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DATE: October 22, 2013

SUBJECT: SUMMARY OF TMDL DEVELOPMENT DATA PERTAINING TO NUTRIENT IMPAIRMENTS IN THE LAGUNA DE SANTA ROSA WATERSHED [REVISED]

INTRODUCTION

The purpose of this memorandum is to summarize information and data analyzed by Regional Water Board staff to date for the development of the Laguna de Santa Rosa Total Maximum Daily Loads (TMDLs) for nitrogen, phosphorus, dissolved oxygen, temperature and sediment – as such are relevant to the development of National Pollutant Discharge Elimination System (NPDES) permits for the City of Santa Rosa Subregional Water Reclamation System and for the Town of Windsor Wastewater Treatment, Reclamation, and Disposal System. In response to public comments received on the aforementioned permits, portions of this memorandum have been revised and clarified since it was originally issued on June 14, 2013. This memorandum supersedes the original version.

The greater Laguna de Santa Rosa watershed consists of the Laguna de Santa Rosa, Santa Rosa Creek, and Mark West Creek hydrologic subareas (HSAs), as mapped in the Water Quality Control Plan for the North Coast Region (NCRWQCB 2011), also known as the Basin Plan.

The information and data summarized herein primarily pertain to the nutrient impairments and the nutrient assimilative capacity of the mainstem of the Laguna de Santa Rosa (hereinafter mainstem Laguna, which approximately begins in the City of Cotati and flows north to its confluence with Mark West Creek) and the lower portion of the mainstem of Mark West Creek (hereinafter, lower Mark West Creek, from its confluence with the

mainstem Laguna to its confluence with the Russian River). These water bodies (and the wetland and riparian areas that surround them) provide habitat for hundreds of species of birds, mammals, reptiles, amphibians, some endangered plants, and several species of fish, including threatened steelhead trout and endangered coho salmon.

STATUS OF 303(d) LISTINGS AND TMDL DEVELOPMENT

On October 11, 2011, the United States Environmental Protection Agency (USEPA) provided final approval of the most current Clean Water Act (CWA) Section 303(d) list of impaired water bodies prepared by the State of California. The list identifies the entire Russian River watershed, including the Laguna de Santa Rosa, Santa Rosa Creek, and Mark West Creek HSAs, as impaired by excess sediment and elevated water temperatures. In addition, Santa Rosa Creek HSA, the Laguna de Santa Rosa HSA, and portions of the Lower and Middle Russian River hydrologic areas are identified as impaired by pathogenic indicator bacteria. The Laguna de Santa Rosa HSA is also identified as impaired by low dissolved oxygen, nitrogen, phosphorus, and mercury.

TMDLs for nitrogen, ammonia, and dissolved oxygen were approved by the USEPA in 1995 in the form of the Waste Reduction Strategy for the Laguna de Santa Rosa (Morris 1995). The Waste Reduction Strategy called for the reduction of nitrogen loads to address ammonia toxicity concerns along the mainstem Laguna and lower Mark West Creek. The Strategy was implemented via improvements to municipal wastewater treatment facilities and dairy management practices in the greater Laguna de Santa Rosa watershed. These improvements are the likely cause of observed reductions in nutrient and ammonia concentrations in the mainstem Laguna between the late 1990s and early 2000s (Sloop et al. 2007).

Regional Water Board staff are currently developing new TMDLs for nitrogen, phosphorus, dissolved oxygen, temperature, and sediment in the greater Laguna de Santa Rosa watershed to address continuing water quality impairments. These TMDLs will apply to all water bodies in the Laguna de Santa Rosa, Santa Rosa Creek, and Mark West Creek HSAs. These TMDLs are estimated to be completed in a few years.

Regional Water Board staff are also currently developing a pathogen TMDL to address indicator bacteria impairments in the Russian River, the Laguna de Santa Rosa, and the Santa Rosa Creek watersheds. The pathogen TMDL is estimated to be completed in 2016. Development of a mercury TMDL for the Laguna de Santa Rosa is not yet scheduled.

SUMMARY OF WATER QUALITY IMPAIRMENTS CAUSED BY NUTRIENTS

Nitrogen compounds (ammonia, nitrate, nitrite, and forms of organic nitrogen) and phosphorus compounds (particulate and dissolved forms of phosphorus) in surface waters can stimulate the growth rates of photosynthetic bacteria, algae, and other aquatic plants. The overabundance of nitrogen and phosphorus compounds in surface water bodies can result in the excessive growth and decay of these organisms, thus accelerating the process of eutrophication, especially in lake-like waters. These phenomena cause dissolved oxygen

levels to drop below concentrations needed for the survival and health of fish and aquatic life, negatively affects the aesthetic quality of water bodies, and impairs beneficial uses

While nutrient inputs to an aquatic system significantly contribute to biostimulatory conditions, there are other contributing factors. These include physical factors that influence how nutrients are processed within a particular water body, including: wind, water temperatures, riparian cover, channel geometry, and stream flows.

In addition to being a causative agent of an aquatic system's biostimulatory response, excessive amounts of nitrogen can also contribute to instream ammonia toxicity, as described by Butkus (2013). Ammonification is the process by which nitrogen compounds are converted to ammonia, which is toxic to fish and aquatic life in its unionized form. High concentrations of total nitrogen can lead to high levels of ammonia toxicity, especially where instream temperatures and pH levels are high.

SUMMARY OF APPLICABLE WATER QUALITY STANDARDS RELATED TO NUTRIENT IMPAIRED CONDITIONS

Biostimulatory Substances

The Basin Plan contains a narrative water quality objective for biostimulatory substances that states: "Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses."

