Jun-04 total | ug/L ppb | 1.46 | 0.11 | 0.30 | dry | dry |
| 30-Dec-04 total | ug/L ppb | 9.41 | ns | 20.79 | 4.62 | ns |
| 30-Dec-04 dissolved | ug/L ppb | 1.2 | ns | 0.74 | 0.97 | ns |

**Table 4.** Results from metals analyses (cont.)

| | | CWCC | CWCLR | CWDC | CWGRC | CWCWC |
|---|---|---|---|---|---|---|
| | | Cherokee | Clear | Dry | Gold Run | Cottonwood |
| Trace Metal | units | Canal | Creek | Creek | Creek | Creek |
| **Silver** | | | | | | |
| 16-Nov-03 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ns |
| 16-Nov-03 dissolved | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ns |
| 8-Dec-03 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | 0.017 |
| 12-Jan-04 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 |
| 3-Feb-04 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 |
| 3-Feb-04 dissolved | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 |
| 9-Feb-04 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 |
| 8-Mar-04 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 |
| 12-Apr-04 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 | ND <0.015 |
| 10-May-04 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | dry | dry |
| 14-Jun-04 total | ug/L ppb | ND <0.015 | ND <0.015 | ND <0.015 | dry | dry |
| 30-Dec-04 total | ug/L ppb | 0.041 | ns | 0.059 | 0.030 | ns |
| 30-Dec-04 dissolved | ug/L ppb | ND <0.015 | ns | ND <0.015 | ND <0.015 | ns |
| **Cadmium** | | | | | | |
| 16-Nov-03 total | ug/L ppb | 0.013 | ND <0.008 | ND <0.008 | ND <0.008 | ns |
| 16-Nov-03 dissolved | ug/L ppb | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 | ns |
| 8-Dec-03 total | ug/L ppb | 0.009 | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 |
| 12-Jan-04 total | ug/L ppb | 0.01 | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 |
| 3-Feb-04 total | ug/L ppb | 0.019 | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 |
| 3-Feb-04 dissolved | ug/L ppb | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 |
| 9-Feb-04 total | ug/L ppb | 0.011 | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 |
| 8-Mar-04 total | ug/L ppb | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 |
| 12-Apr-04 total | ug/L ppb | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 | ND <0.008 |
| 10-May-04 total | ug/L ppb | 0.013 | ND <0.008 | ND <0.008 | dry | dry |
| 14-Jun-04 total | ug/L ppb | ND <0.008 | ND <0.008 | ND <0.008 | dry | dry |
| 30-Dec-04 total | ug/L ppb | 0.019 | ns | 0.064 | 0.011 | ns |
| 30-Dec-04 dissolved | ug/L ppb | ND <0.008 | ns | ND <0.008 | ND <0.008 | ns |

