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MONITORING FOR LONG-TERM TRENDS IN SAN DIEGO COUNTY

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ABSTRACT

A monitoring program was designed with the San Diego County Co-permittees to:

- Be adaptive and provide long-term trend information to predict short- and long-term impacts to receiving waters that result from changes in land use within each watershed
- Provide data that can be analyzed to develop pollutant reduction strategies for those impacts.

A total of 10 mass loading stations covering 9 watersheds were monitored under this program.

Comparisons between watersheds were performed using several different statistical tools. Watersheds were compared both by examining constituents of concern (COC) concentrations across watersheds and by grouping similar watersheds by COC relationships. Statistical analysis for cross watershed comparison included scatterplot analysis, regression analysis, analysis of variance (ANOVA), multivariate cluster analysis, and multiple regression. The relationships between toxicity and COCs have been evaluated by threshold analysis, which is used to test relationships for COC with established thresholds.

These water quality assessment processes provide an iterative tool for watershed stakeholders to evaluate the conditions and improvements of watershed water quality through time.

INTRODUCTION

The County of San Diego, City of San Diego, the San Diego Unified Port District, and 17 other cities (collectively referred to as "Co-permittees") are covered under a municipal National Pollutant Discharge Elimination System (NPDES) permit for discharge of runoff to waters of the United States. A monitoring program was designed with the Co-permittees to be adaptive and provide long-term trend information to predict short- and long-term impacts to receiving waters that result from changes in land use within each watershed, and to provide data that can be analyzed to develop pollutant reduction strategies for those impacts.

This monitoring program includes three elements: Mass Loading Station (MLS) Monitoring, Stream Bioassessment Monitoring, and Ambient Bay and Lagoon Monitoring. The main focus of this discussion will be the MLS monitoring program. A total of 10 mass loading stations covering 9 watersheds were monitored under this program. Some of these stations have been monitored for more than 10 years, and the results from this program will be discussed in this report.

CROSS WATERSHED COMPARISON

Comparisons between watersheds were performed using several different statistical tools. Watersheds were compared both by examining COC concentrations across watersheds and by grouping similar watersheds by COC relationships.

Figure 1 presents the mass loading station water quality results compared to water quality objectives (WQO).