To interpret this narrative objective, Regional Water Board staff evaluate available data and information under three distinct categories: biostimulatory stressors, indicators of a biostimulatory response, and stressor-response relationships.

Biostimulatory stressors (or causal factors) include, but are not limited to: concentrations of total nitrogen and total phosphorus, water temperatures, riparian cover, channel geometry, and stream flows. Recommended numeric criteria for concentrations of total nitrogen and total phosphorus are summarized in the section below.

Response indicators include, but are not limited to: concentrations of dissolved oxygen and chlorophyll *a* (a measure of algal biomass), pH levels, and other observable phenomena such as macrophyte and algae blooms, and changes in the species composition of plant and animal communities that occupy the water body. Recommended numeric criteria for concentrations of chlorophyll *a* are summarized in the section below. Numeric Basin Plan objectives for dissolved oxygen are presented in the subsequent section.

Where sufficient site-specific data are available, staff use a combination of research, analysis, and/or modeling to characterize relationships between biostimulatory stressors and observed responses, and if possible, to determine which stressors cause (or control) those responses in a particular water body.

Nitrogen, Phosphorus, and Chlorophyll *a*

In the early 2000s, the USEPA proposed new total nitrogen, total phosphorus, and chlorophyll *a* criteria for rivers and streams (USEPA 2000) and for lakes and reservoirs (USEPA 2001) based on aggregate ecoregions. Table 1 shows the recommended criteria proposed for Aggregate Nutrient Ecoregion III, which includes the greater Laguna de Santa Rosa watershed. The criteria were empirically derived to represent reference conditions for surface waters, and are based on 25th percentiles of all nutrient data in Aggregate Nutrient Ecoregion III.

Table 1. USEPA Recommended Nitrogen, Phosphorus, and Chlorophyll *a* Criteria for Surface Water Bodies

Constituent	(Lentic) Criteria for Lakes & Reservoirs	(Lotic) Criteria for Rivers & Streams
Total Nitrogen	0.40 mg/L	0.38 mg/L
Total Phosphorus	0.017mg/L	0.02188 mg/L
Chlorophyll *a*	0.0034 mg/L	0.00178 mg/L

In addition, the State Water Resources Control Board (State Water Board) developed evaluation guidelines for assessing biostimulatory conditions to identify impaired waters for the CWA Section 303(d) list (SWRCB 2007). For rivers and streams, State Water Board staff reviewed the California Nutrient Numeric Endpoint (California NNE) technical approach (Tetra Tech 2006) and four subsequent California case studies. For lakes and reservoirs, State Water Board staff reviewed relevant work pertaining to pollutant effects in freshwater lakes and reservoirs (Welch & Jacoby 2004, as cited in SWRCB 2007). These efforts resulted in the development of nutrient numeric screening tools for total nitrogen, total phosphorous, and chlorophyll *a* concentrations in California surface waters to interpret narrative Basin Plan water quality objectives, as shown in Table 2.

Table 2. California Recommended Nitrogen, Phosphorus, and Chlorophyll *a* Criteria for Surface Water Bodies

Constituent	(Lentic) Criteria for Lakes & Reservoirs	(Lotic) Criteria for Rivers & Streams with COLD, REC, MUN, & SPWN Beneficial Uses	(Lotic) Criteria for Rivers & Streams with WARM Beneficial Uses
Total Nitrogen	1.200 mg/L	0.23 mg/L	0.52 mg/L
Total Phosphorus	0.100 mg/L	0.02 mg/L	0.08 mg/L
Chlorophyll *a*	0.010 mg/L	150 mg/m^2	200 mg/m^2

Dissolved Oxygen

The Basin Plan contains numeric water quality objectives for dissolved oxygen, which vary by water body. For the Laguna de Santa Rosa, the Basin Plan states that dissolved oxygen concentrations shall not fall below 7.0 mg/L at any time, that 90% or more of all dissolved oxygen values in a calendar year must be equal to or greater than 7.5 mg/L, and that 50% or more of all monthly mean dissolved oxygen values in a calendar year must be equal to or greater than 10.0 mg/L.

Ammonia Toxicity

The Basin Plan contains a narrative water quality objective for toxicity that states: "All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life."

Water quality criteria for toxicity due to ammonia concentrations in fresh water systems have changed over the last several decades (Butkus 2013). Regional Water Board staff currently rely on USEPA's recommended criteria from the 1999 Update of Ambient Water Quality Criteria for Ammonia (USEPA 1999) to interpret the Basin Plan's narrative objective for toxicity from ammonia. The USEPA recommends acute and chronic water quality criteria for the protection of aquatic life, which are expressed as mathematical formulas. The acute criterion varies depending on pH and on the presence or absence of salmonids. This criterion is expressed as the one-hour concentration of total ammonia nitrogen that shall not be exceeded more than once every three years. The chronic criterion varies depending on pH, water temperature, and the presence or absence of early life stages of fish. This criterion is expressed as the thirty-day average concentration of total ammonia nitrogen that shall not be exceeded more than once every three years. Examples of the acute criteria are presented in Table 3.

Table 3. Acute Toxicity Criteria for Total Ammonia Nitrogen (Criterion Maximum Concentration)

pH	Salmonids Present	Salmonids Absent
7.0	24.1 mg/L	36.1 mg/L
8.0	5.62 mg/L	8.4 mg/L
9.0	0.885 mg/L	1.32 mg/L

SUMMARY OF EXCEEDENCES OF WATER QUALITY OBJECTIVES FOR BIOSTIMULATORY SUBSTANCES AND DISSOLVED OXYGEN

Available data and information suggest that harmful biostimulatory conditions are present in the mainstem Laguna and lower Mark West Creek, as demonstrated by elevated amounts of nutrients in the water column and in aquatic sediments, elevated levels of chlorophyll *a*, frequent low dissolved oxygen levels, and the extensive presence of benthic macrophytes (including *Ludwigia* sp.). These reaches, as well as many of their tributaries, are also facing

significant water quality problems due to high levels of instream sedimentation, hydrologic and physical habitat changes, and high water temperatures.

