California Environmental Protection Agency
REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

CLEAR LAKE NUTRIENT TOTAL MAXIMUM DAILY LOAD CONTROL PROGRAM 5-YEAR UPDATE

FINAL
September 2012

Introduction

Nuisance algal blooms have been observed in Clear Lake throughout the 20th century. Blooms have been well documented and described since the early 1970s. In 1986, Clear Lake was added to the Clean Water Act Section 303(d) List of Impaired Water Bodies because of nuisance algal blooms that impacted recreational uses. Existing study results and data analyses suggest that controlling phosphorus is the best approach for addressing the nuisance blooms. On 23 June 2006, the Central Valley Water Board adopted Resolution No. R5-2006-0060, *Amending the Water Quality Control Plan (Basin Plan) for the Sacramento and San Joaquin Rivers Basins for the Control of Nutrients in Clear Lake* (CVWB, 2006). US EPA approved the control program as a Total Maximum Daily Load (TMDL) on 19 September 2007. The focus of the control program is on reducing phosphorus loading to Clear Lake by including load allocations for point and nonpoint sources to limit the loads of phosphorus entering the Lake.

Numerous actions were implemented prior to adoption of the control program and in the 5 years since the TMDL was approved to reduce the input of sediment and nutrients into Clear Lake. A description of these actions is included in Appendix A. A restoration project on Middle and Scotts Creeks is the most significant activity currently underway. When completed, this project is projected to result in a 28% reduction in phosphorus loads to the Lake. Other actions have been implemented to control discharges from roads, urban areas, agricultural areas and other sources of phosphorus.

The Basin Plan directs Central Valley Water Board staff to review the progress toward meeting the load and waste load allocations for phosphorus in Clear Lake by five years after TMDL approval. At that time, the Central Valley Water Board will consider information developed and determine whether the phosphorus load and waste load allocations should continue to be required or if some other control strategy or approach is more appropriate (CVWB, 2006).

This staff report reviews the progress to date in meeting the control program objectives and provides information on the proposed efforts for the next five years. This update provides the status on control program implementation progress and does not revise or amend the Basin Plan.

Clear Lake Nutrient Control Program

Several studies (Horne, 1975; Richerson et al., 1994; and Winder et. al., 2010) have characterized conditions in Clear Lake (see Figure 1) and concluded that excess phosphorus contributes to the occurrence of nuisance blooms of blue-green algae in Clear Lake during spring, summer and fall periods and that controlling phosphorus inputs should reduce the incidence of nuisance blooms.

Most sources of phosphorus to Clear Lake are sediment driven and include erosion from agricultural and urban areas, instream channel erosion, timber harvesting, runoff from roads, construction, gravel mining, wildfires, control burns, off highway vehicle (OHV) use, and dredging and filling. Fertilizer use (both urban and rural) and sewer and septic overflows may also contribute phosphorus to the Lake.

In addition to phosphorus, these studies indicated there may be other factors that are affecting blue-green algal blooms including iron, (Horne, 1975; Richerson et al., 1994) sulfate, (Richerson et al., 2008) and food chain changes (Winder et al., 2010). Internal phosphorus loading (phosphorus released from the sediments) was also identified as a factor in blue-green algal growth (Richerson et al., 1994). The hydraulic residence time of Clear Lake is 4.7 years (Richerson et al., 2008), so any reduction in phosphorus loads to the Lake will take many years to effect a reduced phosphorus concentration in the Lake water column. However, over the long term (decades) we would expect that decreasing the phosphorus loads to the Lake would decrease concentrations of phosphorus in the sediment and this in turn would lead to reductions in the water column.

The Central Valley Water Board contracted with Tetra Tech (2004) to analyze the available information on Clear Lake and develop technical information on nutrient loading and recommend load reductions that would reduce the frequency of nuisance algal blooms. Central Valley Water Board staff used the technical report prepared by Tetra Tech to develop the control program outlined in the Clear Lake Nutrient TMDL.

In 2006, the Central Valley Water Board amended the Basin Plan. The Basin Plan Amendment, based on the recommendations and conclusions in the Tetra Tech report, included the elements of a TMDL for Clear Lake that established numeric load allocations for point and non-point sources that would result in phosphorus reductions needed to reduce the incidence of algal blooms. The amendment also included an implementation plan to achieve the load reductions. The main focus of the control program was to implement the Middle Creek/Scotts Creek restoration project (aimed at restoring some of the natural filter) and to control phosphorus from sources where human activity has increased loads over pre-European background levels. Specific load limits were set for point source discharges in the watershed (urban storm water and Caltrans road building and maintenance activities) and a general load limit was set for the nonpoint sources, including irrigated lands and agencies responsible for land management activities (such as the County of Lake, U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (Forest Service)). The allocated loading of phosphorus to Clear Lake is 87,100 kg per year. This represents a 40% reduction in the current average annual phosphorus loading. The 87,100 kg is allocated to point and nonpoint source dischargers. Point source dischargers – Lake County Storm Water Permittees (County of Lake, Cities of Clearlake and Lakeport) and the

California Department of Transportation – are given a waste load allocation of 2,000 and 100 kg per year, respectively. Nonpoint source dischargers – BLM, the Forest Service, irrigated agricultural dischargers and Lake County – are given a collective load allocation of 85,000 kg phosphorus per year.

The Basin Plan Amendment also recommended that additional studies be conducted to validate the chlorophyll-a target and load allocations and to determine the effect that other constituents (such as nitrogen or iron) might have on nuisance algae blooms in the Lake.

Algae Problem in Clear Lake

Horne (1975), Richerson (1994, 2000 and 2008) and Winder (2010) provide descriptions of historical conditions in Clear Lake related to algae and the role that nutrients play. For the past 10,000 years Clear Lake has been a warm, eutrophic lake that supported a lot of algae, other aquatic plants and abundant invertebrate and fish populations. There is general agreement that the frequency and severity of algae blooms started getting worse in the 1920s with the initiation of large earth moving activities in the watershed, which increased the loads of nutrients entering the Lake. In addition, since the beginning of European influences in the Basin, more than 85% of its natural wetlands has been lost, which has dramatically altered the nutrient balance of nitrogen and phosphorus cycling. The marshes acted as a natural sediment filter that controlled nutrient loads entering the Lake.

From 1920 to 1970, based on eye witness accounts, news articles and other local sources of information, there were many incidences of nuisance conditions. More systematic monitoring was initiated in 1969 to characterize conditions in the Lake. These monitoring programs provide the information that is discussed in the Horne, Richerson and Winder reports. In the 1970s water clarity was generally poor and there were frequent nuisance algae blooms (including nuisance blue-green algae species – also called cyanobacteria) that impacted recreational uses of the Lake. By the 1990s, there was a general trend toward clearer water and less frequent blooms that continued until 2004. Massive algae blooms and nuisance conditions have been experienced in several years since 2004, most notably the 2009, 2010 and 2011 summers. Recently, different nuisance blue-green algae species seem to be dominating the ecosystem, suggesting that some key controlling factors have changed. The reason for the apparent change in conditions is not known although many factors have been suggested, including changes in nutrient loading, global warming, changes in the food web, changes in turbidity or other factors.

Phosphorus

Limiting Phosphorus

Horne, Richerson and Winder's studies and research on Clear Lake have suggested that controlling nutrients is the best choice for improving conditions in the Lake. The research has suggested that controlling phosphorus loads to the Lake make the most sense for a variety of reasons. The goal would be to reduce phosphorus loads to the Lake so phosphorus concentrations in the Lake would be reduced to levels that limit algal growth (Richerson, 1994). The Richerson (1994) report stated that substantial reductions in Lake phosphorus concentrations have excellent promise of maintaining Lake conditions that favor more desirable algal species, such as diatoms and green algae, over scum forming blue-green algae. This approach is consistent with control programs and research developed in the US and Canada over the past 40 years. For example, studies on a small freshwater lake in Ontario, Canada, concluded that to reduce eutrophication, the focus of management must be on decreasing inputs of phosphorus (Schindler et al., 2008). On these same experimental lakes, algae were observed when a lake was fertilized with phosphorus, nitrogen and carbon, but no algae were observed when the lake was fertilized with only nitrogen and carbon (Schindler, 1974). As has been mentioned previously, this is the approach suggested in the Tetra Tech report (2004).

Phosphorus Cycling

Phosphorus occurs naturally in soils surrounding Clear Lake. The study by Richerson et al. (1994) indicates that erosion from fine sediment entering the Lake during winter runoff is the most important source of phosphorus as fine sediments carry nutrients and trace elements. The increased nutrient load from erosion that has occurred over the past 80 years is likely a result of disturbances to stream channels, filling and other earthmoving activities, and the removal of the filtering capacity of marshes (Winder 2010). Various human activities increase how much phosphorus is eroded from the landscape (roads, agriculture, urban development, logging, etc.). Other sources of phosphorus to the Lake include fertilizers, septic tanks, urban runoff and sewage spills. Past human alteration of the landscape has contributed significantly to increasing loads of phosphorus that reach the Lake. For example, marshes used to fringe the Lake and serve as a filter that removed phosphorus and prevented it from reaching the Lake. Removing the marshes has removed the filter, allowing more phosphorus to enter the Lake.

Some of the phosphorus that enters the Lake is transported through the Lake and out Cache Creek. Most of the phosphorus that enters the Lake in the rainy season partitions into the sediment. Varying amounts of phosphorus are released from the sediment back into the water column in the spring and summer. The amount of phosphorus released varies widely from year to year and there are many factors that seem to play a role, including the weather and

presence or absence of drought conditions. Over time, a portion of the phosphorus is buried in the Lake sediment and is too deep in the sediment to be available for release back into the water column. Phosphorus entering the Lake in the tributaries cannot be used to predict phosphorus concentrations in the Lake, on a year to year basis. However, over the long term (decades) it is logical that decreasing the phosphorus loads to the Lake would decrease concentrations of phosphorus in the sediment.

Status of Phosphorus in Clear Lake

A lot of work has been done in the past 25-30 years that has undoubtedly reduced loads of phosphorus entering the Lake from some sources, and it would be reasonable to suggest that phosphorus loads to the Lake have decreased since the early 1970s. A comprehensive summary of the actions that have been implemented is presented in Appendix A. However, no comprehensive monitoring has been done to document current loads (over the years since the control program was adopted - 2006) of phosphorus in the tributary streams entering the Lake. There is some information on loading from the various source categories and some information on activities and practice implementation that allows us to make some estimates on whether phosphorus loading is likely increasing or decreasing. In addition, there is phosphorus data on Lake water and Lake sediment. This data can provide a general sense on tributary loading, but can't be used for a year to year comparison (as was discussed above).

Lake County conducted a monitoring program in 2007 and 2008 in the three largest tributaries of Clear Lake. Based on three stream gages, the total phosphorus loading from the watershed was estimated at 90,000 to 125,000 kilograms per year (Lake County Watershed Protection District, 2009). These estimates are significantly less than the estimates of 158,000 kg/yr (Richerson et al., 1994) and 150,000 kg/yr (TetraTech, 2006). Additional monitoring of the tributaries is necessary to verify this reduction in phosphorus loading.

