CALIFORNIA
Water Boards

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TO: File: Russian River; TMDL Development and Planning

FROM: Steve Butkus

DATE: July 15, 2013

SUBJECT: TREND ANALYSIS OF FECAL INDICATOR BACTERIA CONCENTRATIONS MEASURED IN THE RUSSIAN RIVER WATERSHED

The North Coast Regional Water Board staff are developing Russian River Total Maximum Daily Loads (TMDLs) for pathogen indicators to identify and control contamination impairing recreational water uses. Potential pathogen contamination has been identified in the lower and middle Russian River watershed leading to the placement of waters within these areas on the federal Clean Water Act Section 303(d) list of impaired waters. The contamination identified has been linked to impairment of the contact recreation (REC-1) and non-contact recreation (REC-2) designated beneficial uses. Health advisories for these waters have been published and posted by Sonoma County and the City of Santa Rosa authorities.

The Regional Water Board and the Sonoma County Water Agency have been collecting water samples for analysis of fecal indicator bacteria (FIB) concentrations from various locations in the Russian River watershed since the 1980s. Criteria exist for FIB concentrations that indicate a potential health risk from exposure to pathogens in recreational waters. FIB do not pose a health risk, but are easier to measure that the actual pathogens that may pose a risk of illness. Fecal coliform bacteria were used as the indicator for risk until 2001. Fecal coliform bacteria concentrations were measured using the multiple tube fermentation analysis method (Standard Method 9221). Since 2001, new analytical methods approved by the U.S. Environmental Protection Agency have been used to measure *E. coli* and *Enterococcus* bacteria concentrations (IDEXX. 2001).

Measured FIB concentrations were compiled and assessed for applicability for statistical trend analysis. Data must be available for an adequate length of time period in order to detect a trend. The length of time needed depends on the measured variability of the data. Trends in FIB concentrations are often difficult to detect due to the large variability inherent in bacteria samples collected from surface waters. This memorandum serves to document observed significant trends in FIB concentrations that were measured at specific locations in the lower Russian River watershed.

Table 1 shows the Russian River watershed locations and dates where data on FIB concentrations have been collected over many years. These data were used to detect statistical trends. In samples where the measured FIB concentrations were outside the minimum or maximum analytical detection limits, the minimum or maximum detection limit values were used to represent FIB concentrations in the sample. The median FIB concentration values were used for concurrently collected replicate samples. Only dry season samples collected between May and October were assessed for trend. All FIB concentrations were log transformed since the data exhibited a positively skewed log normal distribution (Helsel and Hirsch 2002).

Trends in FIB concentrations were assessed using the Seasonal Kendall test (Helsel et al. 2006). The Seasonal Kendall trend test is rank-based procedure especially suitable for data that are not normally distributed, data that show seasonality, censored data, and data containing outliers. The trend test as applied accounted for any differences in FIB concentration between months. The trend test also accounts for any serial correlation. The significance of a linear monotonic trend is evaluated by determining whether the slope of the trend is significantly different from zero. The trend test also produces the slope and the intercept of the overall trend line.

Table 2 shows the probability value and the slope of the trends found to be statistically significant (i.e., $\alpha = 0.05$). Statistically significant trends in *E. coli* bacteria concentrations were observed at only two locations assessed: Monte Rio Beach and Santa Rosa Creek. The *E. coli* bacteria concentrations at both locations showed a declining trend (Figures 1 and 2). No trends were observed in either fecal coliform or *Enterococcus* bacteria concentrations.

The trends observed do not necessary mean that the source loading of FIB has declined or remained the same over time. The trends or the masking of the trends observed may be due to a trend in a correlated variable, and not related to changes in loading from FIB sources. The observed trend results may be caused by changes in stream flow or water temperature over the period of time evaluated. Non-linear regression was applied to assess the relationship between FIB concentrations and mean daily stream flow and temperature.

Table 3 presents the source of the stream flow and water temperature data used for the regressions. Stream flow and FIB concentrations were log transformed since these data exhibited a positively skewed log normal distribution (Helsel and Hirsch 2002).

Table 4 shows the results of the regression analysis, including the probability value and the explained variance. Over half of the data sets showed a significant relationship between FIB concentration, and stream flow and water temperature. The relationship was considered statistically significant whne the probability value was less than or equal to 0.05.