The following sections provide evidence of elevated amounts of total nitrogen, total phosphorus, and chlorophyll *a* in the water column; evidence of harmfully low concentrations of dissolved oxygen; and evidence supporting Regional Water Board staff's conclusion that phosphorus is the limiting nutrient controlling biomass production – and thus water quality responses – in the mainstem Laguna and lower Mark West Creek.

Instream Nitrogen Levels Exceed Recommended Criteria for Biostimulatory Substances

Instream water samples for nitrogen compounds have been collected in the mainstem Laguna and other watershed locations since the 1970s. Regional Water Board staff reviewed data and analyses presented by Otis (1990), NCRWQCB (1992), Church and Zabinsky (2005), Sloop et al. (2007), and NCRWQCB (2008), among others, to determine the overall status and trends of total nitrogen levels over time in the greater Laguna de Santa Rosa watershed.

Using data from the studies referenced above, Figure 1 presents total nitrogen concentrations measured in the water column since 1989 at the four TMDL attainment locations established in the Waste Reduction Strategy for the Laguna de Santa Rosa (Morris 1995), which are located in the mainstem Laguna at Stony Point Road, at Occidental Road, and at Guerneville Road, and in lower Mark West Creek at Trenton-Healdsburg Road.

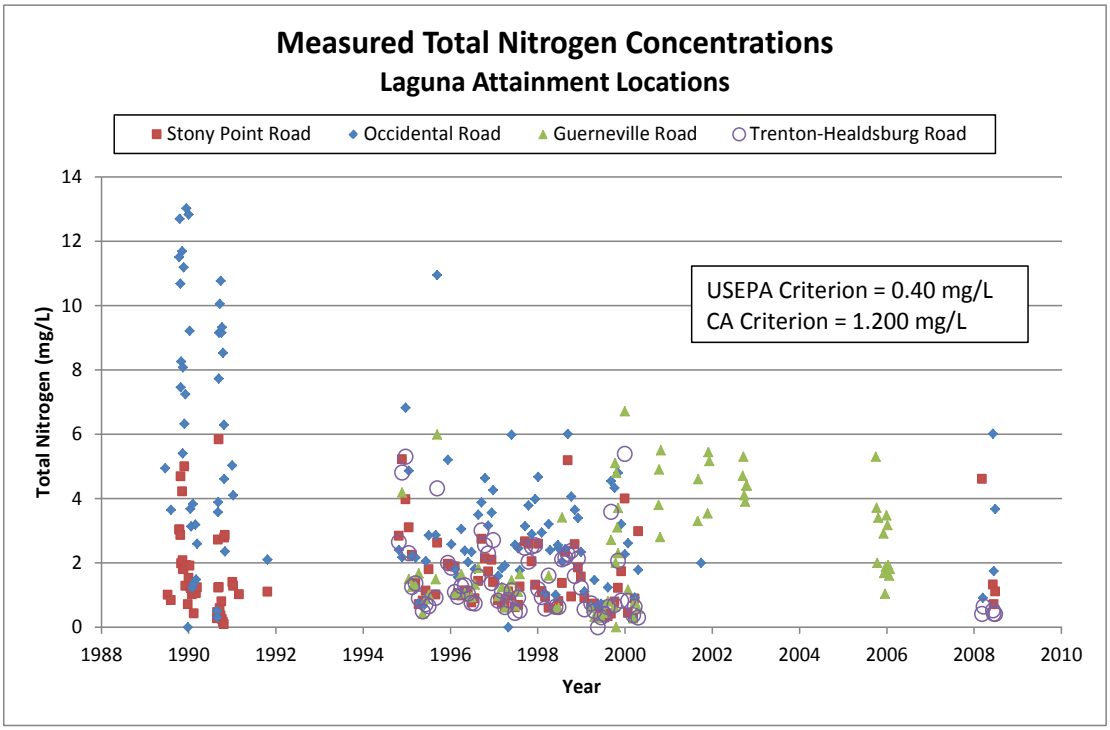

Figure 1. Total Nitrogen Concentrations Measured in the Laguna de Santa Rosa

Data presented in the Figure 1 reveal apparent reductions in total nitrogen concentrations since the late 1980s. However, concentrations measured most recently continue to exceed recommended levels, as summarized in Table 4. In fact, total nitrogen concentrations in 100% of the 42 samples collected and analyzed at the four TMDL attainment locations during the period 2001-2010 exceed the USEPA recommended criterion of 0.40 mg/L, and concentrations in 79% of the samples exceed the California recommended criterion of 1.200 mg/L.

Table 4. Total Nitrogen Concentration Criteria Exceedence Rates in the Laguna de Santa Rosa

Location	Period	# of Samples	Median Total Nitrogen Concentration (mg/L)	Percent Greater than USEPA Criterion (0.40 mg/L)	Percent Greater than CA Criterion (1.200 mg/L)
Laguna TMDL Attainment Locations	1989-1994	84	2.750	93%	76%
	1995-2000	251	1.460	96%	57%
	2001-2010	42	3.235	100%	79%

Instream Phosphorus Levels Exceed Recommended Criteria for Biostimulatory Substances

Instream water samples for phosphorus compounds have been collected in the mainstem Laguna and other watershed locations since the 1970s. Regional Water Board staff reviewed data and analyses presented by Otis (1990), NCRWQCB (1992), Church and Zabinsky (2005), Sloop et al. (2007), and NCRWQCB (2008), among others, to determine the overall status and trends of total phosphorus levels over time in the greater Laguna de Santa Rosa watershed.