Phosphorus in Clear Lake Water

Deep sediment cores collected by the USGS in 1973 and 1980 indicate Clear Lake has existed as a shallow, highly productive (eutrophic) lake for 450,000 years, with productivity increasing during warmer periods (Adams, 1988). Historical records prior to 1920 did not note large blooms of scum forming blue-green algae. By the 1930's, blue-green algal blooms appear to have become more frequent and creating widespread nuisance conditions. This increase in blue-green algae, and presumably phosphorus, have been attributed to reclamation of the historical wetlands in the Rodman Slough area, increased use of mechanized earth moving machinery and road construction, and the advent of strip mining at the Sulfur Bank Mercury Mine. Sediment cores show an increase in inorganic matter deposition after 1927, with decreases in deposition rates after 1954; however, deposition rates are still significantly above the pre-European deposition rates (Richerson et al., 2008). As most of the phosphorus entering

Clear Lake is bound to fine grained sediments, a similar pattern of phosphorus loading probably exists. It is clear that human disturbances in the watershed have impacts on phosphorus loading that are measurable in the Lake and that changing the way we implement projects and activities in the watershed can reduce phosphorus loads.

Phosphorus concentrations in the Lake have varied over the period of record (1969 – present) but there is no definitive long term trend, see Figure 2. Between 1974 and about 1990, the phosphorus concentrations in the Lake were considerably lower with concentrations fluctuating in the vicinity of values that are generally considered to be limiting for algae growth (about 10 ug/l). Phosphorus concentrations in Lake water increased greatly during the drought (1987-93) mostly as a result of phosphorus being released from the sediment. After the drought, the phosphorus concentrations went down but have not returned to levels that were observed before the drought. Phosphorus concentrations are still not at limiting levels for blue-green algae growth.

Because of the phosphorus cycling from the sediments, phosphorus concentrations in the water column reach a maximum in the August to October time period. Water quality data collected by DWR shows 300 to 500 tons of phosphorus enters the water column each year from the sediments. It is not clear why phosphorus cycling increased so dramatically in the late 1980's and has maintained similar levels through the last two decades.

Clarity in the Lake has increased over the period of record (see Figures 3 - 5) and turbidity has decreased, which is indicative of less sediment entering the Lake, and presumably less nutrients. However, the trends are not as strong from the period of TMDL adoption (2006) to present, and the trends are not evident in July and August, which are two months that tend to have algal blooms. As was pointed out earlier, erosion control efforts have not brought Lake phosphorus concentrations to limiting levels for blue-green algae growth.

Phosphorus in Lake Sediment

Lake County has been collecting sediment cores from Clear Lake since 1995 through 2011 to document sediment phosphorus concentrations. In a memo prepared by County staff in 2012, the results of the monitoring are discussed. The memo concluded that total phosphorus concentrations and mass, as well as the solids content have declined slightly in the top 10 cm of the sediment between 1997 and 2011, see Figure 6. Ten centimeter cores were used because previous studies had concluded that 10 cm was a reasonable estimate of the depth where constituents could be recycled into the water column in any given year. The memo also made a comparison between current phosphorus concentrations and concentrations that existed prior to 1927 (1927 would reflect conditions that existed before significant earth moving activities were initiated by European settlers). Based on the analysis, the memo estimated the time it would

take for phosphorus concentrations in the sediment to return to pre-European conditions (assuming that loadings did not change). The estimates varied from a few years to more than a hundred years for the different arms of the Lake. As has been previously mentioned, there has been no observable decrease in Lake phosphorus concentrations. It would be beneficial to have a better understanding of phosphorus cycling dynamics in the Lake.

Nitrogen

The classic rule of thumb is that blue-green algae is limited by dissolved phosphorus concentration of less than 10 ug/L or ratios of nitrogen to phosphorus (N:P) of more than 8:1 by weight (Richerson 1994). N:P ratios increased to around 10 since circa 1980, being highest (>15) in spring and dropping in the summer (2 +/-) as dissolved NH3 is used up, see Figure 7.

In phosphorus rich, dissolved inorganic nitrogen depleted waters (low N:P ratios), nitrogen-fixing cyanobacteria (e.g. *Aphanizomenon* and *Anabaena*) may gain a competitive advantage over non nitrogen-fixing cyanobacteria (e.g. *Microcystis, Lyngbya, Oscillatoria)* (Paerl, 2009).

In addition, changes in nitrogen chemistry were also observed over the past two decades: (1) ammonia and total nitrogen have increased since 1987 while nitrate + nitrite has decreased since the 1970's, (Winder et al. 2010) suggesting a possible switch from "new" (external inputs of nitrogen such as nitrogen fixation or groundwater inflow) to a "regenerated" (due to zooplankton excretion and microbial mineralization) nitrogen production; and (2) although nitrate + nitrite were the dominant nitrogen sources (ca. 90%) in the 1970's (Winder et al., 2010), ammonia is now the dominant nitrogen source, while nitrate + nitrite are now below the detection limits or close to the detection limits.

These changes in nitrogen speciation and water clarity correlate with changes of cyanobacteria assemblage composition, such as the decline of the diazotrophic[1] cyanobacterium *Aphanizomenon* (Winder et al., 2010). Other factors such as zooplankton grazing may have contributed to the changes in cyanobacterial assemblage composition (Winder et al., 2010).

Other Factors

There are probably other factors that influence the composition and abundance of cyanobacterial assemblage. Both Horne and Richerson have identified iron as a possible critical micronutrient, as it is used by blue-green algae for nitrogen

[1] Diazotrophic – Organisms that fix nitrogen gas and produce ammonia.

fixation. During bioassays, with the addition of chelated iron to sampled Lake water, enhanced nitrogen fixation occurred. By reducing sediment inflow to the Lake, the prime method of reducing phosphorus loading, the external iron load would also be reduced.

Richerson et al. (2008) noted that increases in dissolved sulfate occurred circa 1927, probably due to the advent of strip mining at the Sulfur Bank Mercury Mine. Sulphur Bank was mined in 1865 for sulfur, until the economic demand during the 1870s spurred the development of this property for mercury. Underground workings continued until approximately 1906. In 1915, the Sulphur Bank Association began open pit mining at the property, which continued through 1919 and then again from1927 through 1950. In 1990, the Sulphur Bank site was listed on USEPA's National Priorities List under the Comprehensive Environmental Response, Compensation, and Liability Act, more commonly known as Superfund. This historic mining changed the Lake sediment chemistry and has affected nutrient and iron cycling.

Status of TMDL Implementation Efforts (primarily 2006 to 2011)

Middle Creek Flood Damage Reduction and Ecosystem Restoration Project

Many studies and the TMDL have named the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project as one of the most important implementation projects. The Middle/Scotts Creek watershed contributes over 1/2 of the total sediment load to the Lake. By implementing this project, phosphorus loading from these watersheds could be reduced by up to 40%.

Since 1995 Lake County Department of Water Resources has been pursuing the Middle Creek Project, a project to acquire 1,650 acres of reclaimed land at the north end of Clear Lake and restore it to wetlands. This implementation project was identified in the Clear Lake TMDL as well as other studies. It would restore the largest damaged wetland area around the Lake, and the restored wetlands would filter water from the Scotts Creek and Middle Creek Watersheds, which contribute an estimated 57% of the inflow and 71% of the phosphorus loading to the Upper Arm of Clear Lake (USACE, 1997). The United States Army Corps of Engineers (USACE) estimates that phosphorus and sediment inputs from Scotts and Middle Creeks would be reduced 40% by the Middle Creek Project, which amounts to an estimated 28% reduction for the Upper Arm of Clear Lake. They estimate that chlorophyll would decline approximately 34% from a historical average of 92µg/l down to 61µg/l. These reductions in the Upper Arm are significant because over 75% of the Clear Lake Watershed drains into the Upper Arm and due to prevailing wind direction, it is a source of much of the algae in the Lower and Oaks Arms (Lake County and West Lake Resource Conservation District, 2010b). Lake County Department of Water Resources has received $5.714 million in grants from DWR to begin land acquisition in the area, and as of

December 2007, 134 acres had been acquired. In May 2011, an additional $7 million was added to the grant award. Since that time, five additional properties have been appraised (Lake County, 2011). Lake County estimates another 74 properties need to be acquired, all or in part. This estimates to roughly $11 million still needed for all land acquisition.

The following source categories were identified in the TMDL as responsible parties and given a load allocation. For each of the categories, a brief update is presented on implementation efforts that have been conducted within the last five years since adoption of the TMDL. More detailed implementation efforts can be found in Appendix A for each source.

Agricultural Sources

Nearly all of the non-rangeland agricultural acreage in Lake County is within the Clear Lake watershed. There is some potential for phosphorus loading to the Lake from agricultural lands that are regulated under the Central Valley Water Board's Irrigated Lands Regulatory Program (ILRP). Under the Sacramento Valley Water Quality Coalition, the Lake County Farm Bureau implements the ILRP in the Clear Lake watershed. There is one monitoring station located on Middle Creek upstream of Highway 20.

The majority of agricultural acreage in Lake County is grapes, pears and walnuts. Crop reports for Lake County indicate that total agricultural acreage has decreased by about 10% since 2002. There has been a 45% increase in grape acreage and a decline in pears. Walnut acreage has essentially stayed the same but with more irrigated acreage (see Table 1).

Table 1. Lake County Agricultural Department's Annual Crop Reports

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wine Grapes	5465	6219	7076	7518	7842	7949	8004	7715	7939
Pears	3024	2764	2557	2482	2240	2208	2208	2208	2118
Walnuts (irrigated)	575	565	565	950	952	952	952	858	1240
Walnuts (non-irrigated)	2224	2174	2141	1745	1750	1750	1698	1742	1860
Total	11288	11722	12339	12695	12784	12859	12862	12523	13157

Beginning in the late 1980s, an agricultural conversion from walnut orchards to wine grape vineyards has been occurring in the Clear Lake watershed. Total vineyard acreage in 1991 was about 3,000 acres, and in 2010 it was about 8,000 acres. These conversions may result in an increase in the erosion hazard on a

converted parcel due to accelerated sheet, rill, and gully erosion during and for several years after the process is complete. Although there are no quantitative data regarding this process, orchard-to-vineyard conversion impacts on erosion and sedimentation rates are estimated to be short-term in nature. However, conversion of native vegetation to vineyards likely increases both short- and long-term erosion and sedimentation rates unless extensive erosion and sediment control measures are implemented. To mitigate erosion, Lake County has regulated development of conversion of agricultural properties for over 10 years due to the erosion hazard. Under the current Grading Ordinance (Chapter 30, LCC, adopted July 17, 2007) implementation of BMP's is required for new agricultural properties (native vegetation to agriculture) and conversions of deep rooted crops (orchard to vineyard) on soils with a moderate to severe hazard rating. Since 1992, phosphorus fertilizer use has varied widely from year to year varying from 600 kg to 32,000 kg of P. Erosion control management practices are implemented to limit the amount of sediment runoff and fertilizer runoff.

A 2007 survey conducted by the Lake County Farm Bureau Watershed Program indicated that 90% of vineyard acreage is maintaining a permanent or winter annual cover crop. The Lake County Winegrape Commission reports that 70% of the vineyard acreage and 145 winegrape growers have begun the process to become certified as sustainable winegrowers as part of the California Sustainable Winegrowing Alliance (CSWA). Management practices promoted by the CSWA include: soil management, cover cropping for erosion control and irrigation and nutrient management practices (Larry Walker Associates, 2011).