Trend analysis was also conducted using the Seasonal Kendall test (Helsel et al. 2006). Other variables may influence the results of the trend test. For example, a trend in water temperature over the measurement period may show a trend in FIB concentration, even though FIB loading may not have changed. The same effect may be observed with stream flow, where a possible decrease in stream flow over time may show a trend in FIB concentration that does not really exist. Therefore, the effect on these two variables (i.e. water temperature and stream flow) was removed from the trend analysis. The residual values of FIB concentration were determined from the significant regression equations with water temperature and stream flow. The Seasonal Kendall test was then applied to these residual values.

Table 5 shows the probability value and the slope of the trends in residual values found to be statistically significant (i.e., $\alpha = 0.05$). Statistically significant trends in fecal coliform bacteria concentrations corrected for stream flow and water temperature were observed at Camp Rose. The fecal coliform bacteria concentrations showed an increasing trend (Figures 3).

No trends were observed in either *E. coli* or *Enterococcus* bacteria concentrations that had been corrected for possible trends in the covariates of stream flow and water temperature. The statistically significant trends in *E. coli* bacteria concentrations observed at Monte Rio Beach and Santa Rosa Creek were likely due to changes in stream flow and water temperature over time for the specific days sampled.

Findings

- Statistically significant trends in *E. coli* bacteria concentrations were observed at only two locations assessed: Monte Rio Beach and Santa Rosa Creek. The E. coli bacteria concentrations at both locations showed a declining trend.

- No trends were observed in either fecal coliform or *Enterococcus* bacteria concentrations.

- Over half of the data sets showed a significant relationship of FIB concentration with stream flow and water temperature.

- Statistically significant trends in fecal coliform bacteria concentrations corrected for stream flow and water temperature were observed at Camp Rose. The fecal coliform bacteria concentrations showed an increasing trend in the seven years between 1995 and 2001. Fecal coliform bacteria concentrations have not been measured since 2001.

- No trends were observed in either *E. coli* or *Enterococcus* bacteria concentrations that had been corrected for possible trends in the covariates of stream flow and water temperature.

- The statistically significant trends in *E. coli* bacteria concentrations observed at Monte Rio Beach and Santa Rosa Creek were likely due to changes in stream flow and water temperature over time for the specific days sampled.

CITATIONS

Helsel, D.R. and R.M. Hirsch. Chapter A3 - Statistical Methods in Water Resources; Book 4 - Hydrologic Analysis and Interpretation; Techniques of Water-Resources Investigations of the United States Geological Survey. Available at: http://water.usgs.gov/pubs/twri/twri4a3/

Helsel, D.R., Mueller, D.K. and J.R.Slack. 2006. Computer Program for the Kendall Family of Trend Tests. Scientific Investigations Report 2005-5275. U.S. Geological Survey, Reston Virginia.

IDEXX. 2001. Colilert® and Enterolert® Test Pack Procedures IDEXX Laboratories, Inc., Westbrook, Maine. (http://www.idexx.com/view/xhtml/en_us/water/water-microbiology.jsf).

TABLES

Table 1. Russian River watershed locations and date range of the fecal indicator bacteria concentrations have been collected over many years

Fecal Indicator Bacteria	Watershed Location	Data Range of Available Concentration Data
Fecal coliform	Camp Rose Beach	1995 – 2001
	Healdsburg Memorial Beach	1987 – 2001
	Johnson's Beach	1995 – 2001
	Monte Rio Beach	1997 – 2001
E. coli	Camp Rose Beach	2002 – 2012
	Healdsburg Memorial Beach	2002 – 2012
	Johnson's Beach	2002 – 2012
	Monte Rio Beach	2002 – 2012
	Santa Rosa Creek at Railroad St.	2001 – 2012
Enterococcus	Camp Rose Beach	2006 – 2012
	Healdsburg Memorial Beach	2006 – 2012
	Johnson's Beach	2008 – 2012
	Monte Rio Beach	2006 – 2012
	Santa Rosa Creek at Railroad St.	2001 – 2012

Table 2. Trend test results for FIB concentrations observed in Russian River watershed locations.

Fecal Indicator Bacteria	Watershed Location	Probability Value	Trend Slope
Fecal coliform	Camp Rose Beach	0.2355	No significant trend
	Healdsburg Memorial Beach	0.0839	No significant trend
	Johnson's Beach	0.2532	No significant trend
	Monte Rio Beach	0.6953	No significant trend
E. coli	Camp Rose Beach	0.5822	No significant trend
	Healdsburg Memorial Beach	0.3326	No significant trend
	Johnson's Beach	0.3486	No significant trend
	Monte Rio Beach	***0.0014***	***Declining***
	Santa Rosa Creek at Railroad St.	***0.0002***	***Declining***
Enterococcus	Camp Rose Beach	0.1114	No significant trend
	Healdsburg Memorial Beach	0.1074	No significant trend
	Johnson's Beach	0.8897	No significant trend
	Monte Rio Beach	0.6336	No significant trend
	Santa Rosa Creek at Railroad St.	0.0809	No significant trend

Table 3. Data Sources for Stream Flow and Water Temperature Data used in the Regressions Analysis.