Using data from the studies referenced above, Figure 2 presents total phosphorus concentrations measured in the water column since 1972 at the four TMDL attainment locations established in the Waste Reduction Strategy. These data reveal large reductions in total phosphorus concentrations since the 1970s, which are likely due to significant improvements to municipal wastewater treatment facilities and dairy management practices over the last several decades. Figure 3 presents the same total phosphorus concentrations measured since 1984 in order to depict more recent data in a clearer graphic. The data suggest that reductions appear to continue to decline over more recent time periods.

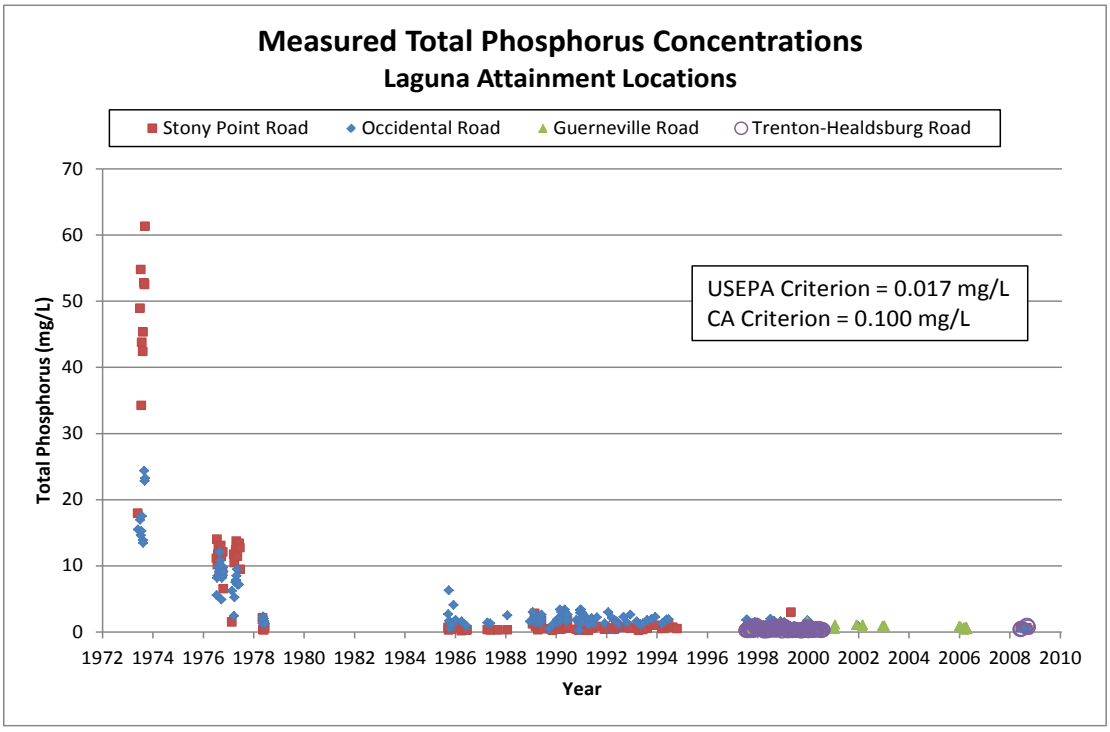

Figure 2. Total Phosphorus Concentrations Measured in the Laguna de Santa Rosa since 1972