Unregulated Agricultural Sources

Illegal *Cannabis* on Forest Service and BLM land is steadily increasing in Lake County. Illicit marijuana grow operations frequently rely on water diversions from streams, and during summer months these diversions may de-water small streams in the upper watershed and reduce flows or cause streams to dry earlier in the lower watershed. There have been observations of ponds built adjacent to streams for fertilizer mixing, which cause both sediment and fertilizer inputs to streams. Diesel spills from generators used to power pumps or other equipment have also contaminated waterways. These operations sometimes intentionally poison wildlife, and they leave behind large amounts of waste (Lake County and West Lake RCD, 2010). According to a University of California study (Giusti, 2010) there were roughly 140 garden sites on BLM land and 61 gardens on the Mendocino National Forest Upper Lake Resource District in 2009. The 61 sites totaled approximately 384,000 plants with the average garden size at 6,300 plants. The extent of phosphorus contributions from these operations is unknown.

Septic Tanks

There are currently about 12,300 septic tank systems in the watershed. The systems are concentrated around the Lower and Oaks Arms of the Lake. Earlier

reports have concluded that septic tank systems are likely not an important source of phosphorus. It is known that phosphorus binds to soil, so by the time a discharge from a septic tank/leach field reaches the Lake, there would likely be little phosphorus. On the other hand septic tanks could be a significant source of nitrogen to the Lake. It is probably safe to conclude that septic tanks are not a source that would be increasing phosphorus loading.

Storm Water

Lake County, City of Clearlake and City of Lakeport are co-permittees in the Municipal Storm Water Program. The Small Municipal Separate Storm Sewer System General Permit was adopted in 2003, and the State Water Board is updating the Permit at this time. Lake County implements numerous BMPs through their Clean Water Program that address sediment runoff which will ultimately reduce phosphorus loads to Clear Lake.

The County continues to aggressively enforce the Grading and Storm Water Ordinances, and has abated a number of illegal marijuana cultivation sites that have resulted in significant storm water violations. The County also continues to conduct annual cleanups of illegal dumpsites. Additional storm water implementation efforts are outlined in Appendix A.

California Department of Transportation

Caltrans maintains a statewide Stormwater Program, which integrates appropriate stormwater control activities into ongoing projects, making control of stormwater pollution a part of Caltrans normal business practices (Caltrans, 2003). The Stormwater Program includes a *Stormwater Management Plan*, District workplans, monitoring and best management practice development, public education, and guidance for design, construction and maintenance activities (Caltrans, 2007). The *Stormwater Management Plan* identifies how Caltrans will comply with the provisions of the National Pollutant Discharge Elimination System (NPDES) permit Order No. 99-06-DWQ, issued by the State Water Board on July 15, 1999 (SWRCB, 1999). Caltrans' Municipal Separate Storm Sewer System (MS4) permit (Order 99-06 DWQ) is being renewed.

In September 2008, Central Valley Water Board staff approved an implementation plan to install four (4) monitoring stations at sites along the northern portion of Clear Lake where Caltrans facilities lie in close proximity to the Lake (Caltrans, 2008). Flow weighted composite samples will be collected from these stations in order to estimate the concentration of total phosphorus in the runoff. Data will need to be collected for at least two years before current loads can be assessed. Once current loads have been established, a compliance plan will be developed that will include best management practices that are feasible and effective in controlling phosphorus loading.

As of October 2010, the monitoring stations were installed and have captured two storm events. Two of the stations had no flow during the rain events during the winter of 2010/2011. Caltrans has recommended relocating a monitoring station and implementing flow monitoring modifications to Station 4, which experienced unexplained dry weather flows (Caltrans, 2011). As of now, phosphorus loads to Clear Lake cannot be determined from this monitoring effort.

United States Forest Service

Since the nutrient control program was adopted in September 2007, the Mendocino National Forest, Upper Lake Ranger District has implemented road drainage maintenance activities on approximately 12 miles of forest road in the Middle Creek and Nice-Lucerne watersheds, maintained approximately 19.5 miles of off-highway vehicle (OHV) trails, decommissioned 800 feet and closed 250 feet of OHV trails and constructed a native vegetation sediment basin adjacent to the OHV practice area in the Middle Creek camp ground (USFS, 2011). Additional efforts the USFS has and is implementing can be found in Appendix A.

United States Bureau of Land Management

USBLM, in coordination with the Scotts Valley Band of Pomo Indians, received a grant from the National Fish and Wildlife Foundation, Tribal Wildlife Grant Program, in the amount of $187,670 for the Eightmile Valley Sediment Reduction and Habitat Enhancement Project Design. Additional funding was received by the Tribe from the U.S. Bureau of Reclamation in the amount of $50,000. One component of this project is monitoring sediment loads from this area, which are expected to be lessened considerably with project implementation. This project is recognized by Clear Lake Watershed stakeholders as central to controlling sediment entering the Lake.

Recent Research

In 2009-2010, Lake County contracted with University of California – Davis to update the analysis of the California Department of Water Resources Clear Lake data set. In 2010 and 2011, Lake County staff assisted Dr. Cecile Mioni, a University of California – Santa Cruz post-Doctoral researcher, in evaluating Clear Lake for cyanotoxin productions. Her research has provided additional insights to Clear Lake's current limnological functions. Lake County is moving forward with working with Dr. Mioni and other researchers to further their understanding of phosphorus and other variables on the growth of blue-green algae with additional work in 2012 - 2013.

Conclusion

The Clear Lake phosphorus control program was built on the premise that phosphorus load reductions will result in reduced lake phosphorus

concentrations that will limit the growth of cyanobacteria. It is reasonable to assume that actions implemented to reduce sediment discharges to the Lake (see Appendix 1) have reduced overall phosphorus loads to the Lake, thereby reducing lake phosphorus concentrations. It is clear that we have not reached phosphorus concentrations in the Lake that would limit algal production and we lack definitive information on phosphorus load reductions from the various sources, to the Lake.

The trend of increasing water clarity that generally occurred from 1990 to around 2004 provided some comfort that we were headed in the right direction with regard to sediment control. However, since 2004, the incidence of nuisance conditions has increased, so there is renewed concern about the control efforts.

The control program lists the single largest phosphorus input reduction project as the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project. As we discussed earlier, this project is still, at best, several years from implementation, as land is still under acquisition. Therefore, it is important that other sources contributing phosphorus to the Lake are implementing phosphorus reductions according to the allocations in the adopted control program.

Since 2009, the predominant bloom-forming cyanobacteria are characterized by *Lyngbya* in July/August and *Microcystis* in September/October. *Lyngbya* had been present in Clear Lake in the past but was not a nuisance prior to 2009. It has been suggested that the increase in clarity since the 1990's may have led to the predominance of *Lyngbya* since 2009. The fact that both nitrogen-fixing and non-nitrogen-fixing cyanobacteria taxa are now coexisting in the Lake, raises concern as to whether P, N, or both P and N inputs should be controlled to mitigate the cyanobacteria.

Mioni et al. (2012) suggested that the ability to mitigate cyanobacteria blooms in Clear Lake relies on more than one single nutrient. Although results suggest that phosphorus is a key variable….results also highlight the importance of other environmental variables such as temperature and nitrogen....The success of non-nitrogen fixers, such as *microcystis aeruginosa*, during summer (nitrogen-limiting and phosphorus-replete conditions) suggests that internal nitrogen-cycling might be an important environmental driver to consider. Mioni also notes that other variables, such as light, dissolved organic nitrogen, trace metals, iron and sulfates may influence blue-green algae occurrence and severity.

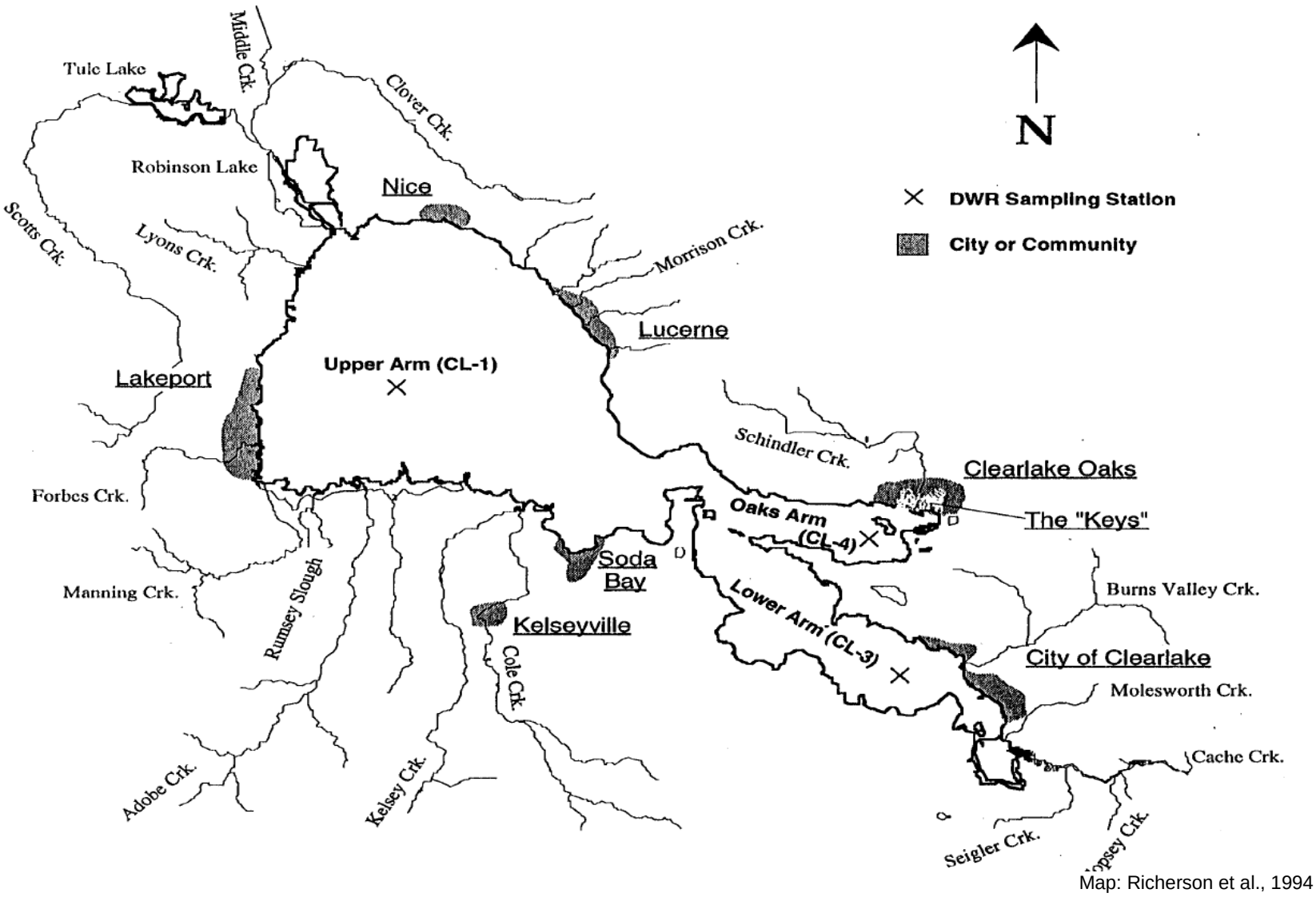
Staff Conclusions and Recommendations

After a review of all available information, staff has four main conclusions.