**Table 4.** Results from metals analyses (cont.)

| | | CWCC | | CWCLR | | CWDC | | CWGRC | | CWCWC |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cherokee | | Clear | | Dry | | Gold Run | | Cottonwood |
| Trace Metal | units | Canal | | Creek | | Creek | | Creek | | Creek |
| **Lead** | | | | | | | | | | |
| 16-Nov-03 total | ug/L ppb | 0.225 | | 0.233 | | 0.054 | | 0.055 | | ns |
| 16-Nov-03 dissolved | ug/L ppb | 0.043 | | 0.083 | | 0.021 | | 0.015 | | ns |
| 8-Dec-03 total | ug/L ppb | 0.18 | | 0.053 | | 0.067 | | 0.061 | | 0.191 |
| 12-Jan-04 total | ug/L ppb | 0.325 | | 0.054 | | 0.123 | | 0.078 | | 0.078 |
| 3-Feb-04 total | ug/L ppb | 0.898 | | 0.546 | | 0.419 | | 0.537 | | 0.222 |
| 3-Feb-04 dissolved | ug/L ppb | ND <0.015 | | 0.018 | | ND <0.015 | | ND <0.015 | | ND <0.015 |
| 9-Feb-04 total | ug/L ppb | 0.565 | | 0.081 | | 0.095 | | 0.097 | | 0.087 |
| 8-Mar-04 total | ug/L ppb | 0.262 | | 0.367 | | 0.224 | | 0.113 | | 0.068 |
| 12-Apr-04 total | ug/L ppb | 0.221 | | 0.104 | | 0.032 | | 0.171 | | 0.071 |
| 10-May-04 total | ug/L ppb | 0.47 | | 0.093 | | 0.051 | | dry | | dry |
| 14-Jun-04 total | ug/L ppb | 0.164 | | 0.022 | | 0.041 | | dry | | dry |
| 30-Dec-04 total | ug/L ppb | 1.21 | | ns | | 3.12 | | 0.809 | | ns |
| 30-Dec-04 dissolved | ug/L ppb | 0.107 | | ns | | 0.110 | | 0.126 | | ns |
| **Selenium** | | | | | | | | | | |
| 16-Nov-03 total | ug/L ppb | NA | | NA | | NA | | NA | | NA |
| 16-Nov-03 dissolved | ug/L ppb | NA | | NA | | NA | | NA | | NA |
| 8-Dec-03 total | ug/L ppb | 0.046 | | ND <0.030 | | 0.045 | | ND <0.030 | | 0.041 |
| 12-Jan-04 total | ug/L ppb | 0.123 | | 0.090 | | 0.155 | | 0.108 | | 0.047 |
| 3-Feb-04 total | ug/L ppb | 0.055 | | ND <0.030 | | 0.080 | | ND <0.030 | | ND <0.030 |
| 3-Feb-04 dissolved | ug/L ppb | 0.086 | * | ND <0.030 | | 0.117 | * | 0.065 | * | ND <0.030 |
| 9-Feb-04 total | ug/L ppb | 0.066 | | ND <0.030 | | 0.097 | | ND <0.030 | | ND <0.030 |
| 8-Mar-04 total | ug/L ppb | 0.070 | | ND <0.050 | | 0.061 | | ND <0.050 | | ND <0.050 |
| 12-Apr-04 total | ug/L ppb | ND <0.050 | | ND <0.050 | | ND <0.050 | | ND <0.050 | | ND <0.050 |
| 10-May-04 total | ug/L ppb | ND <0.050 | | ND <0.050 | | ND <0.050 | | dry | | dry |
| 14-Jun-04 total | ug/L ppb | ND <0.050 | | ND <0.050 | | 0.067 | | dry | | dry |
| 30-Dec-04 total | ug/L ppb | NA | | ns | | NA | | NA | | ns |
| 30-Dec-04 dissolved | ug/L ppb | NA | | ns | | NA | | NA | | ns |

Notes

* Dissolved fraction greater than total, but Frontier Geosciences does not consider the difference to be analytically significant. Effectively all in dissolved form.

ND-Sample concentration less than reporting limit

NA - Not analyzed

ns - Not sampled

**Table 5.** Dissolved vs. total metals

| | | | CWCC | | CWCLR | | CWDC | | CWGRC | | CWCWC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trace Metal | | units | Cherokee Canal | % dissolved fraction | Clear Creek | % dissolved fraction | Dry Creek | % dissolved fraction | Gold Run Creek | % dissolved fraction | Cottonwood Creek | % dissolved fraction |
| **Mercury** | | | | | | | | | | | | |
| 16-Nov-03 | total | ng/L ppt | 3.43 | | 2.39 | | 1.90 | | 0.48 | | ns | |
| 16-Nov-03 | dissolved | ng/L ppt | 1.39 | 41% | 1.78 | 74% | 1.67 | 88% | 0.31 | 65% | ns | |
| 3-Feb-04 | total | ng/L ppt | 17.9 | | 3.77 | | 7.97 | | 5.14 | | 3.94 | |
| 3-Feb-04 | dissolved | ng/L ppt | 3.31 | 18% | 1.91 | 51% | 3.47 | 44% | 1.83 | 36% | 2.47 | 63% |
| 30-Dec-04 | total | ng/L ppt | 26.5 | | ns | | 279 | | 7.82 | | ns | |
| 30-Dec-04 | dissolved | ng/L ppt | 4.68 | 18% | ns | | 8.26 | 3% | 3.49 | 45% | ns | |