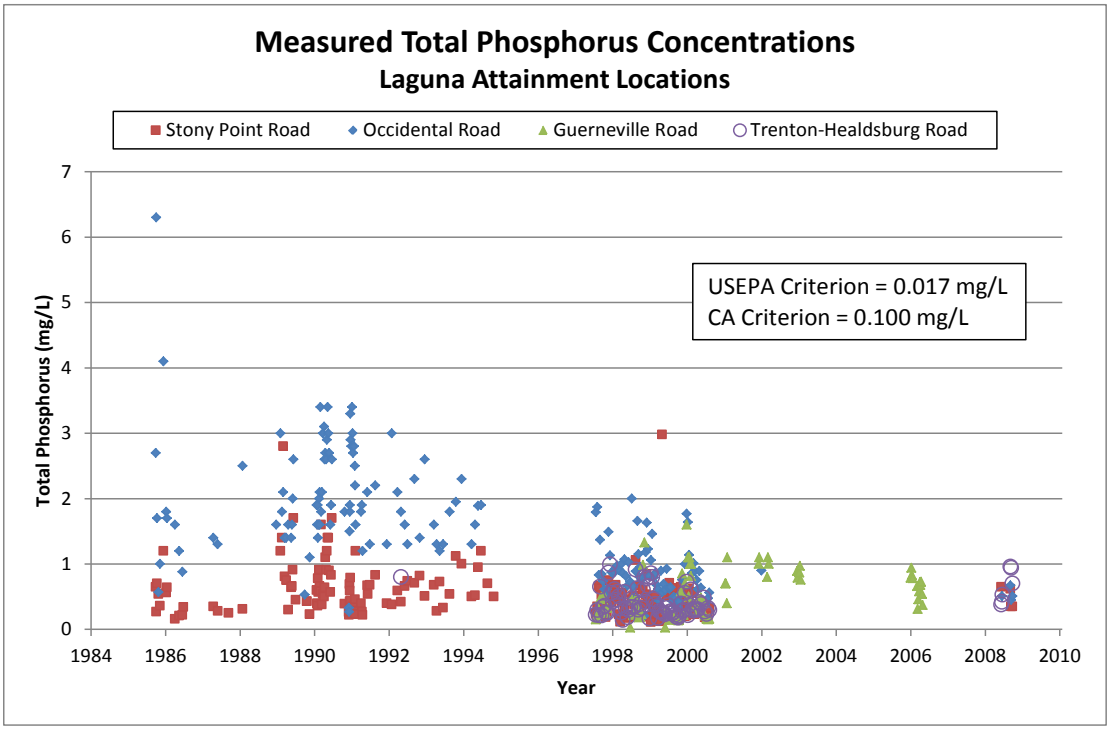

Figure 3. Total Phosphorus Concentrations Measured in the Laguna de Santa Rosa since 1985

While data presented in the above figures indicate substantial reductions in total phosphorus over time, concentrations nonetheless continue to far exceed recommended levels, as summarized in Table 5. In fact, total phosphorus concentrations in 100% of the 43 samples collected and analyzed at the four TMDL attainment locations during the period 2001-2010 exceed both the USEPA recommended criterion of 0.017 mg/L and the California recommended criterion of 0.100 mg/L.

Table 5. Total Phosphorus Concentration Criteria Exceedence Rates in the Laguna de Santa Rosa

Location	Period	# of Samples	Median Total Phosphorus Concentration (mg/L)	Percent Greater than USEPA Criterion (0.017 mg/L)	Percent Greater than CA Criterion (0.100 mg/L)
Laguna TMDL Attainment Locations	1970-1984	81	10.440	100%	100%
	1985-1994	191	1.200	100%	100%
	1995-2000	291	0.430	100%	100%
	2001-2010	43	0.700	100%	100%

Chlorophyll *a* Levels Exceed Recommended Criteria for Biostimulatory Indicators

Instream water samples for concentrations of chlorophyll *a* have been collected in the mainstem Laguna and other watershed locations since the early 1990s. Regional Water Board staff reviewed data and analyses presented by Otis (1990), NCRWQCB (1992), Church and Zabinsky (2005), Sloop et al. (2007), and NCRWQCB (2008), among others, to determine the overall status and trends of chlorophyll *a* over time in the greater Laguna de Santa Rosa watershed.

Using data from the studies referenced above, Figure 4 presents chlorophyll *a* concentrations measured in the water column since 1990 at three of the four TMDL attainment locations established in the Waste Reduction Strategy. (There are no available data for the Guerneville Road location.)

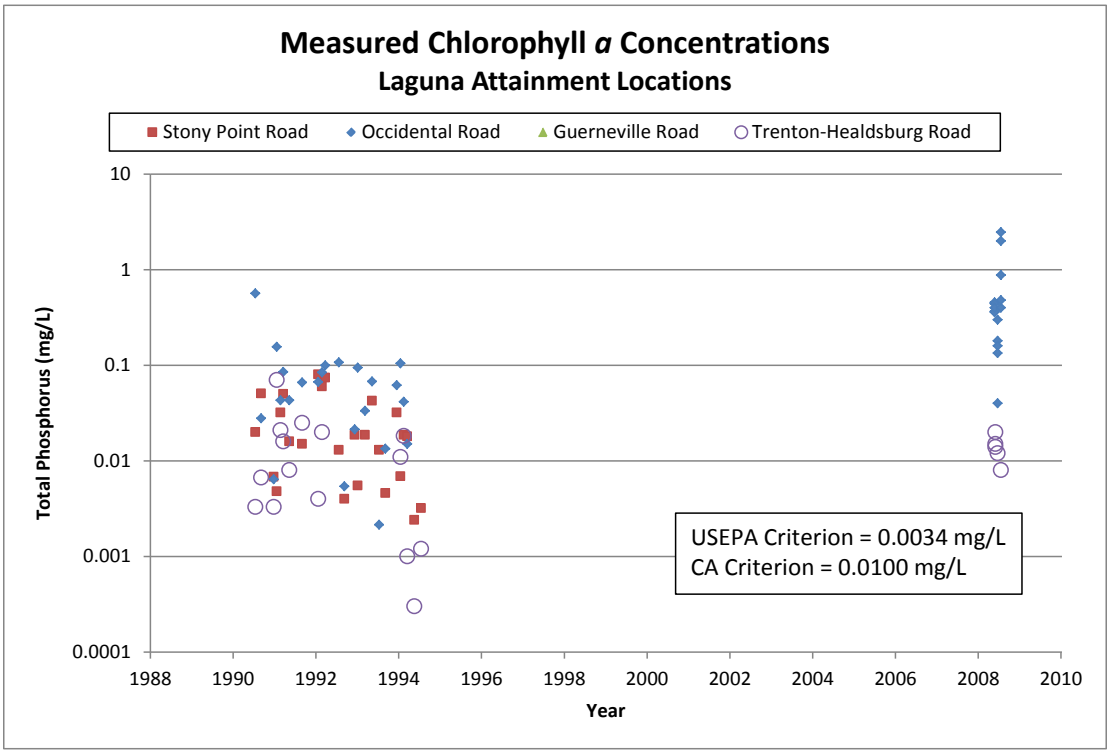

Figure 4. Chlorophyll *a* Concentrations Measured in the Laguna de Santa Rosa since 1990

Data presented in Figure 4 reveal apparent increases in chlorophyll *a* concentrations since the early 1990s. Concentrations measured most recently far exceed recommended levels, as summarized in Table 6. In fact, chlorophyll *a* concentrations in 100% of the 20 samples collected and analyzed at two of the four TMDL attainment locations during the period 2001-2010 exceed the USEPA recommended criterion of 0.0034 mg/L, and concentrations in 95% of the samples exceed the California recommended criterion of 0.0010 mg/L.