- The TMDL adopted by the Central Valley Water Board in 2006 for control of phosphorus in Clear Lake is still appropriate.
- TMDL responsible parties have taken numerous actions directed toward reducing phosphorus inputs to the lake, including developing management plans, implementing sediment reduction BMPs, applying for planning and implementation grants, and conducting monitoring. Nevertheless, there is inadequate information available to 1) determine current phosphorus loading to the Lake from the various sources, 2) evaluate the effectiveness of implemented phosphorus control practices, and 3) evaluate overall compliance with the TMDL.
- Staff agrees with the conclusion of researchers that factors (in addition to phosphorus) likely play a role in determining the occurrence of bloom conditions and that more study is needed to evaluate these factors.
- The 2017 TMDL compliance date may be unrealistic because a major component of the implementation plan (Middle Creek Flood Damage Reduction and Ecosystem Restoration Project) is behind schedule despite efforts by Lake County to move this project forward.

Based on the above conclusions, staff should implement the following actions:

- Responsible parties should 1) aggressively implement sediment reduction BMPs to decrease phosphorus loading to the Lake, 2) evaluate the effectiveness of BMPs in reducing phosphorus loading to the Lake and 3) provide this information to the Central Valley Water Board on an annual basis. Staff will consider regulatory options if the above actions are not implemented.
- Staff will continue to support efforts by the County and other stakeholders to obtain grant funding for monitoring, implementing phosphorus reduction practices, and evaluating factors (other than phosphorus) that influence the frequency and duration of nuisance algae blooms.
- Staff will continue to support efforts of the County in obtaining grants and other help to move the Middle Creek Flood Damage Reduction and Ecosystem Restoration project forward.
- Staff will consider the need for a Basin Plan amendment to change the 2017 compliance time line.