**Table 6.** Results from analyses of general constituents

| **Cherokee Canal** | | Monthly | Monthly | Event | Monthly | Monthly | Monthly | Monthly | Monthly |
|---|---|---|---|---|---|---|---|---|---|
| Analyte | units | 8-Dec-03 | 12-Jan-04 | 3-Feb-04 | 9-Feb-04 | 8-Mar-04 | 12-Apr-04 | 10-May-04 | 14-Jun-04 |
| Hardness | mg/L | 59 | 45 | 30 | 46 | 49 | 75 | 34 | 29 |
| Alkalinity | mg/L | 69 | 48 | 34 | 50 | 54 | 52 | 41 | 38 |
| Bicarbonate | mg/L | 84 | 59 | 41 | 61 | 66 | 63 | 50 | 46 |
| Total Dissolved Solids (TDS) | mg/L | 125 | 100 | 90 | 89 | 100 | 75 | 57 | 60 |
| Total Suspended Solids (TSS) | mg/L | 10 | 16 | 55 | 22 | 17 | 17 | 14 | 15 |

| **Cottonwood Creek** | | Monthly | Monthly | Event | Monthly | Monthly | Monthly | Monthly | Monthly |
|---|---|---|---|---|---|---|---|---|---|
| Analyte | units | 8-Dec-03 | 12-Jan-04 | 3-Feb-04 | 9-Feb-04 | 8-Mar-04 | 12-Apr-04 | 10-May-04 | 14-Jun-04 |
| Hardness | mg/L | 31 | 33 | 22 | 35 | 41 | 93 | dry | dry |
| Alkalinity | mg/L | 37 | 37 | 27 | 38 | 51 | 82 | dry | dry |
| Bicarbonate | mg/L | 45 | 45 | 32 | 46 | 62 | 99 | dry | dry |
| Total Dissolved Solids (TDS) | mg/L | 74 | 77 | 57 | 72 | 109 | 102 | dry | dry |
| Total Suspended Solids (TSS) | mg/L | 3 | 2 | 12 | 4 | 8 | 10 | dry | dry |

| **Gold Run Creek** | | Monthly | Monthly | Event | Monthly | Monthly | Monthly | Monthly | Monthly |
|---|---|---|---|---|---|---|---|---|---|
| Analyte | units | 8-Dec-03 | 12-Jan-04 | 3-Feb-04 | 9-Feb-04 | 8-Mar-04 | 12-Apr-04 | 10-May-04 | 14-Jun-04 |
| Hardness | mg/L | 35 | 33 | 23 | 28 | 25 | 25 | dry | dry |
| Alkalinity | mg/L | 45 | 34 | 29 | 32 | 33 | 27 | dry | dry |
| Bicarbonate | mg/L | 55 | 41 | 35 | 39 | 40 | 33 | dry | dry |
| Total Dissolved Solids (TDS) | mg/L | 83 | 82 | 70 | 57 | 67 | 39 | dry | dry |
| Total Suspended Solids (TSS) | mg/L | 4 | 3 | 22 | 4 | 4 | 8 | dry | dry |