Table 6. Chlorophyll *a* Concentration Criteria Exceedence Rates in the Laguna de Santa Rosa

Location	Period	# of Samples	Median Chlorophyll *a* Concentration (mg/L)	Percent Greater than USEPA Criterion (0.0034 mg/L)	Percent Greater than CA Criterion (0.0010 mg/L)
Laguna TMDL Attainment Locations	1990-1994	63	0.0187	87%	70%
	1995-2000	0	---	---	---
	2001-2010	20	0.3300	100%	95%

Dissolved Oxygen Levels Do Not Meet Basin Plan Objectives

Instream water samples for concentrations of dissolved oxygen have been collected in the mainstem Laguna and other watershed locations since the 1970s, although diel (i.e., near-continuous, 24-hour) data for most sites are not available prior to the late 1990s. Diel dissolved oxygen data collected at various monitoring sites in the greater Laguna de Santa Rosa watershed between 1995 and 2011 are presented and analyzed by Butkus (2010) and (2011). Regional Water Board staff assessed these data and analyses, as well as analyses by Sloop et al. (2007), among others, to determine the overall status and trends of dissolved oxygen concentrations over time in the greater Laguna de Santa Rosa watershed.

Using data from the studies referenced above, Figure 5 presents distributions of daily minimum dissolved concentrations measured in the water column at the four TMDL attainment locations, and at Laguna tributary sites. The figure shows that, for the large majority of measurements taken, waters of the mainstem Laguna and lower Mark West Creek regularly fail to meet the minimum Basin Plan water quality objective of 7.0 mg/L, although levels tend to increase as water flows downstream.

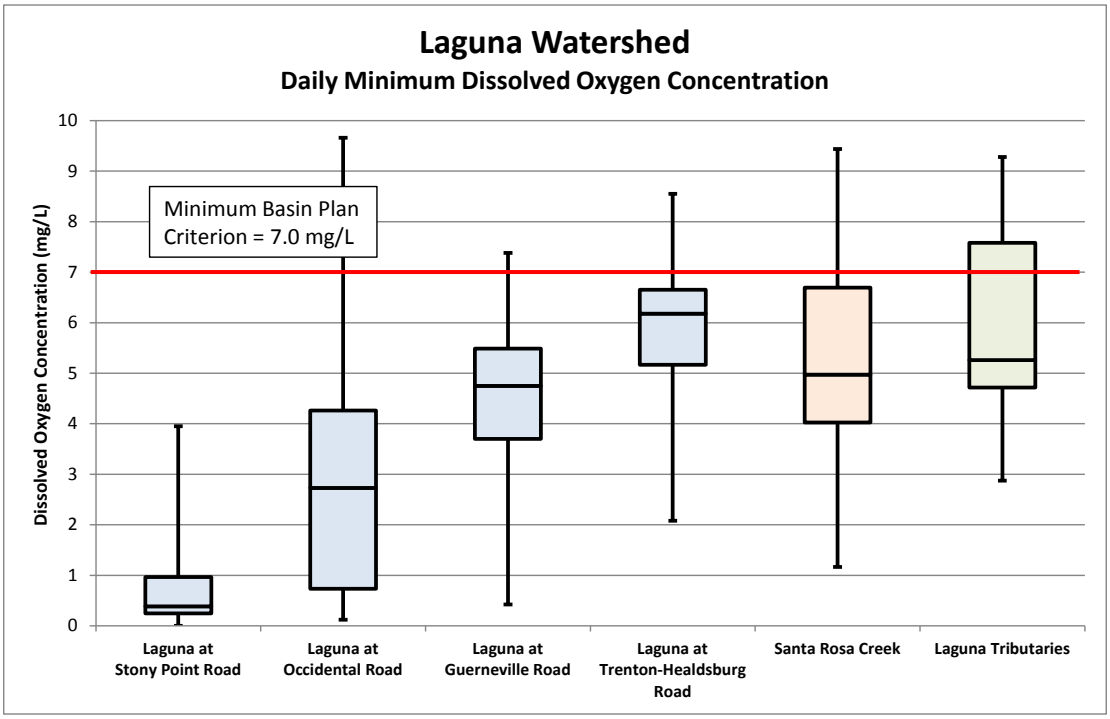

Figure 5. Distribution of Daily Minimum Dissolved Oxygen Concentrations Measured in the Laguna de Santa Rosa Watershed

(Note: Box plots indicate 90th, 75th, 50th, 25th, and 10th percentile concentrations.)

Phosphorus Levels Limit Biomass Production and Cause Harmful Biostimulatory Responses

Where sufficient site-specific data are available, Regional Water Board staff use a combination of research, analysis, and/or modeling to characterize relationships between biostimulatory stressors and observed responses, and if possible, to determine which stressors cause (or control) those responses in a particular water body.

As described below, data and information available for the mainstem Laguna and lower Mark West Creek indicate that, based on current conditions in these water bodies, phosphorus is the primary nutrient stressor that limits algal and macrophytic biomass production, and thus causes harmful biostimulatory responses such as decreases in dissolved oxygen levels.