Map: Richerson et al., 1994

Figure 1. Clear Lake

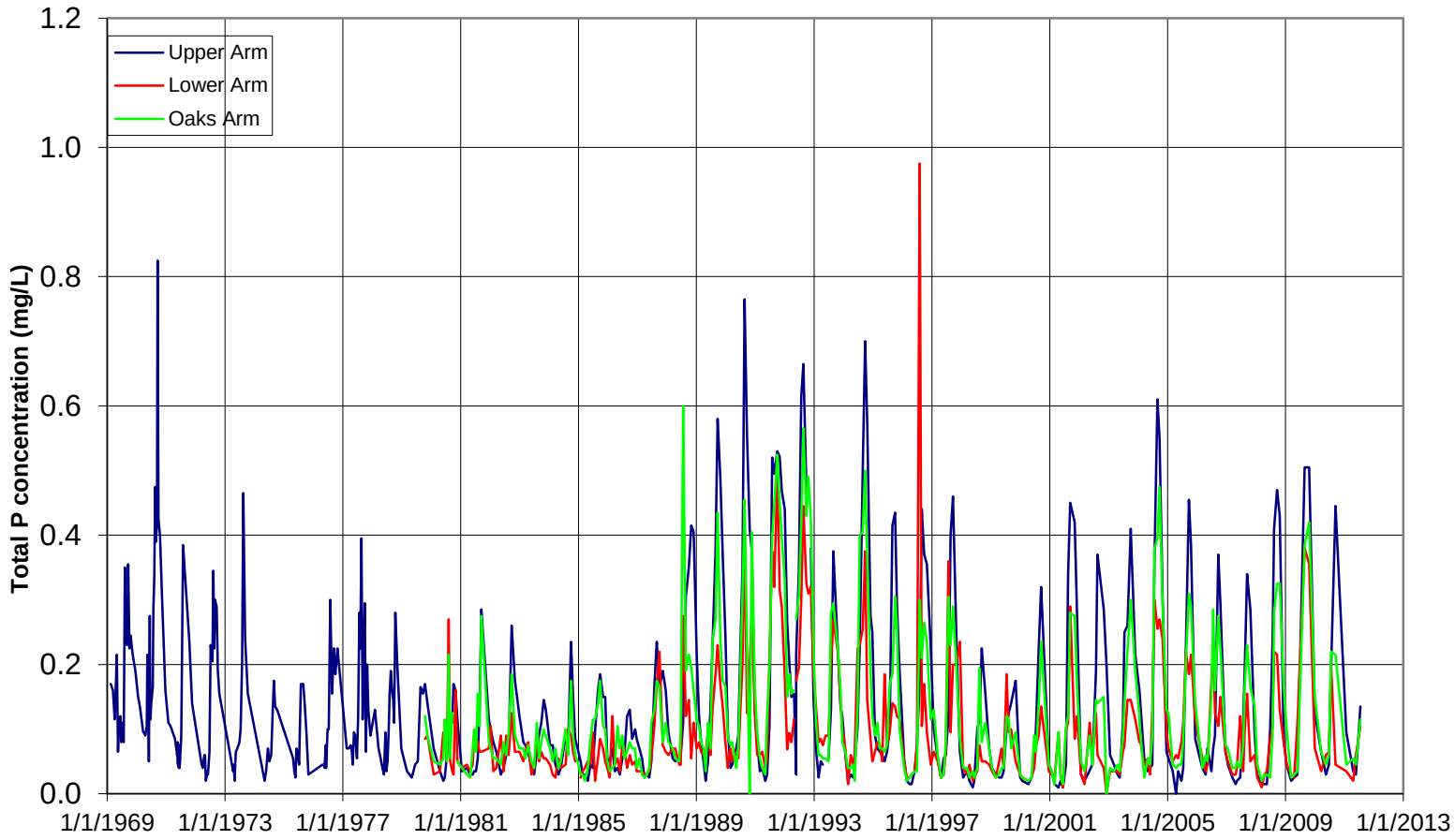


Figure 2. Total Phosphorus in Water Column, 1969-2010

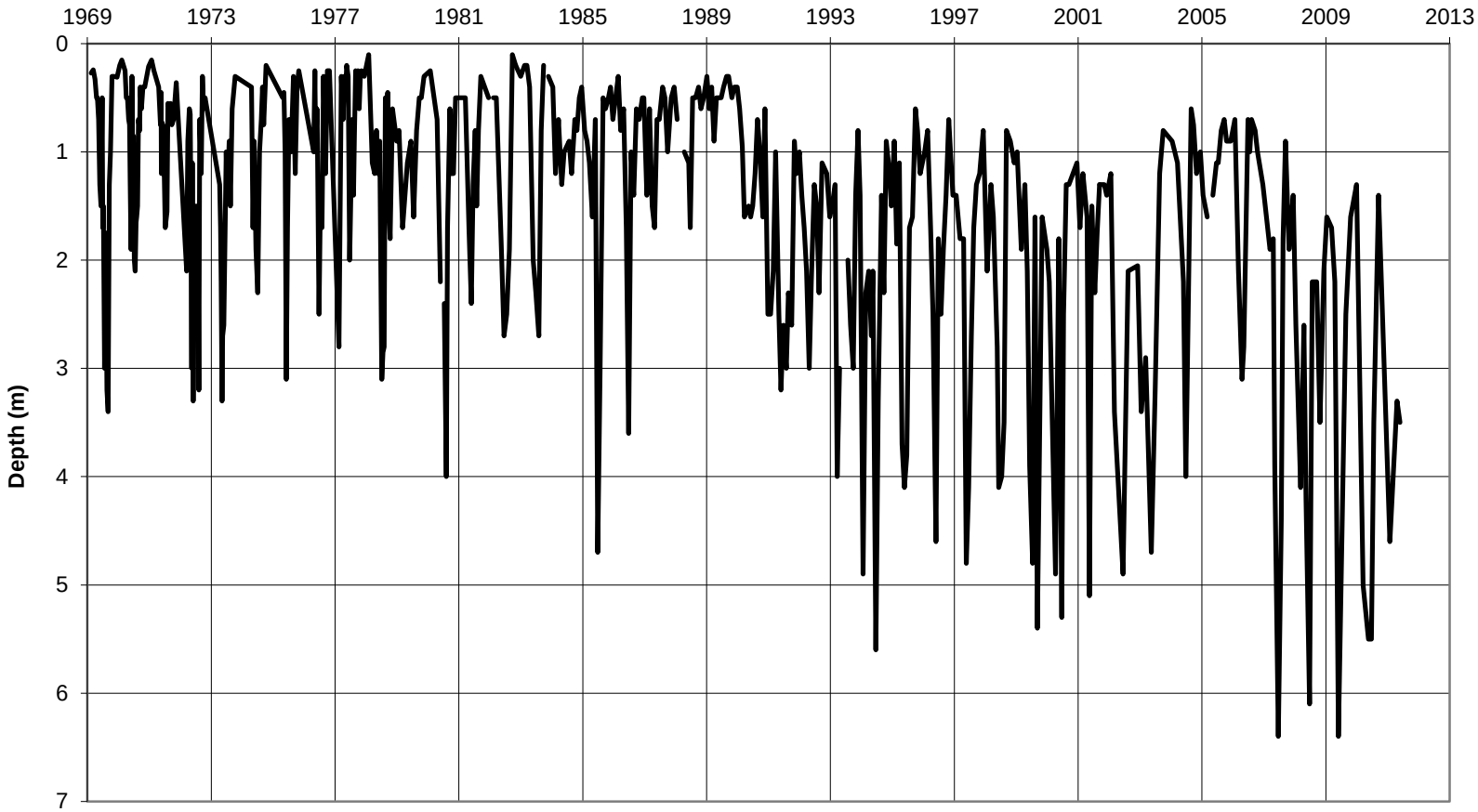


Figure 3. Clear Lake – Upper Arm Secchi Depth, 1969-2011

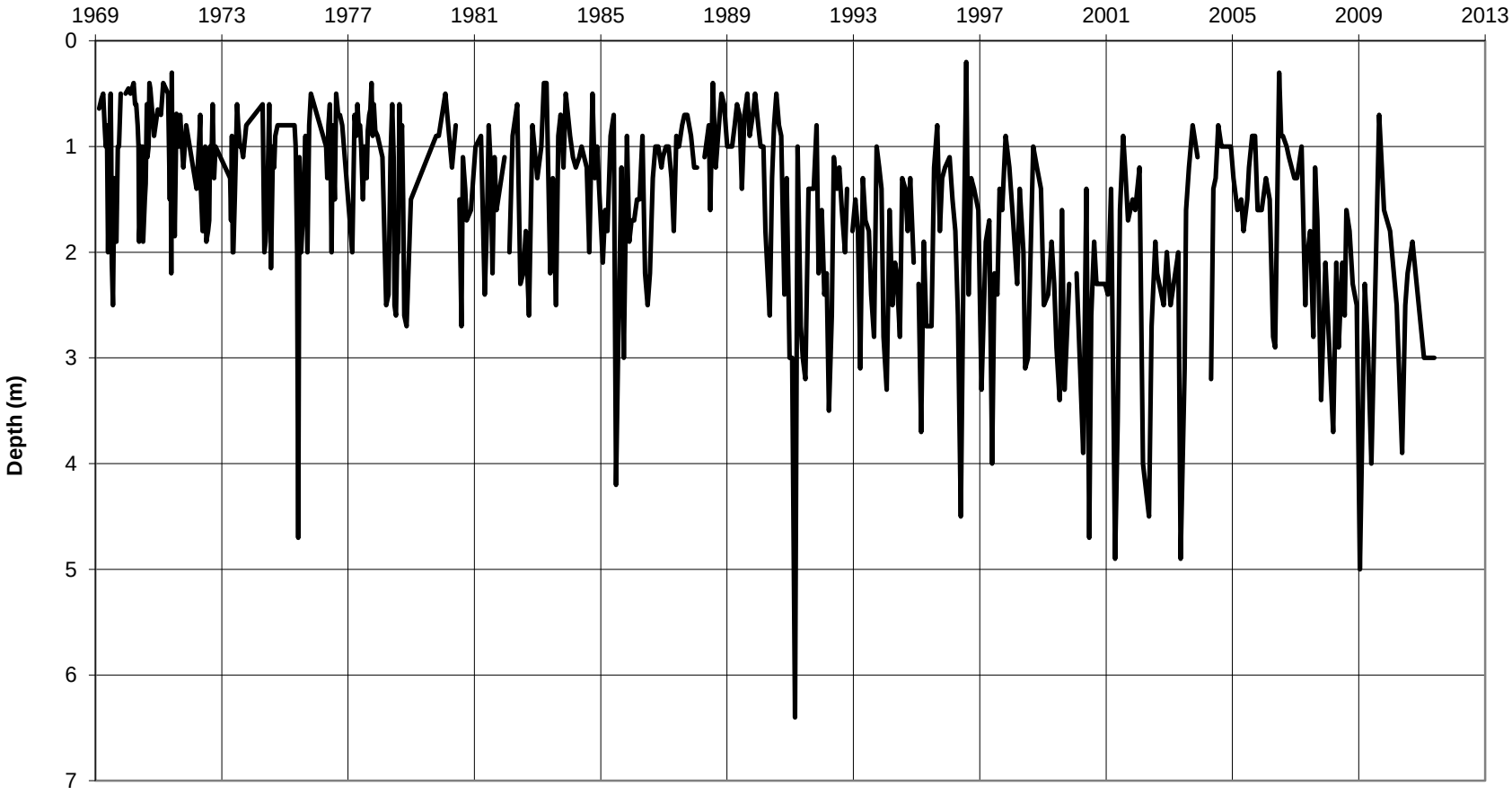


Figure 4. Clear Lake – Lower Arm Secchi Depth, 1969-2011

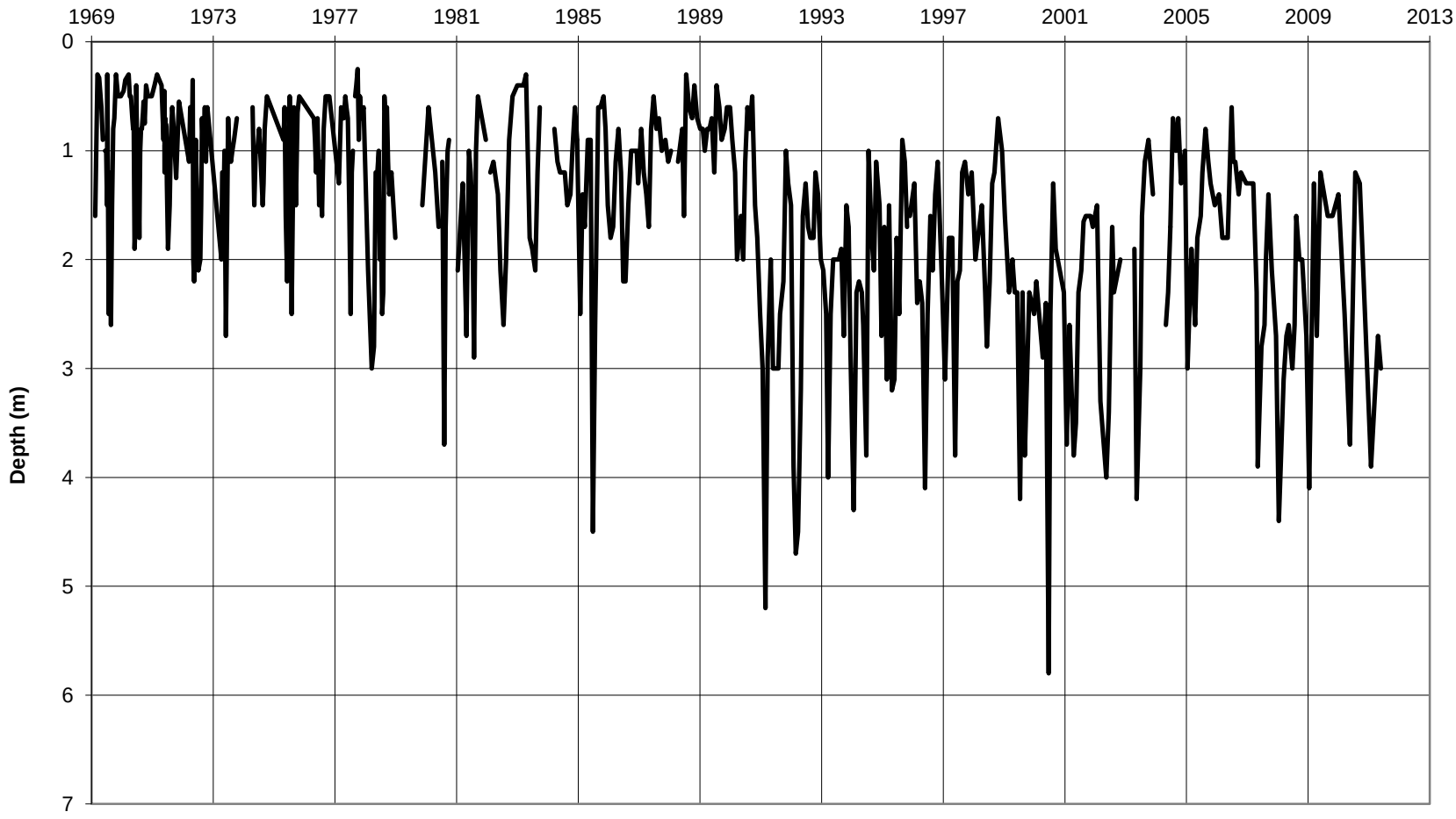


Figure 5. Clear Lake – Oaks Arm Secchi Depth, 1969-2010

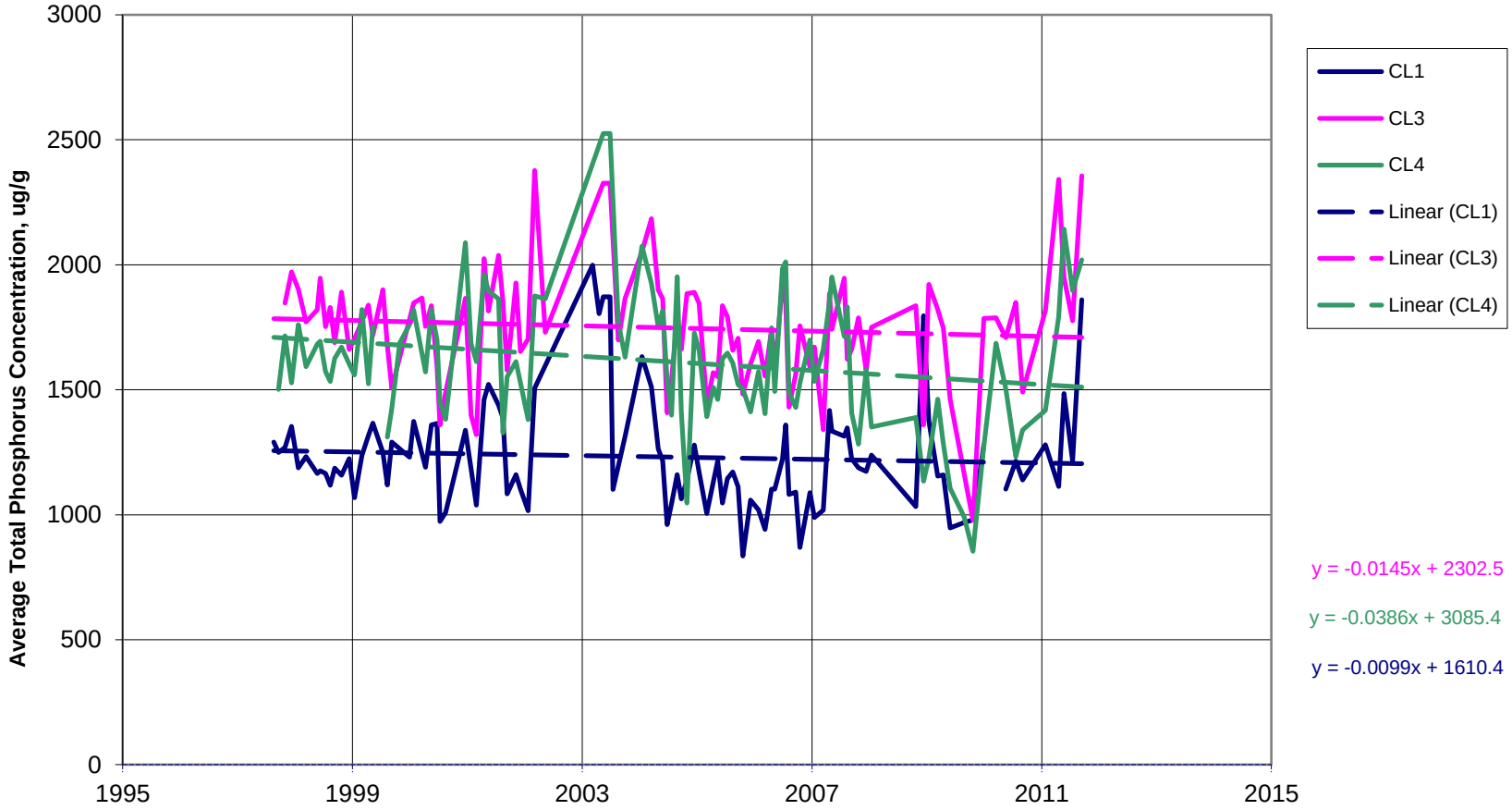


Figure 6. Average Total Phosphorus Concentrations in Top 10 cm of Clear Lake Sediments