| **Dry Creek** | | Monthly | Monthly | Event | Monthly | Monthly | Monthly | Monthly | Monthly |
|---|---|---|---|---|---|---|---|---|---|
| Analyte | units | 8-Dec-03 | 12-Jan-04 | 3-Feb-04 | 9-Feb-04 | 8-Mar-04 | 12-Apr-04 | 10-May-04 | 14-Jun-04 |
| Hardness | mg/L | 49 | 47 | 41 | 54 | 48 | 63 | 55 | 60 |
| Alkalinity | mg/L | 55 | 46 | 41 | 49 | 50 | 61 | 66 | 70 |
| Bicarbonate | mg/L | 67 | 56 | 50 | 60 | 60 | 74 | 81 | 85 |
| Total Dissolved Solids (TDS) | mg/L | 105 | 98 | 93 | 92 | 111 | 102 | 88 | 110 |
| Total Suspended Solids (TSS) | mg/L | 5 | 6 | 13 | 7 | 11 | 6 | 4 | 4 |

| **Clear Creek** | | Monthly | Monthly | Event | Monthly | Monthly | Monthly | Monthly | Monthly |
|---|---|---|---|---|---|---|---|---|---|
| Analyte | units | 8-Dec-03 | 12-Jan-04 | 3-Feb-04 | 9-Feb-04 | 8-Mar-04 | 12-Apr-04 | 10-May-04 | 14-Jun-04 |
| Hardness | mg/L | 57 | 57 | 44 | 60 | 52 | 69 | 59 | 61 |
| Alkalinity | mg/L | 62 | 65 | 51 | 65 | 60 | 66 | 78 | 73 |
| Bicarbonate | mg/L | 76 | 79 | 62 | 79 | 73 | 81 | 95 | 88 |
| Total Dissolved Solids (TDS) | mg/L | 139 | 107 | 106 | 105 | 113 | 113 | 108 | 122 |
| Total Suspended Solids (TSS) | mg/L | 4 | ND<2 | 21 | 3 | 3 | 7 | 5 | ND<2 |

Notes

ND-Sample concentration less than reporting limit

**Table 7.** Results from event samples for nutrients and pathogens

| Analyte | | units | Cherokee Canal | Cottonwood Creek | Gold Run Creek | Dry Creek | Clear Creek |
|---|---|---|---|---|---|---|---|
| Nitrate+nitrite | 16-Nov-03 | mg/L ppm | 0.05 | NS | ND<0.05 | 0.06 | 0.22 |
| | 3-Feb-04 | | 0.2 | 0.2 | 0.24 | 0.28 | 0.38 |
| Orthophosphate | 16-Nov-03 | mg/L ppm | 0.04 | NS | 0.02 | ND<0.01 | ND<0.01 |
| | 3-Feb-04 | | 0.01 | 0.03 | 0.05 | ND<0.01 | ND<0.01 |
| Fecal Coliform | 16-Nov-03 | MPN/100ml | 300 | NS | NS | NS | NS |
| | 3-Feb-04 | | >1600 | NS | NS | NS | NS |