Regional Water Board staff reviewed available scientific literature regarding nutrient limitations on biomass production (Butkus 2012a), including the *Report to Russian River Watershed Protection Committee and City of Santa Rosa on Phosphate Loading and Eutrophication in the Laguna de Santa Rosa* (Wickham and Rawson 2000) which summarizes the role of dissolved reactive phosphorus (i.e., phosphate) in freshwater ecosystems as follows:

> "Limnologists widely regard phosphate as the predominant limiting nutrient for plant production in freshwater ecosystems. While other nutrients combine with phosphate to fulfill the metabolic needs of plants, such as nitrogen, sulfur, iron, and various other mineral and organic compounds, phosphate is typically the compound that is in lowest availability in free form. Where all available phosphate has been consumed in the course of the production cycle, plant growth stops. This can occur even though all other nutrients, including nitrogen, remain abundant." (p. 1)

Furthermore, regarding the role of nitrogen in the Laguna de Santa Rosa, the report states:

> "Nitrogen, however, can never be completely controlled since it is available from numerous other sources, including natural ones. Nitrogen oxides are readily available from polluted air typical of an urbanized area such as the Santa Rosa Plain. Many species of photosynthetic bacteria and blue-green algae are nitrogen fixers capable of drawing nitrogen in molecular form from the atmosphere and incorporating it into plant tissue as they photosynthesize. The attempt to limit nitrogen in the Laguna, while a worthy goal for many reasons, is potentially fruitless if it is the sole nutrient being addressed." (p. 6)

Based on these and similar findings and works cited by Butkus (2012a) and Schindler (2012), and given the widespread presence of nitrogen-fixing plant species such as *Azolla filiculoides* (a native water fern) in the mainstem Laguna and lower Mark West Creek, staff conclude that total phosphorus concentrations limit algal and macrophytic biomass production in these water bodies.

Preliminary TMDL linkage analysis and modeling results by Butkus (2012b) provide further evidence that total phosphorus concentrations drive benthic and planktonic algal biomass production in the lentic and lotic reaches of the greater Laguna de Santa Rosa watershed. Results suggest that linkages exist between instream total phosphorus concentrations, algal biomass, carbonaceous biochemical oxygen demand (CBOD), and sediment oxygen demand (SOD) in the mainstem Laguna and lower Mark West Creek.

According to Butkus (2012b), benthic and planktonic forms of algal biomass contribute to CBOD in the water column, and upon senescence and settling, contribute to SOD. SOD is caused by the oxidation of organic matter in benthic sediments. Sources of organic matter in sediments include leaf litter, soil entering the water body through erosion and deposition, particulate matter from storm water and wastewater discharges, and deposition of algal and macrophytic biomass. Regardless of the source, the oxidation of organic matter in benthic sediments will exert a SOD on the water column, and drive concentrations of dissolved oxygen to harmfully low levels.

Based on these measured and modeled linkages, Regional Water Board staff conclude that reductions in total phosphorus concentrations are needed to reduce algal (and presumably macrophytic) biomass in these water bodies, which will ultimately lead to lower levels of CBOD and SOD, higher levels of dissolved oxygen in the water column, and a reduced biostimulatory response. Such reductions may be achieved by controlling phosphorus loads from external sources (such as those discharged by municipal wastewater treatment facilities) and by removing or treating internal phosphorus loads, where feasible.

In summary, although the Laguna de Santa Rosa TMDLs are not yet fully developed, evidence is clear that biostimulatory conditions exist and that instream phosphorus concentrations control harmful biostimulatory responses. Currently, the mainstem Laguna and lower Mark West Creek have no apparent capacity to assimilate additional phosphorus loads without continuing to exceed Basin Plan water quality objectives for biostimulatory substances and dissolved oxygen. Regional Water Board staff therefore conclude that reductions in internal and external phosphorus loads to these water bodies are needed to protect their beneficial uses, and to ultimately improve water quality conditions. On the contrary, because phosphorus is the limiting nutrient in these water bodies, reductions in nitrogen loads beyond current levels are not expected to result in added protection of the beneficial uses, or significant water quality improvements.

SUMMARY OF ATTAINMENT OF WATER QUALITY OBJECTIVES FOR TOXICITY

Instream Ammonia Levels Do Not Exceed Toxicity Criteria

Instream water samples for concentrations of ammonia have been collected in the mainstem Laguna and other watershed locations since the 1970s. Regional Water Board staff reviewed data and analyses presented by Otis (1990), NCRWQCB (1992), Morris (1995), Church and Zabinsky (2005), Sloop et al. (2007), and NCRWQCB (2008), among others, to determine the overall status and trends of total ammonia concentrations and ammonia toxicity over time in the greater Laguna de Santa Rosa watershed.

Using data from the studies referenced above, Figure 6 presents total ammonia concentrations measured in the water column since 1989 at the four TMDL attainment locations established in the Waste Reduction Strategy for the Laguna de Santa Rosa (Morris 1995). These data reveal apparent reductions in total ammonia concentrations since the late 1980s.