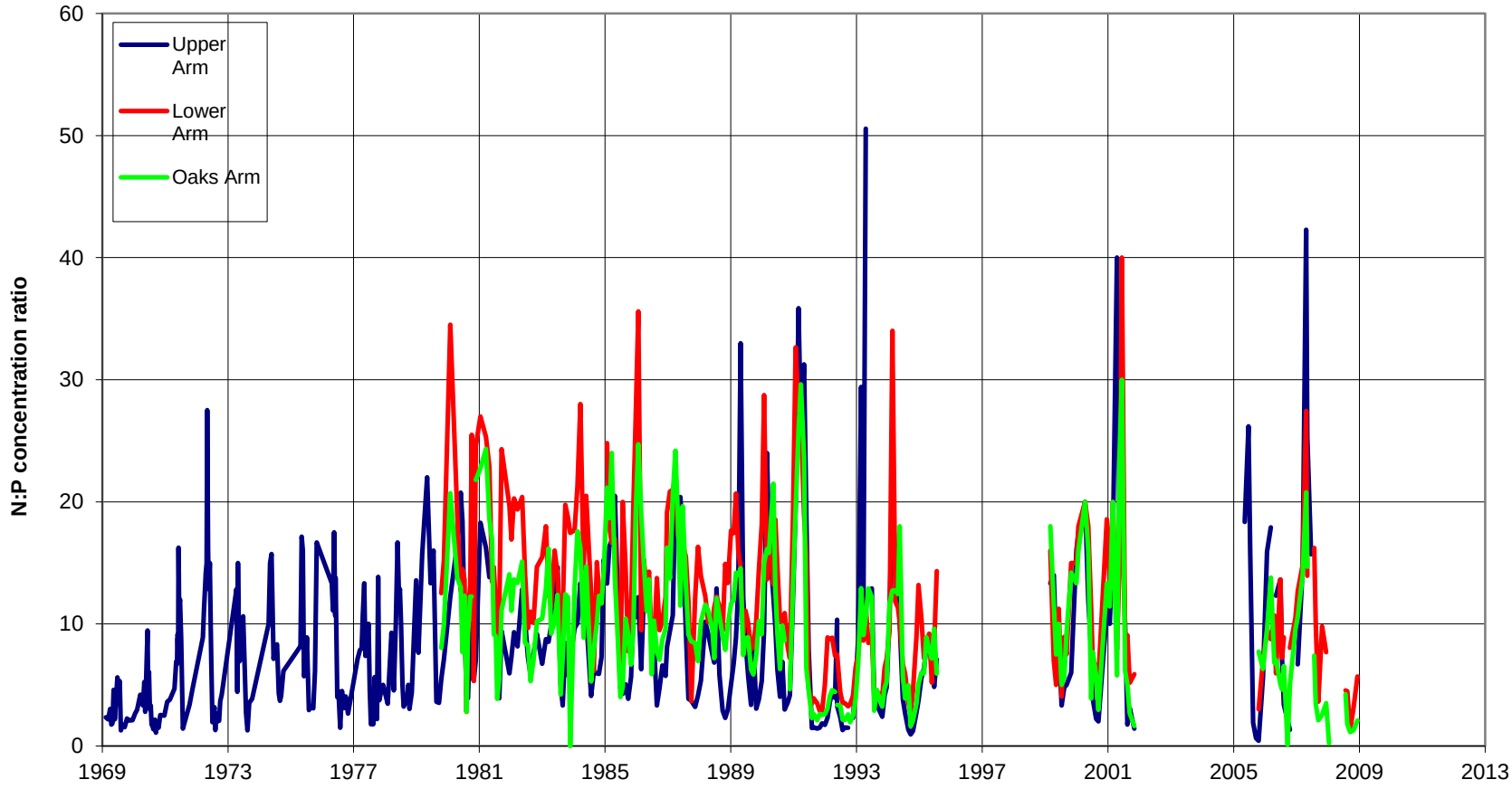


Figure 7. N:P Concentration Ratios, Clear Lake, 1969-2010

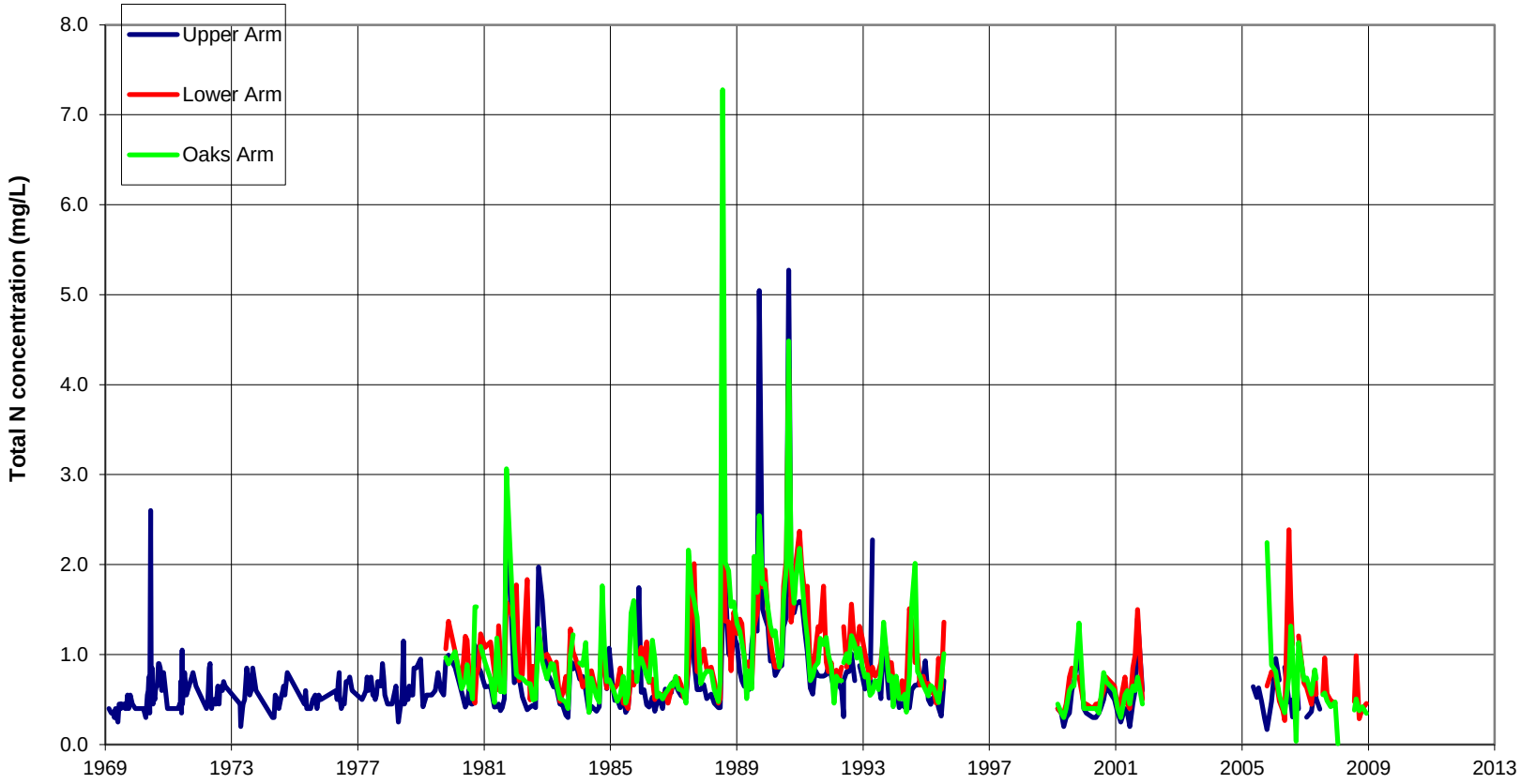


Figure 8. Total Nitrogen Concentration in Water Column, 1969 to 2010

Appendix A

Status of TMDL Implementation Efforts (primarily 2006 to 2011)

Central Valley Water Board Staff Efforts to Coordinate TMDL Implementation

Central Valley Water Board staff has been working with Clear Lake stakeholders to implement the TMDL. Staff efforts include, but are not limited to, providing technical guidance, reviewing plans, guidance and environmental documents to ensure consistency with TMDL objectives, enforcement coordination, and attendance to meetings, such as the Lake County Coordinating Resource Management Committee, Lake County Clean Water Program Advisory Council, Lake County Board of Supervisors meetings, and other interested stakeholder meetings as requested. Central Valley Water Board staff maintains a positive working relationship with Clear Lake Watershed stakeholders and are routinely contacted about local issues.

Central Valley Water Board staff work with Clear Lake Watershed stakeholders to ensure activities across the watershed are not counter- productive to actions and efforts implementing the Clear Lake Nutrient TMDL objectives. These types of actions may include, the incorporation of best management practices (i.e., water pollution controls) to control erosion in proposed projects and actions located within the Clear Lake Watershed, which are subject to the California Environmental Protection Act (CEQA) and National Environmental Policy Act (NEPA), respectively. For all local and state proposed projects subject to CEQA, environmental documents should address water quality issues, as applicable. During the CEQA review process, mitigation measures should incorporate best management practices pertaining to erosion control to reduce proposed local and state project impacts to less than significant, as applicable and feasible. Similarly, for all federal proposed actions subject to NEPA, environmental documents should address water quality issues, as applicable. During the NEPA review process, environmental commitments should suggest best management practices pertaining to erosion control be incorporated to reduce proposed action impacts, as applicable and feasible.

Specific Highlighted Actions

Land management agencies have collaborated and coordinated in the development and preparation of implementation plans. For example, in October 2008, Central Valley Water Board staff approved the *Monitoring and Implementation Plan, Clear Lake Mercury and Nutrient TMDLs,* that was developed by Lake County, in coordination and collaboration with land management agencies and other Clear Lake Watershed stakeholders, for both

the Clear Lake Nutrient TMDL and Clear Lake Mercury TMDL (Lake County, 2008a). The *Monitoring and Implementation Plan* describes the Nutrient and Mercury TMDLs and stakeholder efforts or plans to monitor and implement nutrient and mercury reduction and will be periodically updated. A Memorandum of Understanding formalizing the stakeholder's intent and willingness to leverage resources, share information and cooperate in the development of the implementation plan was submitted as part of this approved package.

Tribes and other Clear Lake stakeholders routinely collaborate and coordinate with the land management agencies to improve the water quality of the Clear Lake Watershed. Efforts include, but are not limited to, watershed coordination, water quality and sediment sampling, best management practice implementation, annual creek cleanup events, streambank restoration or stabilization projects, off-highway vehicle trail maintenance, public education and outreach, and collaborations to pursue plan or project funding.

Hereon, specific actions are listed in federal, state, and local order.

Federal Agencies and Actions

United States Bureau of Land Management

The following actions have contributed to or will contribute to the reduction of sediment loading to Clear Lake:

- In 2011, USBLM, in coordination and collaboration with other Clear Lake Watershed stakeholders, was awarded a grant for the Eight Mile Valley Sediment Reduction and Habitat Enhancement project. One component of this project is monitoring sediment loads from this area, which are expected to be lessened considerably with project implementation. This project is recognized by Clear Lake Watershed stakeholders as central to controlling sediment entering the Lake.

- The USBLM has developed an *Off-Highway Vehicle (OHV) Wet Weather Closure Policy for the South Cow Mountain OHV Area*, a popular OHV recreational area in the watershed. The policy provides a temporary closure to all motorized vehicles during specific conditions to reduce erosion.

- The USBLM conducts annual trail maintenance in the Cow Mountain Recreation Area, with a goal of minimizing soil loss, which ultimately reduces soil loss and sediment production.

- USBLM is initiating a soil monitoring program for the South Cow Mountain OHV Area, which will include a plan for revegetation.

- USBLM maintains a program or plan for fire suppression.

- USBLM does not authorize grazing allotments or grazing leases around Clear Lake.

- In 2006, USBLM issued the *Ukiah Resource Management Plan*, which presents the decisions and visions for management areas in the Ukiah Field Office, including Cow Mountain. For water resources, USBLM has listed several objectives, including "achieve and maintain the beneficial uses of water bodies as outlined by the Regional Water Quality Control Board Basin Plans." This document also notes mitigation measures for sediment erosion control under soil resources (USBLM 2006).