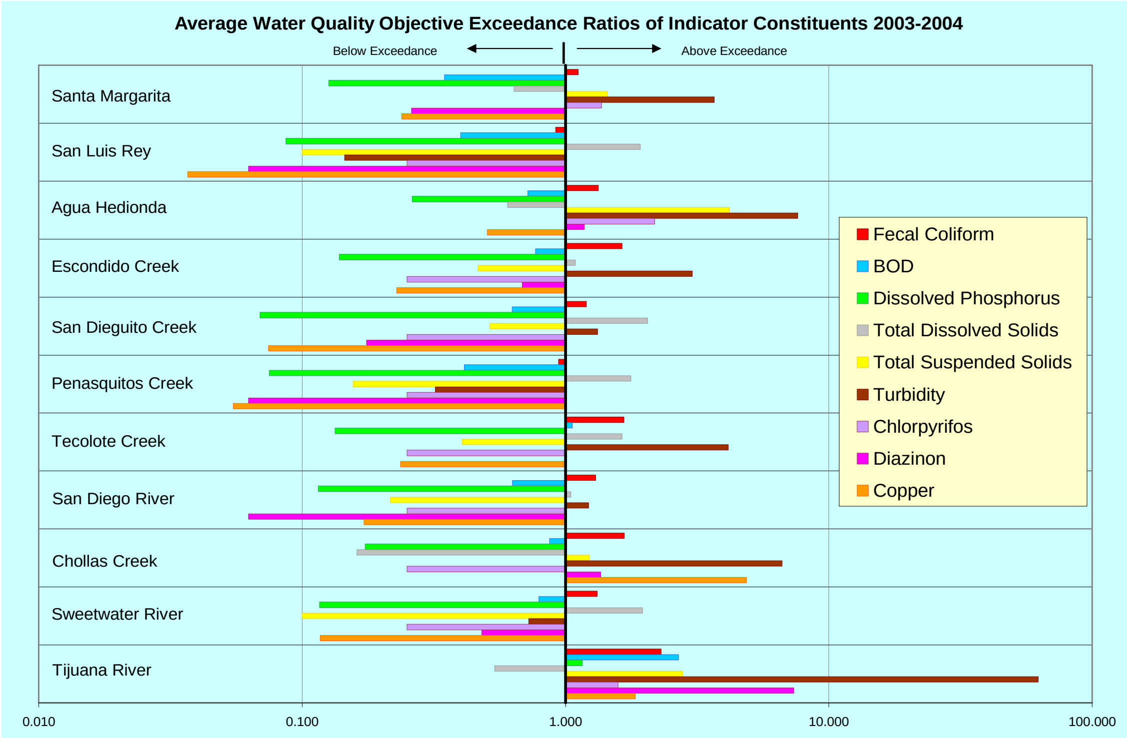


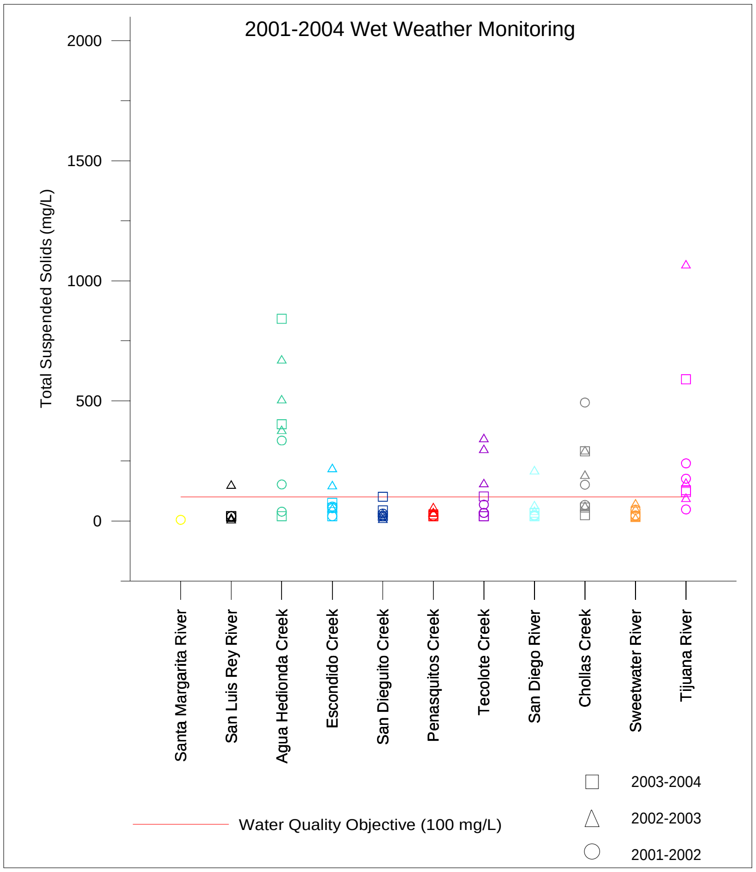
Figure 1. Water quality objective exceedances.

Statistical analysis for cross watershed comparison included scatterplot analysis, regression analysis, analysis of variance (ANOVA), multivariate cluster analysis, and multiple regression. Scatterplots provide a COC-based comparison among watersheds and monitoring years. The ANOVA was used to determine statistical differences between the watersheds for the year as a whole (storms were used for replication), and cluster analysis was used to identify mass loading stations and sampling dates with similar COC loadings. Multiple regression compared toxicity results to COC concentrations.

SCATTERPLOT AND TREND ANALYSIS RESULTS

Scatterplots provide a visual representation of the relative concentrations of COCs between stations and storm events. Scatterplots are simple plots of concentrations of COC plotted on the y-axis against the mass loading station identified on the x-axis. For this program, each COC and toxicity test was represented by its own scatterplot with all sampling dates for the past 3 monitoring years plotted on a single graph. The data shown in the trend data plots were tested by regression analysis to determine significant trends. Information collected during the 2001-2002, 2002-2003, and 2003-2004 wet seasons provided the basis for long-term trend analysis for the majority of MLS. As these stations continue to be monitored, more meaningful trend analysis will be possible.

The trend analysis of long-term data sets is intended to track increases or decreases of the COC through time. Constituents of concern for MLS with historical data are currently reviewed to identify trends in the concentration levels of these constituents. Other MLS will have larger data sets in the future that will allow for trend analysis spanning 4 to 5 years of monitoring during wet weather. Analyzing the concentration data to identify trends is only one of many ways to evaluate improving or deteriorating water quality. An increasing trend that shows that concentrations or levels of pollutants are nearing a WQO or continue to increase (when the water quality objective is already exceeded) is of particular concern and should be considered in the development of watershed actions that attempt to slow or reverse the trend.