Watershed Location	**Stream Flow Data**	**Water Temperature Data**
Camp Rose Beach	USGS Gage 11464000 Russian River near Healdsburg	1995- 2002: USGS Gage 11464000 - Russian River near Healdsburg 2003-2013: USGS Gage 11463980 - Russian River near Diggers Bend
Healdsburg Memorial Beach		
Johnson's Beach	USGS Gage 11467000 Russian River near Guerneville	CDEC Metrological Station STA in Santa Rosa: Daily mean air temperature was used as surrogate for daily mean water temperature
Monte Rio Beach		
Santa Rosa Creek at Railroad St.	USGS Gage 11466320 Santa Rosa Creek at Willowside Road	USGS Gage 11466200 Santa Rosa Creek at Pierson Street

Table 4. Results of regression analysis of FIB concentrations with observed stream flow and water temperatures in Russian River watershed locations.

Fecal Indicator Bacteria	Watershed Location	Probability Value	Explained Variance
Fecal coliform	Camp Rose Beach	<0.001	19%
	Healdsburg Memorial Beach	0.744	Not significant
	Johnson's Beach	0.003	14%
	Monte Rio Beach	0.912	Not significant
E. coli	Camp Rose Beach	0.748	Not significant
	Healdsburg Memorial Beach	0.342	Not significant
	Johnson's Beach	<0.001	31%
	Monte Rio Beach	0.083	Not significant
	Santa Rosa Creek at Railroad St.	0.002	11%
Enterococcus	Camp Rose Beach	<0.001	19%
	Healdsburg Memorial Beach	0.496	Not significant
	Johnson's Beach	<0.001	12%
	Monte Rio Beach	0.004	7%
	Santa Rosa Creek at Railroad St.	0.002	16%

Table 5. Trend test results of the residuals of FIB concentrations observed and predicted from the significant regression equations.

Fecal Indicator Bacteria	Watershed Location	Probability Value	Trend Slope
Fecal coliform	Camp Rose Beach	0.0197	***Increasing***
	Johnson's Beach	0.7578	Not significant
E. coli	Johnson's Beach	0.8293	Not significant
	Santa Rosa Creek at Railroad St.	0.6117	Not significant
Enterococcus	Camp Rose Beach	0.1785	Not significant
	Johnson's Beach	0.7062	Not significant
	Monte Rio Beach	0.2317	Not significant
	Santa Rosa Creek at Railroad St.	0.0515	Not significant

FIGURES

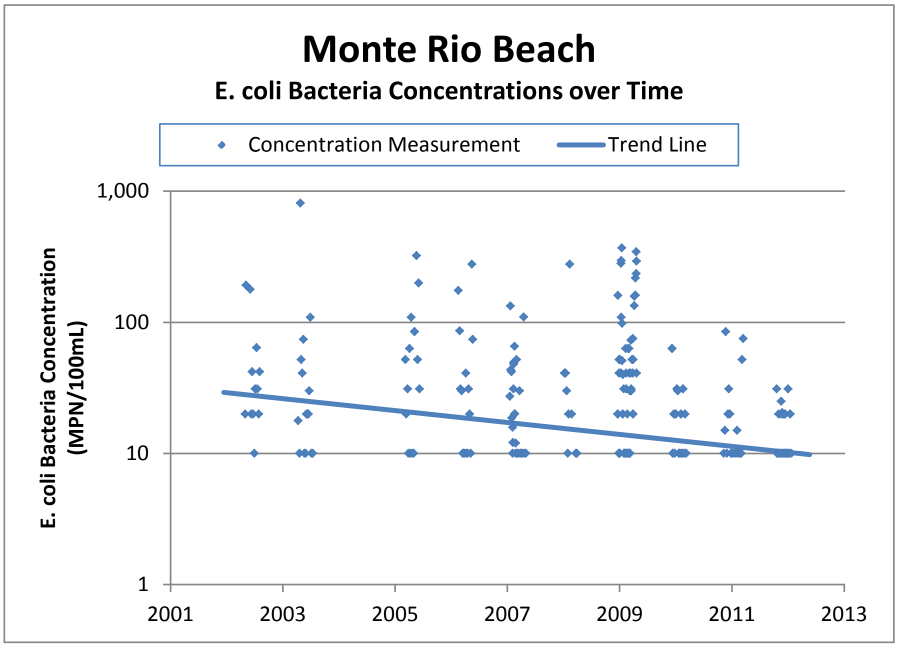

Figure 1. Concentrations of *E .coli* bacteria measured between 2001 and 2013 at Monte Rio Beach