United States Forest Service

The following actions have contributed to or will contribute to the reduction of sediment loading to Clear Lake:

- As a result of a 1996 fire that burned approximately 30% of the Middle Creek subwatershed, the USFS has implemented fuel reduction projects to reduce the potential of a wildfire that could increase sediment inputs to the Lake. Specifically, the USFS continues to implement fuel reduction projects within the watershed, which include prescribed fires, mastication of fuels, and fuel breaks in the Mendocino National Forest. These projects are designed to reduce the size and impact of future unintentional fires, which can lead to large areas susceptible to sediment production.

- The USFS continues to implement watershed improvement projects and to update their Watershed Improvement Needs Inventory. Projects include rerouting problem OHV trail segments and installing a sediment buffer strip along the Middle Creek open riding area. The USFS has inventoried unsurfaced roads in the Middle Creek Watershed, landslide mapping was completed and the agency is pursuing funding sources to implement road improvements to alleviate identified road based problems. USFS efforts implementing best management practices to control erosion in an effort to maintain roads and trails of the Mendocino National Forest lands is notable in the Clear Lake Watershed.

- There are several active grazing allotments on USFS lands within the watershed. Livestock grazing is allowed to occur in the Mendocino National Forest under permit. Herds are small in size and the permittees are required to follow best management practices as a condition of their permit.

- The USFS uses the GYR (green-yellow-red) trail monitoring protocol developed in conjunction with Roger Poff and the State OHV Commission. The results of the monitoring are reported annually to the Off-Highway Motor Vehicle Recreation Commission, California Department of State Parks.

- The USFS Pacific Southwest Region (Region 5), which includes the Mendocino National Forest, is party to the 1981 Management Agency Agreement with the State Water Resources Control Board (State Water Board) pertaining to water quality in the State. As part of this agreement, the USFS uses the *Best Management Practices Evaluation Program User's Guide, Investigating Water Quality in the Pacific Southwest Region*, June 2002 (USFS, 2002). This guide directs the evaluation of best management practices for all of the forests actions from fuel reduction projects to foot trail, OHV trail and road maintenance. All of the monitoring performed to comply with the agreement is housed in a regional database.

- In 2009, the USFS, Pacific Southwest Region (Region 5), published the *Water Quality Protection on National Forests in the Pacific Southwest Region: Best Management Practices Evaluation Program*, 2003-2007 (USFS, 2009a). This document summarized the randomly selected onsite evaluations of best management practice implementation and effectiveness over a five-year period. Results are region wide, and include those implemented in the Mendocino National Forest.

- The USFS annually developed a *Soil Conservation Plan* for the Mendocino National Forest OHV Motor Vehicle Recreation Program (USFS, 2009b). This plan outlines protocols for assessment, maintenance and monitoring of trails used for authorized OHV use, and implementation of best management practices. USFS OHV monitoring is reported annually to the OHV Commission as part of the Soil Conservation Strategy submitted each grant cycle.

- Pursuant to State Water Resources Control Board Resolution No. 2009-0064, *Directing Staff to Develop a Statewide Approach Addressing Forest Activities on National Forest System Lands, including Timber Harvesting, Grazing, Off-Road Vehicle Recreation and Fire Suppression*, the State Water Board, in collaboration with USFS Region 5, is developing a new Water Quality Management Plan (SWRCB, 2009a). This plan will address control of nonpoint source pollution generated by various activities on National Forest System lands in California including the Mendocino National Forest. More effective best management practices have been developed for several forest management activities, including roads, OHV trails, and range management. This new plan will replace the existing

plan which was originally certified by the State Water Board in 1981 and is intended to be the basis for a State Water Board regulatory action. This process is underway and expected to be completed by February 2011 (SWRCB, 2010).

Tribal Actions

Collectively, the Tribes have been instrumental in conveying and collaborating on Lake County water quality projects. The Tribal Environmental Departments are actively participating on the following committees:

- California Environmental Protection Agency Tribal Advisory Board Member
- California Indian Environmental Alliance
- Chi Council
- Clarks Island Restoration Workgroup
- Clear Lake Advisory Committee
- Clear Lake Planning Taskforce
- Hinthil Environmental Resource Consortium (HERC)
- Integrated Regional Water Management Program
- Invasive Species Council
- Lake County Coordinating Resource Management Committee
- Lake County Coordinated Resource Management and Planning groups
- Nice Mutual Water Board Member
- Sacramento River Watershed Program Trustee
- State Water Board – Biological Objectives Stakeholders
- TMDL Stakeholder Committee
- Tribal Regulatory Environmental Taskforce
- USEPA Regional Tribal Operations Committee

Tribal outreach and education includes:

- Alternative Energy research and implementation outreach to Tribal communities
- Annual Tule Boat Festival held at Big Valley Rancheria
- Earth Day events
- Environmental Campouts
- Kids-In-The Creek Day held at Middle Creek and Field Days are held in Middletown
- Lake County Fair HERC booth
- Present current environmental trends and conditions at regional USEPA Tribal Conferences and meetings
- Supplemental environmental inserts into monthly Tribal newsletters

- Tribal watershed outreach presentation at public schools

State Agencies and Actions

California Department of Transportation

The following actions have contributed or will contribute to the reduction of sediment loading to Clear Lake:

- In September 2008, Central Valley Water Board staff approved an implementation plan to install four (4) monitoring stations at sites along the northern portion of Clear Lake where Caltrans facilities lie in close proximity to the Lake (Caltrans, 2008). Flow weighted composite samples will be collected from these stations in order to estimate the concentration of total phosphorus in the runoff. Data will need to be collected for at least two years before current loads can be assessed. Once current loads have been established, a compliance plan will be developed that will include best management practices that are feasible and effective in controlling phosphorus loading.

- The monitoring stations were installed in October 2010 and have captured two storm events. Two of the stations had no flow during the rain events, Stations 1 and 3. Caltrans has recommended relocating monitoring Station 1 and implementing flow monitoring modifications to Station 4, which experienced unexplained dry weather flows (Caltrans, 2011).

- Caltrans maintains a statewide Stormwater Program, which integrates appropriate stormwater control activities into ongoing projects, making control of stormwater pollution a part of Caltrans normal business practices (Caltrans, 2003). The Stormwater Program includes a *Stormwater Management Plan*, District workplans, monitoring and best management practice development, public education, and guidance for design, construction and maintenance activities (Caltrans, 2007). The *Stormwater Management Plan* identifies how Caltrans will comply with the provisions of the National Pollutant Discharge Elimination System (NPDES) permit Order No. 99-06-DWQ, issued by the State Water Board on July 15, 1999 (SWRCB, 1999). Caltrans' Municipal Separate Storm Sewer System (MS4) permit (Order 99-06 DWQ) is being renewed.

- In 2010, in accordance with Caltrans' Stormwater Program, the *District 1 Workplan for the North Coast and Central Valley Regions for Fiscal Year 2010-2011* has been developed. This workplan outlines activities that will implement the program during the next fiscal year, including those activities located within the Clear Lake Watershed (Caltrans, 2010).

- Caltrans implements best management practices for both construction and maintenance activities as part of Caltrans normal business practices. In addition Caltrans installs and maintains post construction best management practices on new projects throughout Clear Lake Watershed.

Local Agencies and Actions

Lake County, City of Clearlake and City of Lakeport

Lake County, City of Clearlake and City of Lakeport are co-permittees in the Municipal Stormwater Program, thus this discussion integrates all three jurisdictions. The following actions have contributed to or will contribute to the reduction of sediment loading to Clear Lake:

- As co-permittees in the Municipal Stormwater Program, the County and Cities have collaborated and coordinated in the development of a Stormwater Management Plan (Lake County, *et al.* 2003a). This plan describes the Lake County Clean Water Program's approach to reducing storm water pollution, while serving as the basis for the National Pollution Discharge Elimination System (NPDES) permit application to the Central Valley Water Board (Lake County, *et al.* 2003b). This plan contains a component to review and evaluate impacts to storm water from existing road repair and maintenance activities, including the development of best management practices. The Lake County Clean Water Program was developed as requirement of the NPDES Phase II regulations and is compliance with the provisions described in NPDES General Permit No. CAS000004 (Lake County, *et al*, 2003b; SWRCB 2003). This permit is being renewed and a new draft permit was released for comment in summer 2011. The new permit is expected in 2012.
  The Stormwater Management Plan describes best management practices, and associated measurable goals, that include:

  - Public participation and outreach on storm water impacts;
  - Public involvement/participation;
  - Illicit discharge detection and elimination;
  - Construction site storm water runoff control;
  - Post-construction storm water management in new development and redevelopment; and
  - Pollution prevention/good housekeeping for municipal operations.

- The County and Cities have made significant progress in addressing these minimum control measures. The County and Cities participate in regular meetings of the Lake County Water Quality Council and produce an annual report on the planning and implementation efforts of the Lake County Clean Water Program (Lake County, *et al.* 2011b). Most notably,

the County and Cities have collaborated in an a public outreach and education campaign, providing pertinent storm water information on the Lake County and City of Lakeport's websites (Lake County 2009c, 2010a). The County and Cities have also completed a project mapping inputs and outflows of storm water drains within their jurisdictions.

- Construction projects within the Clear Lake Watershed implement maintenance and post-construction best management practices as applicable and in accordance with State Water Resources Control Board's Construction General Order No. 2009-0009-DWQ, effective September 2011 (SWRCB, 2009a).

- The Lake County Clean Water program includes the Construction Site Runoff Control (CON) Program. One goal of this Program is to reduce the discharge of storm water pollutants to the maximum extent practicable (MEP) by: (1) requiring construction sites to reduce sediment in site runoff; and (2) requiring construction sites to reduce other pollutants such as litter and concrete washout wastes through good housekeeping procedures and proper waste management. To achieve this goal, the following objectives have been developed:
    - Effectively prohibit non-storm water discharges and require controls to reduce the discharge of pollutants during construction;
    - Minimize land disturbance at construction sites;
    - Protect water quality from pollutants generated by construction activities;
    - Require BMP implementation at construction sites; and,
    - Develop and implement measurable goals to evaluate the success of the BMPs.

- In 2009, the final report for the 2003 Proposition 13 grant was submitted by Lake County and approved by Central Valley Water Board staff (Lake County, 2009a). The grant was awarded for $147,182 and applied to both the Clear Lake Mercury and Nutrient TMDLs. Specific to the Clear Lake Nutrient TMDL, project objectives included estimating nutrients entering the Lake and the average annual nutrient loading at three key streams with DWR stream gaging stations (Kelsey Creek below Kelseyville, Middle Creek near Upper Lake and Scotts Creek at Eickhoff Road). Results from the monitoring suggest there was a weak flow-nitrogen relationship with no clear pattern, making it difficult to accurately estimate the nitrogen loading. Total phosphorus-flow relationships showed a better correlation, as did total phosphorus-total suspended solids relationship. However, there was no relationship between ortho-phosphate and flow. Total phosphorus estimates were significantly lower than previous estimates, including the TMDL, which estimate the average annual phosphorus load

at 158,000 kg/yr. Flow – concentration regressions were developed for the three locations. Average annual subwatershed loading rates were calculated at all three locations, which were extrapolated to the entire Clear Lake watershed, see Table 1.