Notes
ND - Sample concentration less than reporting limit
NS - Not sampled

**Table 8.** Cherokee Watershed Bioassessment Results April 2004

| *Site Name:* | Cherokee Creek Canal | | Cottonwood Creek | | Gold Run Creek | | Clear Creek | | Dry Creek | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Site Code:* | 520CCC162 | | 520CWCH99 | | 520GRCH99 | | 520CLC149 | | 520DRC149 | |
| | **Mean** | **CV** | **Mean** | **CV** | **Mean** | **CV** | **Mean** | **CV** | **Mean** | **CV** |
| *Taxonomic Richness* | 14 | 22 | 10 | 28 | 12 | 17 | 15 | 13 | 16 | 25 |
| *Cumulative Taxa* | 21 | | 16 | | 16 | | 18 | | 35 | |
| *Percent Dominant Taxon* | 69 | 15 | 61 | 16 | 45 | 11 | 38 | 12 | 50 | 42 |
| *Ephemeroptera Taxa* | 3 | 22 | 1 | 87 | 1 | 0 | 6 | 10 | 4 | 31 |
| *Plecoptera Taxa* | 0 | - | 0 | - | 0 | - | 2 | 0 | 2 | 125 |
| *Trichoptera Taxa* | 2 | 25 | 1 | 100 | 1 | 87 | 2 | 25 | 3 | 96 |
| *EPT Taxa* | 5 | 20 | 2 | 25 | 2 | 35 | 10 | 10 | 9 | 53 |
| *Cumulative EPT Taxa* | 8 | | 4 | | 2 | | 11 | | 21 | |
| *EPT Index (%)* | 10 | 72 | 2 | 41 | 7 | 24 | 95 | 3 | 54 | 66 |
| *Sensitive EPT Index (%)* | 3 | 122 | 0 | 87 | 0 | 114 | 50 | 5 | 21 | 97 |
| *Shannon Diversity* | 1.2 | 32 | 1.2 | 17 | 1.7 | 9 | 1.8 | 9 | 1.7 | 29 |
| *Tolerance Value* | 5.9 | 2 | 6.4 | 6 | 6.7 | 3 | 3.1 | 3 | 4.8 | 22 |
| *Percent Intolerant Taxa (0-2)* | 2 | 136 | 0 | - | 0 | - | 50 | 5 | 20 | 98 |
| *Percent Tolerant Taxa (8-10)* | 5 | 51 | 22 | 68 | 32 | 22 | 1 | 47 | 1 | 94 |
| *Percent Baetidae* | 2 | 114 | 1 | 92 | 0 | - | 38 | 12 | 26 | 111 |
| *Percent Chironomidae* | 73 | 13 | 62 | 16 | 46 | 11 | 1 | 131 | 27 | 131 |
| *Percent Hydropsychidae* | 0 | 99 | 0 | - | 0 | - | 1 | 26 | 3 | 173 |
| *Percent Diptera* | 1 | 173 | 1 | 141 | 2 | 87 | 2 | 95 | 15 | 29 |
| *Diptera Taxa* | 0 | 173 | 1 | 100 | 1 | 87 | 2 | 35 | 2 | 49 |
| *Percent Non-Insect Taxa* | 16 | 2 | 33 | 23 | 40 | 20 | 2 | 41 | 4 | 113 |
| *Non-Insect Taxa* | 5 | 11 | 3 | 33 | 5 | 11 | 2 | 25 | 3 | 58 |
| *Percent Collector/ Gatherers* | 87 | 7 | 78 | 21 | 68 | 3 | 72 | 9 | 72 | 21 |
| *Percent Collector/ Filterers* | 2 | 44 | 0 | - | 5 | 160 | 3 | 53 | 16 | 84 |
| *Percent Scrapers* | 1 | 44 | 18 | 72 | 19 | 40 | 16 | 15 | 1 | 91 |
| *Percent Predators* | 5 | 58 | 4 | 85 | 8 | 64 | 9 | 60 | 9 | 49 |
| *Percent Shredders* | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| *Percent Omnivores* | 0 | 87 | 0 | - | 0 | - | 0 | - | 0 | 173 |
| *Percent Piercer Herbivore* | 4 | 52 | 0 | 119 | 0 | 114 | 0 | - | 0 | 173 |
| *Abundance (#/ sample)* | 971 | 28 | 1349 | 104 | 2764 | 95 | 2518 | 53 | 842 | 92 |