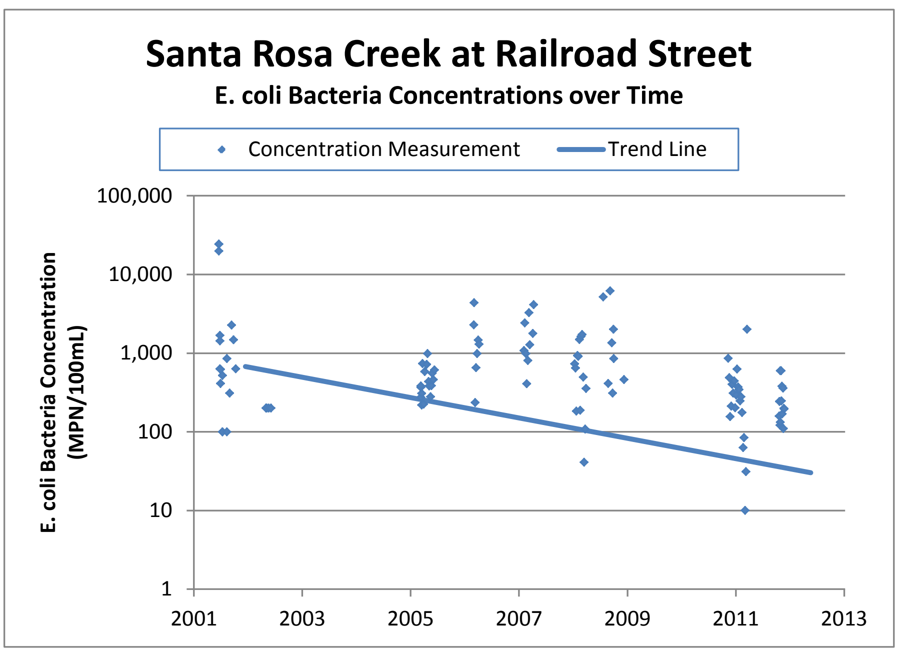

Figure 2. Concentrations of *E .coli* bacteria measured between 2001 and 2013 in Santa Rosa Creek at Railroad Street

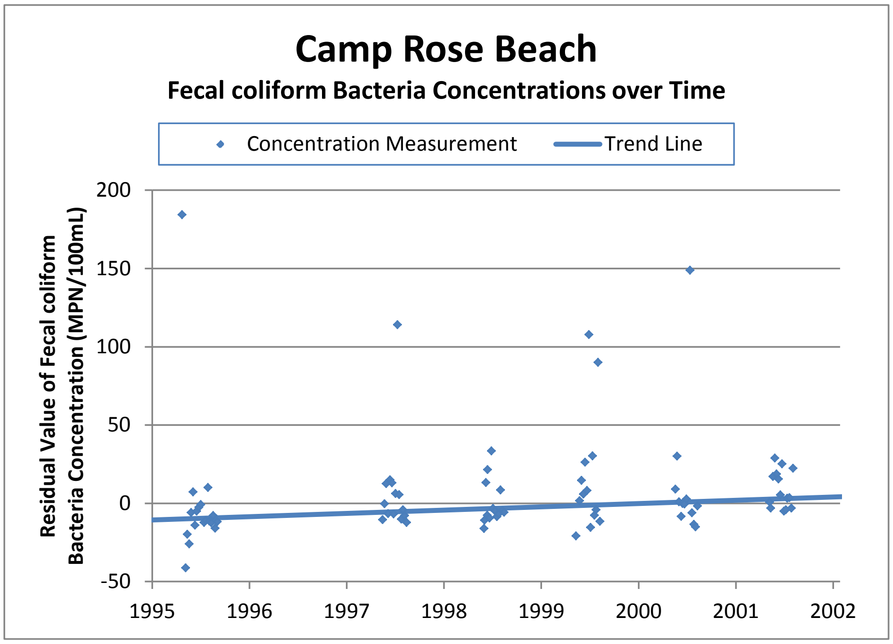

Figure 3. Residual Values of Fecal Coliform Bacteria Concentrations measured between 1995 and 2002 at Camp Rose Beach