Figures 2 and 3 provide examples of plots for total suspended solids (TSS). The red line in Figure 2 indicates the water quality objective value. From this example, total suspended solids during 2003-2004 were consistently over WQOs at Tijuana River, and over WQOs on two of three storm events at Agua Hedionda and Chollas Creek. In Figure 3, long-term trends were observed at all three long-term MLS; significant decreasing trends at Chollas Creek and Tecolote Creek, and significant increasing trends at Agua Hedionda Creek.

Scatter plots and trend analysis graphs of COCs can be used as a starting point when comparing levels in different watersheds. As the historical record for each mass loading station is built, watershed stakeholders can transition to using these and similar tools to assess water quality issues.

Figure 2. Total suspended solids concentrations scatterplot, 2001-2004.

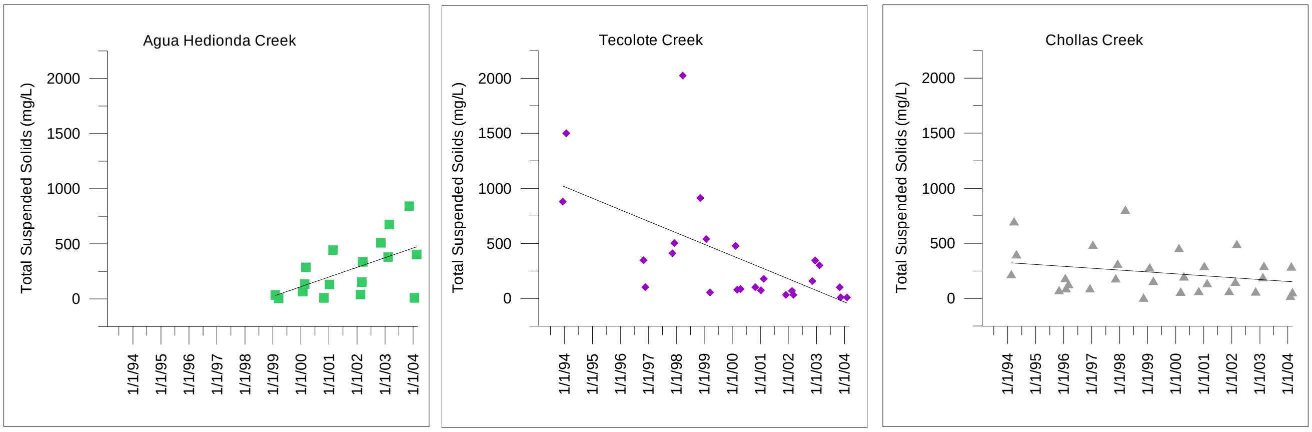


Figure 3. Total suspended solids trends, 1993-2004.

ANOVA RESULTS

ANOVA was used to determine differences between MLS for the COC. The term analysis of variance is sometimes a source of confusion. In spite of its name, ANOVA is concerned with differences between means of groups, not differences between variances. The analysis uses variances to detect whether the means are different. The ANOVA determines the variation (variance) within the groups that are being compared (e.g., monitoring stations), then compares that variation to the differences between the groups, taking into account how many subjects there are in the groups. If the observed differences between the means of groups are larger than those expected by chance relative to the underlying variance, statistical significance is achieved. For this study, each of the COCs that were observed in any sample above the MDL was tested by ANOVA.

Table 1 presents an example of the ANOVA analyses performed on the *Ceriodaphnia* toxicity results for the 2003-2004 monitoring data, which indicate that there were statistically-significant differences ($p<0.05$) between mean station toxicity endpoints for three of the five toxicity tests performed. The probability value of the ANOVA for each of the toxicity test endpoints and the COC are shown next to the corresponding test. The mean station values are shown in ascending order for the toxicity endpoints and in descending order for the COC. The colored lines under the means designate the stations that were not significantly different from each other. Conversely, two stations without a common line were significantly different from each other. For instance, for the *Ceriodaphnia* acute survival test, the mean no observed effect concentration (NOEC) value for the Tijuana River mass loading station (TJR) was significantly different from all the other mean station values, but all the other mean station values were not significantly different from each other. Tijuana River appeared to be the worst of the watersheds monitored in terms of toxicity levels and COC concentrations. Tijuana River had the lowest mean toxicity NOEC levels (i.e., highest toxicity) for all three toxicity tests, the highest mean concentrations of all three of the bacterial indicators, and the highest mean concentrations of 13 of the remaining 16 COCs for which significant results were obtained. ANOVA tests for *Ceriodaphnia* acute survival, chronic survival, and chronic reproduction endpoints based on NOEC values show that toxicity was significantly higher at Tijuana River than any other site in the county.