**Table 9.** Field Water Quality Data

**Cherokee Canal**

| Date | Temperature | pH | D.O. | EC | Turbidity |
|---|---|---|---|---|---|
| 16-Nov-03 | 12.5 | 7.55 | 7.8 | 30 | 6.5 |
| 8-Dec-03 | 10.2 | 7.18 | 7.4 | **18** | 10 |
| 30-Dec-03 | NS | NS | NS | NS | 50.0 |
| 12-Jan-04 | 10.8 | 6.15 | 7.2 | **31** | 36.7 |
| 3-Feb-04 | 8 | 7.1 | 8.7 | **12** | **NS** |
| 9-Feb-04 | 9.6 | 6.8 | 9.8 | 136 | 27 |
| 27-Feb-04 | 10 | 7.31 | 12.4 | 82 | NS |
| 8-Mar-04 | 15.7 | 7.21 | 9.9 | 117 | 17.2 |
| 12-Apr-04 | 19.2 | 6.55 | 7.4 | 107 | 9 |
| 10-May-04 | 16.4 | 6.26 | 10.7 | 77 | 6 |
| 14-Jun-04 | 18.1 | 6.01 | 10.3 | 120 | 6 |
| 30-Dec-04 | 8.8 | 7.34 | 9.6 | 68 | 38.8 |

**Cottonwood Creek**

| Date | Temperature | pH | D.O. | EC | Turbidity |
|---|---|---|---|---|---|
| 16-Nov-03 | NS | NS | NS | NS | NS |
| 8-Dec-03 | 11 | 7.03 | 8.5 | **11** | 4.59 |
| 30-Dec-03 | NS | NS | NS | NS | 28.6 |
| 12-Jan-04 | 10.1 | 6.96 | 8.9 | **16** | **35.4** |
| 3-Feb-04 | 7.8 | 7.09 | 9.4 | **15** | **NS** |
| 9-Feb-04 | 9.8 | 7.5 | 10.4 | 100 | 5.5 |
| 8-Mar-04 | 17.2 | 7.37 | 9.9 | 99 | 5.8 |
| 12-Apr-04 | 21 | 6.65 | 6.5 | 159 | 3.5 |
| 10-May-04 | dry by April 27 according to Carl Starkey | | | | |
| 14-Jun-04 | | | dry | | |
| 30-Dec-04 | NS | NS | NS | NS | NS |

**Gold Run Creek**

| Date | Temperature | pH | D.O. | EC | Turbidity |
|---|---|---|---|---|---|
| 16-Nov-03 | 12.8 | 7.8 | 8.3 | 62 | 3.1 |
| 8-Dec-03 | 8.1 | 7.86 | 7.9 | 83 | 4.18 |
| 30-Dec-03 | NS | NS | NS | NS | 36.7 |
| 12-Jan-04 | 9.8 | 5.2 | 8.2 | **28** | **62.3** |
| 3-Feb-04 | 7.5 | 7.21 | 9.3 | **10** | **NS** |
| 9-Feb-04 | 9.5 | 7.23 | 9.5 | 82 | 8 |
| 8-Mar-04 | 15.5 | 7.37 | 10.6 | 63 | 8 |
| 12-Apr-04 | 19.3 | 6.45 | 8.6 | 50 | 8.3 |
| 10-May-04 | | | dry | | |
| 14-Jun-04 | | | dry | | |
| 30-Dec-04 | 9.1 | 7.34 | 9.4 | 35 | 22 |

**Table 9.** Field Water Quality Data (cont.)

**Dry Creek**

| Date | Temperature | pH | D.O. | EC | Turbidity |
|---|---|---|---|---|---|
| 16-Nov-03 | 12.9 | 7.9 | 9 | 42 | 2.25 |
| 8-Dec-03 | 9.2 | 6.93 | 8 | 125 | 5.45 |
| 30-Dec-03 | NS | NS | NS | NS | >50.0 |
| 12-Jan-04 | 10 | 7.51 | 10.2 | **10** | 18 |
| 3-Feb-04 | 8.5 | 7.52 | 10.2 | **6** | **NS** |
| 9-Feb-04 | 10.2 | 7.51 | 10.2 | 151 | 11 |
| 8-Mar-04 | 16.4 | 7.37 | 9.5 | 111 | 23.6 |
| 12-Apr-04 | 19.5 | 7.4 | **14.8** | 127 | 3.4 |
| 10-May-04 | 19.9 | 7.4 | **14.6** | 122 | 3 |
| 14-Jun-04 | 27.6 | 7.16 | 7.1 | 142 | 2 |
| 30-Dec-04 | 9.3 | 7.43 | 9.3 | 72 | 39 |