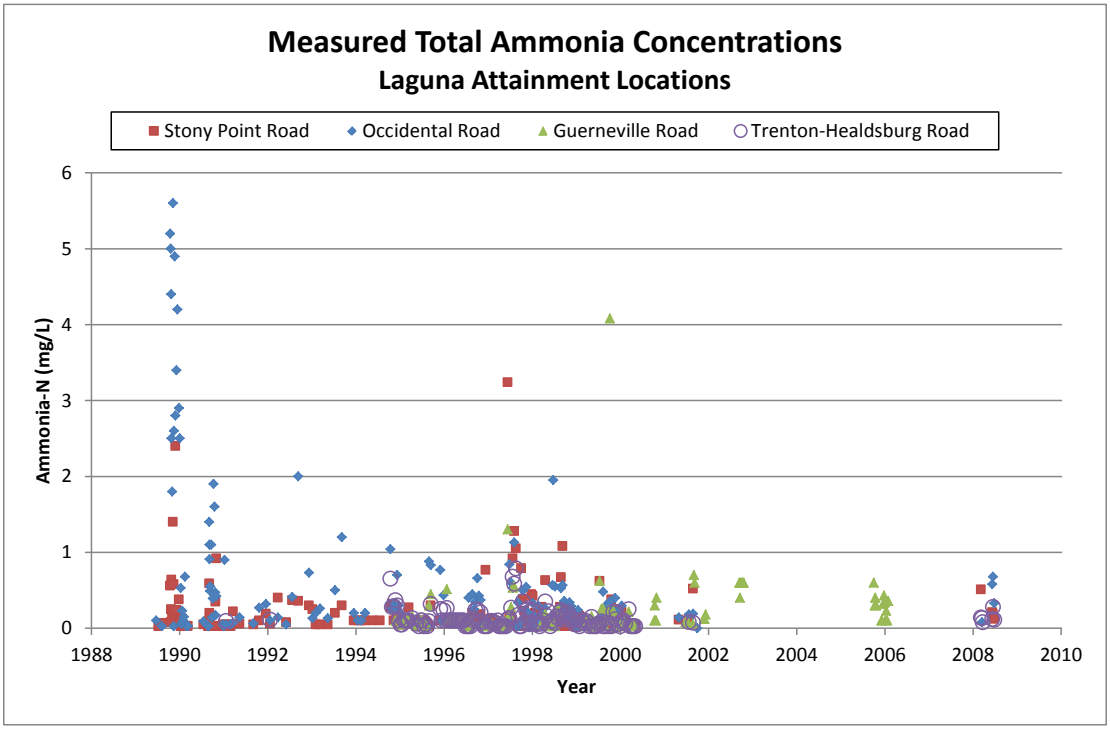

Figure 6. Total Ammonia Concentrations Measured in the Laguna de Santa Rosa since 1989

Regional Water Board staff coupled data presented in the above figure with corresponding (measured or inferred) water column pH values, and evaluated them against the 1999 USEPA recommended criterion for acute ammonia toxicity, assuming the presence of salmonids. None of the measured ammonia concentrations exceed the current acute criterion, as summarized in Table 7. Staff are currently unable to conduct a similar evaluation against the 1999 USEPA criterion for chronic ammonia toxicity, due to lack of sufficiently frequent measurements during the sampled period.

Table 7. Acute Ammonia Toxicity Exceedence Rates in the Laguna de Santa Rosa

Location	Period	# of Ammonia Samples	Median Total Ammonia Conc. (mg/L)	Median pH	Percent Greater than 1999 USEPA Criterion
Laguna TMDL Attainment Locations	1989-1994	139	0.13	7.7	0%
	1995-2000	503	0.10	7.7	0%
	2001-2010	53	0.20	7.78	0%

CRITICAL CONDITIONS

The most critical conditions for dissolved oxygen concentrations and saturation levels - primary indicators of a biostimulatory response – vary spatially along the length of the mainstem Laguna and lower Mark West Creek and also temporally throughout the year. Available data demonstrating these conditions are presented by Butkus (2010) and (2011).

Available data show that dissolved oxygen concentrations and saturation levels generally increase and improve as water flows downstream from the upper portions of the mainstem Laguna toward the Russian River, although most measurements still do not meet the Basin Plan's water quality objectives.

In the greater Laguna de Santa Rosa watershed, the most critical conditions for biostimulatory impairment generally occur in, but are not strictly limited to, the late summer. This is mainly due to the timing of the highest daily maximum air temperatures during the year, which cause higher water temperatures. High water temperatures lower the saturation potential for dissolved oxygen concentrations and increase activity rates for many biochemical processes, which lower dissolved oxygen concentrations even further. This seasonal critical condition is readily observed in data from the mainstem Laguna at Occidental Road with lower dissolved oxygen concentration and saturation values in the summer and higher values in the spring and fall. However, seasonal conditions at other locations vary and show dissolved oxygen concentrations at low levels throughout the year.

HYDRAULIC/HYDROLOGIC PHENOMENA IN THE LAGUNA DE SANTA ROSA WATERSHED

Available evidence suggests that during high flows in the Russian River, the mainstem Laguna and lower Mark West Creek back up, or even flow in reverse, creating conditions that favor the deposition of nutrient-laden solids. Sloop et al. (2007) describe the unique hydrology of these water bodies and conditions under which backwater effects caused by high flows in the Russian River occur. Philip Williams & Associates (2004) describe a geologic outcrop in the area of the Trenton-Healdsburg Road crossing that limits the sediment transport capacity of the mainstem Laguna and lower Mark West Creek. In addition, available stream flow data from the United States Geological Survey (USGS) indicate reverse flows in the mainstem Laguna during at least four separate storm events since 2009, measured as far upstream as the bridge at Occidental Road (USGS Gage No. 11465750).

There are many uncertainties regarding hydrologic phenomena and the dynamics of nutrient fate and transport in the mainstem Laguna and lower Mark West Creek. However, based on available information, it is reasonable to conclude that wastewater discharges of particulate phosphorus into these water bodies are captured and stored in channels and floodplains, and later become bioavailable to growing aquatic plants. Similarly, it is reasonable to conclude that wastewater discharges of dissolved phosphorus are captured and stored in the system, as dissolved phosphorus readily adheres to mineral and organic sediments present in the water column, channel bottom, and floodplain at the time of discharge. Any such discharges will contribute to existing biostimulatory conditions in the mainstem Laguna and lower Mark West Creek, and thus further promote harmful biostimulatory responses.

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