Table 1. Watershed Nutrient Loading Estimates

Ortho-P, kg/yr	Total P, kg/yr	Suspended Solids, T/yr	Iron, T/yr	Sulfate, T/yr	Total Nitrogen, T/yr
37,100 – 51,400	89,900 – 125,000	75,000 – 104,000	4,130 – 5,730	1,940 – 2,700	273 – 379

- In 2010, Lake County, in collaboration and coordination with Clear Lake stakeholders, finalized the *Clear Lake Integrated Watershed Management Plan* (Lake County and West Lake Resource Conservation District, 2010b). The plan described past and current conditions of the watershed and watershed management, with a goal to plan and work towards an environmentally and economically healthy watershed that benefits the community and is sustainable for future generations. This plan addresses both surface and groundwater quality concerns.

  In addition to the *Clear Lake Integrated Water Management Plan*, the Kelsey Creek, Middle Creek and Scotts Creek Watershed Assessments were also finalized in 2010 in collaboration and coordination with Clear Lake stakeholders. The purpose of each assessment was to collect and integrate information on past and present watershed conditions and management in order to educate landowners on watershed conditions and management needs (Lake County and West Lake Resource Conservation District 2010c, 2010d, 2010e).

  These plans were completed under a DWR Proposition 50 CalFED Watershed grant for $400,000 obtained by the West Lake Resource Conservation District. The West Lake Resource Conservation District was the grantee and lead agency in the production of each of these plans, and Lake County was a partner in this effort.

- Enforcement of active ordinances, including, but not limited to those listed in the *Lake County General Plan* or other local planning or guidance documents (Lake County, 2008b). Of particular interest is any County or City ordinance relating to development dedications, erosion, grading, sediment control, use of off-highway vehicles, Clear Lake (shoreline or near shoreline), rezoning, and roads.

- Lake County Fire Safe Council promotes fire safety education and encourages citizens to create and maintain defensible space, in order to protect life and property in the event of a wildfire.

References

California Department of Transportation (Caltrans), 2003. *Statewide Storm Water Management Plan*, California Department of Transportation, May 2003

California Department of Transportation (Caltrans), 2007. *Statewide Stormwater Program*, California Department of Transportation. Last updated 2007; accessed November 10, 2010. http://www.dot.ca.gov/hq/env/stormwater/

California Department of Transportation (Caltrans), 2008. *Clear Lake Watershed Nutrient TMDL Evaluation, Final Technical Memorandum*, California Department of Transportation, July 2008.

California Department of Transportation (Caltrans), 2010. *Stormwater Management Program, District 1 Workplan, North Coast and Central Valley Regions, Fiscal Year 2010-2011*, California Department of Transportation, April 10, 2010.

California Department of Transportation (Caltrans), 2011. Interim Monitoring Report 2010-2011 Storm Season Clear Lake Nutrient Data Collection. CTSW-RT-11. 288.03.1. October 2011.

Central Valley Regional Water Quality Control Board (CVWB), 2006. *Amendment to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Nutrients in Clear Lake (Lake County)*, June.

Giusti, Gregory A. 2010. Illicit *Cannabis* production on Forest and Wildland Resources. Power Point Presentation. University of California. April 13, 2010.

Horne, A.J. 1975. The Effects of Copper, Major and Minor Nutrient Element Additions, and Lake Water Movements on Blue-Green Algal Bloom Development in Clear Lake.

Lake County, *et al.*, 2003a. *Agreement Providing for Implementation of the Lake County Clean Water Program*, County of Lake, City of Clearlake and City of Lakeport, 2003.

Lake County, *et al*., 2003b. *Storm Water Management Plan, Fiscal Years 2003-2004 through 2007-2008*, Lake County Clean Water Program, County of Lake, City of Clear Lake and City of Lakeport, 2003.

Lake County, 2008a. *Monitoring and Implementation Plan, Clear Lake*

Mercury and Nutrient TMDLs. Lake County, in cooperation and collaboration with Clear Lake stakeholders, October 21, 2008.

Lake County, 2008b. *Lake County General Plan*, prepared by Matrix Design Group, Mintier & Associates, in association with URS, VWA, ADE, for the County of Lake, September 2008.

Lake County, 2009a. *Clear Lake Watershed TMDL Monitoring Program, Final Report*, Grant Agreement SWRCB No. 03-237-555-0, County of Lake, April 22, 2009.

Lake County, 2009c. *Construction & Development (BMP)*. County of Lake, 2009. Last updated April 29, 2009; accessed March 27, 2012. http://www.co.lake.ca.us/Government/Directory/Community_Development/cwp/Construction.htm

Lake County, 2010a. *Clean Water Program: Illegal Activities Impact Water Quality*. County of Lake, 2010. Accessed March 27, 2012. http://www.co.lake.ca.us/Government/Directory/Community_Development/cwp/impact.htm

Lake County, 2011. Letter from Public Works Director Scott De Leon, County of Lake, to Holly Grover (November 22, 2011), at p. 2.

Lake County, *et al.*, 2011b. *Lake County Clean Water Program, Fiscal Year 2010/2011 Annual Report, submitted in compliance with SWRCB Water Quality Order No. 2003-0005-DWQ, NPDES General Permit No. CAS000004*. County of Lake, City of Clearlake, and City of Lakeport, September 15, 2011.

Lake County, 2012. Memo from Tom Smythe, Water Resources Engineer with the Department of Water Resources. Sediment Phosphorus Monitoring and Trends. January 9, 2012

Lake County and West Lake Resource Conservation District, 2010a. *Clear Lake Integrated Watershed Management Plan*, Lake County Watershed Protection District, in collaboration with Clear Lake stakeholders, February 2010.

Lake County and West Lake Resource Conservation District, 2010c. *Kelsey Creek Watershed Assessment*. Lake County Watershed Protection District, in collaboration with Clear Lake stakeholders, February 2010.

Lake County and West Lake Resource Conservation District, 2010d. *Middle Creek Watershed Assessment*. Lake County Watershed Protection

District, in collaboration with Clear Lake stakeholders, February 2010.

Lake County and West Lake Resource Conservation District, 2010e. *Scotts Creek Watershed Assessment*. Lake County Watershed Protection District, in collaboration with Clear Lake stakeholders, February 2010.

Larry Walker Associates, 2011. *Clear Lake Nutrient TMDL Progress Information Request, Memorandum* to Bruce Houdesheldt, NCWA. November 23, 2011.

Mioni et al., 2012. Cecile Mioni, Raphael Kudela, and Dolores Baxa. "Harmful cyanobacteria blooms and their toxins in Clear Lake and the Sacramento-San Joaquin Delta (California). April 2012.

Richerson et al., 1994. Richerson, P. J. and Suchanek, T. H. and Why, S. J., "The Causes and Control of Algal Blooms in Clear Lake, Clean Lakes Diagnostic/Feasibility Study For Clear Lake, California." University of California, Davis.

Richerson et al., 1997. Richerson, P. J., Stauffacher, K., Suchanek, T. H., Vaughn, C.E., Thibeau, D. and, Why, S. J., "The Phosphorus Cycle in an Iron Limited Lake", First Annual Clear Lake Science and Management Symposium Proceedings Volume, 1997.

Richerson et al., 2000. P.J. Richerson, T.H. Suchanek, J.C. Becker, A.C. Heyvaert, D.G. Slotton, J.G. Kim, X. Li, L.M. Meiller, D.C. Nelson, and C.E. Vaughn. *The History of Human Impacts in the Clear Lake Watershed (California) as deduced from Lake Sediment Cores*.

Richerson et al., 2008. Richerson, Peter J., Thomas H. Suchanek, Robert A. Zierenberg, David A. Osleger, Alan C. Heyvaert, Darell G. Slotten, Collin A. Eagles-Smith, and Charles E. Vaughn, "Anthropogenic Stressors and Changes in the Clear Lake Ecosystem Recorded in Sediment Cores," Ecological Applications, 18(8) Supplement, 2008, pp. A257–A283

Schindler 1974. Schindler, D. W. *Eurtrophication and recovery in experimental lakes: Implications for lake management.* Science, 184: pp. 897-899. May 24, 1974.

Schindler et al., 2008. Schindler, David W., R. E. Hecky, D. L. Findlay, M. P. Stainton, B. R. Parker, M. J. Paterson, K. G. Beaty, M. Lyng, and S. E. M. Kasian, "Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment," Proceedings of the National Academy of Sciences, vol. 105, no. 32 pp. 11254-11258. August 12, 2008.

State Water Resources Control Board (SWRCB), 1999. *Fact Sheet for National Pollutant Discharge Elimination System (NPDES) Permit for Storm Water Discharges from the State of California, Department of Transportation (Caltrans) Properties, Facilities, and Activities (Order No. 99-06-DWQ)*. State Water Resources Control Board, July 15, 1999.

State Water Resources Control Board (SWRCB), 2003. *Storm Water Program: The General Permit for the Discharge of Storm Water from Small Municipal Separate Storm Sewer Systems*, State Water Resources Control Board, 2003. Last updated October 14, 2008; accessed November 10, 2010. http://www.waterboards.ca.gov/water_issues/programs/stormwater/sm_municipal_swmp.shtml

State Water Resources Control Board (SWRCB), 2009a. *National Pollutant Discharge Elimination System (NPDES) General Permit for Storm Water Discharges Associated with Construction and Land Disturbance Activities, Order No. 2009-0009-DWQ, NPDES No. CAS000002*, State Water Resources Control Board, Effective July 1, 2010.

State Water Resources Control Board (SWRCB), 2009b. *Resolution No. 2009-0064, Directing Staff to Develop a Statewide Approach Addressing Forest Activities on National Forest System Lands, including Timber Harvesting, Grazing, Off-Road Vehicle Recreation, and Fire Suppression*, State Water Resources Control Board, August 4, 2009.

State Water Resources Control Board (SWRCB), 2010. *Nonpoint Source Pollution Control Program: Water Quality Management Plan for National Forest System Lands in California*. State Water Resources Control Board Last updated December 6, 2011; accessed March 27, 2012. http://www.waterboards.ca.gov/water_issues/programs/nps/wqmp_forests.shtml

State Water Resources Control Board (SWRCB), 2011. *Draft Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems.* State Water Resources Control Board, September 30, 2011. http://www.waterboards.ca.gov/water_issues/programs/owts/docs/draft_publiccommentd093011.pdf

Tetra Tech. 2004. Total Maximum Daily Load for Nutrients in Clear Lake, Lake County, California, Technical Report. Prepared for the Central Valley Regional Water Quality Control Board. December 1, 2004.

USACE (United States Army Corps of Engineers). 1997. Middle Creek Ecosystem Restoration Reconnaissance Study. US Army Corps of Engineers May 1997.

United States Bureau of Land Management, 2006. *Ukiah Resource Management Plan*, Ukiah Field Office, Bureau of Land Management, United States Department of the Interior, September 2006.

United States Forest Service (USFS), 2002. *Best Management Practices Evaluation Program User's Guide, Investigating Water Quality in the Pacific Southwest Region*, Pacific Southwest Region, Forest Service, United States Department of Agriculture, June 2002.

United States Forest Service (USFS), 2009a. *Water Quality Protection on National Forests in the Pacific Southwest Region: Best Management Practices Evaluation Program, 2003-2007*. Pacific Southwest Region, Forest Service, United States Department of Agriculture, September 19, 2009.

USFS 2011. Letter from Acting Forest Supervisor Lee D. Johnson, United States Forest Service, Mendocino National Forest, to Holly Grover (December 2, 2011).

Winder et al., 2010. Winer, Monika, Reuter, John and Schladow, Geoff. "Clear Lake Historical Data Analysis." University of California, Davis 2010.