**Clear Creek**

| Date | Temperature | pH | D.O. | EC | Turbidity |
|---|---|---|---|---|---|
| 16-Nov-03 | 13.1 | 8 | NS | 49 | 7.98 |
| 8-Dec-03 | 9.1 | 7.64 | 8.1 | 146 | 8.51 |
| 30-Dec-03 | NS | NS | NS | NS | 24.8 |
| 12-Jan-04 | 10.2 | 7.52 | 9.9 | **7** | **58** |
| 3-Feb-04 | 8.5 | 7.87 | 8.7 | **6** | **NS** |
| 9-Feb-04 | 11.6 | 7.8 | 11.3 | 178 | 4 |
| 8-Mar-04 | 17.4 | 7.37 | 11.4 | 125 | 3 |
| 12-Apr-04 | 20.2 | 7.4 | **13.3** | 133 | 4 |
| 10-May-04 | 21.8 | 7.4 | **ND** | 130 | 3 |
| 14-Jun-04 | 28.8 | 7.16 | 9.2 | 140 | 1 |
| 30-Dec-04 | NS | NS | NS | NS | NS |

Notes
NS - Not sampled
**Results in bold type** Apparent instrument malfunction
ND - No data collected

**Table 10.** Surface Water Quality Criteria for Selected Constituents

| Constituent | Objective |
|---|---|
| Temperature ($^{o}$F) | < 5 $^{o}$F increase over background |
| pH | 6.5-8.5 |
| Electrical Conductivity (µmhos/cm) | <230 |
| Turbidity (NTU) | < 20% increase over background |
| Dissolved Oxygen, % of Saturation | 85% |
| Total Phosphorus (mg/l as P) | nc[1] |
| ortho-Phosphate (mg/L) | nc[1] |
| Total Kjeldahl Nitrogen (mg/l as N) | nc[1] |
| Nitrate (mg/l as N) | 10[2] |
| Total Arsenic | nc[1] |
| Dissolved Arsenic (µg/l) | 10 |
| Total Cadmium (µg/l) | nc[1] |
| Dissolved Cadmium (µg/l) | 0.22[2] |
| Total Chromium (µg/l) | 50[2] |
| Dissolved Chromium (µg/l) | 50[2] |
| Total Copper (µg/l) | nc[1] |
| Dissolved Copper (µg/l) | 10[2] |
| Total Lead (µg/l) | nc[1] |
| Dissolved Lead (µg/l) | 15[2] |
| Total Mercury (µg/l) | nc[1] |
| Dissolved Mercury (µg/l) | 2[2] |
| Total Nickel (µg/l) | nc[1] |
| Dissolved Nickel (µg/l) | 100[2] |
| Total Selenium (µg/l) | nc[1] |
| Dissolved Selenium (µg/l) | 50[2] |
| Total Silver (µg/l) | nc[1] |
| Dissolved Silver (µg/l) | 10 |
| Total Zinc (µg/l) | nc[1] |
| Dissolved Zinc (µg/l) | 100[2] |
| Fecal coliform (per 100 ml) | 400 |
| Total coliform | nc[3] |

NOTES:

nc[1] No criteria, Water Quality Objective or Maximum Contaminant Level (MCL) for municipal/domestic use has not been established.

[2] Where Basin Plan does not specifically establish a Water Quality Objective, DHS primary, or secondary (as applicable), drinking water MCL used.

nc[3] No criteria, Water Quality Objective or Maximum Contaminant Level (MCL) for contact recreation use not established.

SOURCES:

Sacramento River Basin Water Quality Control Plan, 1995, Central Valley RWQCB.
Calif. Dept. Health Services, Drinking Water Standards.