Analyte	Prob > F	Stations										
Toxicity Endpoints												
Ceriodaphnia acute survival NOEC	<0.001	TJ	TC	SLR	SM	SR	SDC	SDR	PC	EC	CC	AH
		12.5	100	100	100	100	100	100	100	100	100	100
Ceriodaphnia chronic survival NOEC	<0.001	TJ	TC	SLR	SM	SR	SDC	SDR	PC	EC	CC	AH
		8.33	100	100	100	100	100	100	100	100	100	100
Ceriodaphnia chronic reproduction NOEC	<0.001	TJ	TC	SLR	SM	SR	SDC	SDR	PC	EC	CC	AH
		10.42	83.33	83.33	100	100	100	100	100	100	100	100

Table 1. Results of station toxicity comparisons by Analysis of Variance (ANOVA).

Cluster Results

Multivariate cluster analysis was applied to the COC and the toxicity endpoints (in terms of NOEC values) for each MLS and sampling time. This approach groups the station/times by the commonality of the COC concentrations found at each one. Likewise, it groups the COC according to similar loadings at stations. Prior to the analysis, the bacteriological measures were $\log_{10}$ transformed and the data for each COC was standardized by the overall mean value for each COC.

Cluster analyses were performed to determine the degree of similarity among stations and/or storm events relative to the COC concentrations for those events. They can be useful in assessing the characteristics of a site in relation to storm water runoff as well as providing information on the inter-relationships of the COC. The results of the cluster analyses for the 2003-2004 wet season are presented in Figure 4. The size of the square in each cell of the table was determined by the value of the COC at each station/storm event compared to the mean value for that COC for all station/storm events in the 2003-2004 wet season.

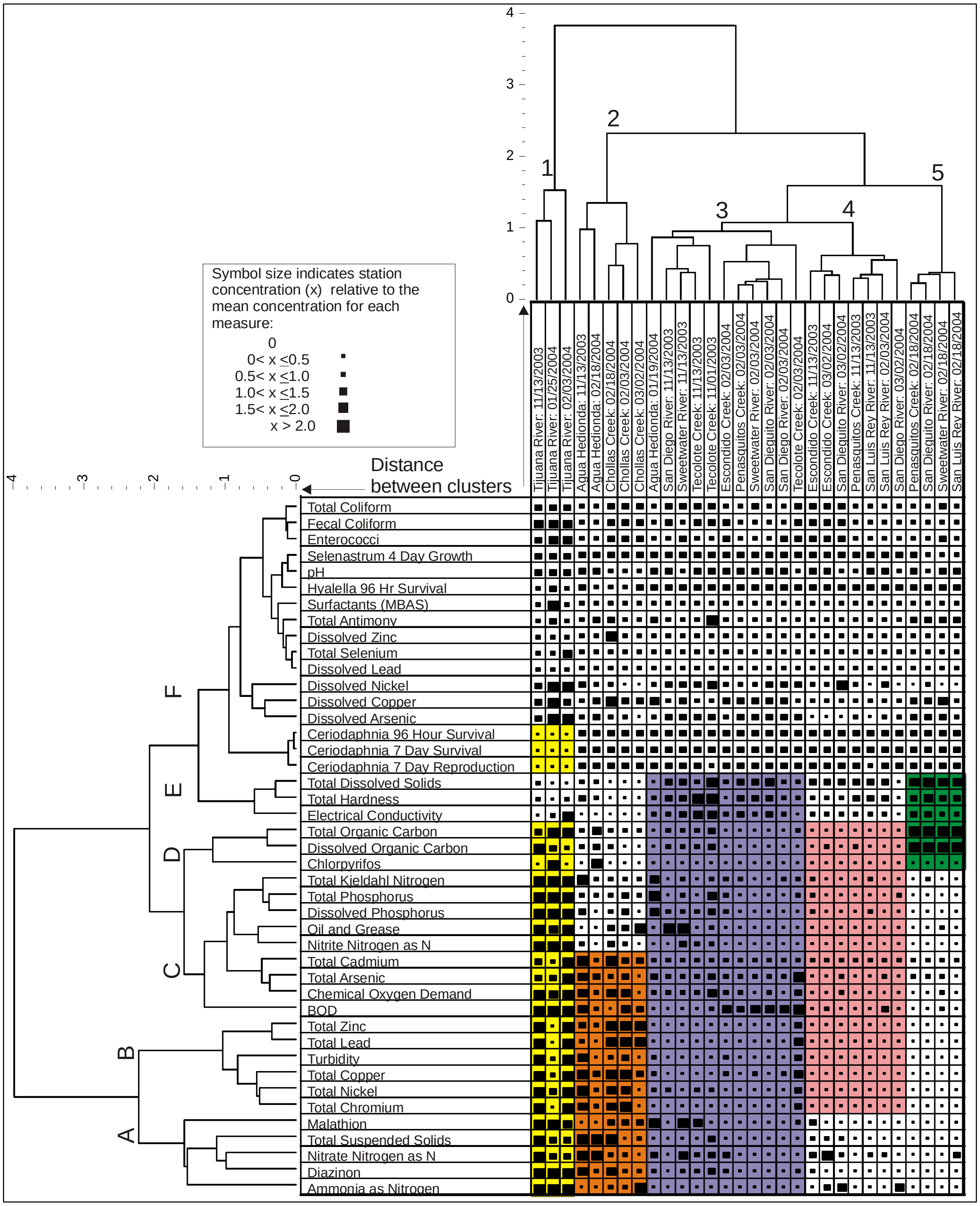


Figure 4. Results of cluster analyses for the 2003-2004 mass loading stations/storm events and COC.

Thus, large squares represent values that were greater than the mean COC value for the season and small squares represent values that were less than the mean. The colored boxes indicate the COC groups that best define each station cluster group.

In general, the station/storm events for the 2003-2004 wet season cluster primarily by station and then by storm.

Relationships Between Toxicity and Constituents of Concern

The relationships between toxicity and COCs were evaluated looking at thresholds. The threshold analysis uses COC levels reported to be toxic in the literature where available and compares them to COC levels in the storm water samples. The statistical testing procedure is used to establish a two-by-two matrix with one column of "less than the threshold" and the second column of "greater or equal to the threshold," and with one row of "no observed effect" and a second row of "effect observed." Fisher's Exact Test (2-tail) was used to establish the exact probability of the table outcome by chance. A small probability (<0.05) was used to determine if the assigned threshold values were significant in explaining the outcomes of the toxicity tests.

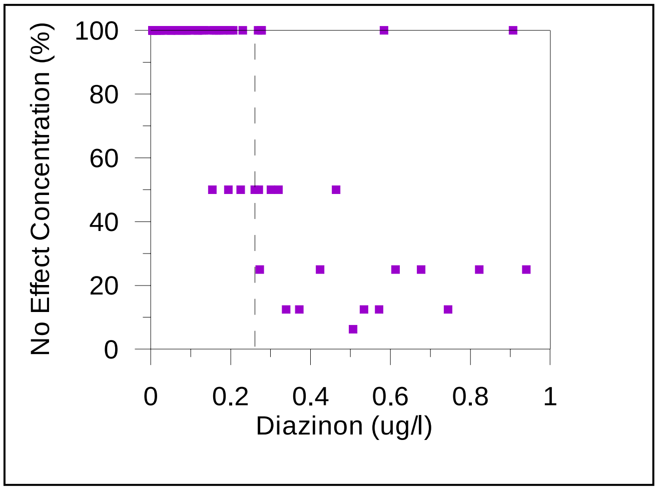


Figure 5. Results of threshold analysis.

Comparison of *Ceriodaphnia* survival with threshold concentrations resulted in significant tests for the several pesticides and metals. These results are visually shown by plotting the toxicity result against the COC concentration as shown for diazinon (threshold=0.26 µg/L) in Figure 5. The test was significant with 90 of 97 observations matching the expected result.

These water quality assessment processes provide an iterative tool for watershed stakeholders to evaluate the conditions and improvements of watershed water quality through time.

This monitoring program is designed to be adaptive and allow for more focused studies to answer the specific questions that may arise from the monitoring program. These questions can be answered on either a regional or a watershed scale, depending upon the question at hand. As various watersheds identify issues of concern, specific special studies can be designed to answer those questions. These potential studies can help answer specific questions that address which management actions will best remedy the identified water quality problems.