Nutrient Numeric Endpoints for TMDL Development: Malibu Creek Case Study

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Abstract:

In this analysis, the recently developed risk-based California nutrient numeric endpoints (NNE) tools were applied to three nutrient impaired streams and four lakes in the Malibu Creek watershed. Site-specific information on nutrient levels, physical conditions (e.g. stream temperature, light), and biological response for sites with different land uses and habitat conditions was used to develop site-specific nutrient targets. The results indicated the calculated nutrient targets are variable among sites, depending on site characteristics. The results suggested a TN target of 1 mg/L and TP target of 0.1 mg/L are generally the upper bound of the targets calculated by the tools. For stream sections with human influence in the surrounding watershed, lower nutrient target values may be required.

1 Introduction

Tetra Tech, under contract to U.S. EPA Region IX and California State Water Resources Control Board, has developed a risk-based approach for estimating site-specific nutrient numeric endpoints (NNE) for California waters. In recognizing the limitation of using ambient nutrient concentrations alone in predicting the impairment in beneficial uses, the proposed approach uses secondary indicators. Secondary indicators are defined as parameters that are related to nutrient concentrations, but are more directly linked to beneficial uses than nutrient levels alone. An example of a secondary indicator that is used in this memo is algal density.

The CA NNE approach also incorporates risk cofactors other than nutrient concentrations and nutrient supply that affect algal productivity including: light availability, flow rate and variability, and biological community structure. The approach also recognizes that there is no scientific consensus on precise levels of nutrient concentrations or response variables that result in impairment of beneficial uses. Therefore, water bodies in California are classified into three categories, termed Beneficial Use Risk Categories (BURCs). BURC I waterbodies are expected to exhibit no impairment in beneficial uses due to nutrients. BURC III waterbodies have high probability of exhibiting impairment due to nutrients. BURC II waterbodies have intermediate probability of showing nutrient-caused impairment, and additional information and analysis may be needed to determine if impairment may occur. Based on a review of the scientific literature, input from regional experts, and Federal guidance documents, Tetra Tech (2006a) proposed preliminary numeric targets of secondary indicators for boundaries between BURC I/II and BURC II/III. Simple modeling tools were also developed to relate secondary indicator targets and water column nutrient concentrations.

One important use of the NNE tool is for setting initial nutrient endpoints for waterbodies requiring nutrient TMDLs. Tetra Tech, under contract to USEPA, will apply the NNE method to develop nutrient endpoints for selected California waterbodies requiring TMDLs. The purpose of these case studies is to demonstrate the NNE process and test and refine the tools. The case study reported here (Malibu Creek watershed) is one of the case studies under this task. The Malibu watershed NNE pilot study provides analyses for three creeks within the watershed including: Medea Creek; Las Virgenes Creek; and Malibu Creek. In addition the pilot study also includes four lakes within the Malibu watershed: Sherwood Lake; Westlake; Lindero Lake; and Malibou Lake. This case study does not address conditions within the Malibu Lagoon estuary. A separate framework for developing nutrient numeric endpoints for estuaries is currently under development by EPA Region IX (Tetra Tech 2006b).

1.1 SITE

Malibu Creek watershed, located about 35 miles west of Los Angeles, California, drains an area of 109 square miles. The watershed extends from the Santa Monica Mountains and adjacent Simi Hills to the Pacific coast at Santa Monica Bay (Bowie et al., 2002, Figure 1). Several creeks and lakes are located in the upper portions of the watershed, and they ultimately drain into Malibu Creek at the downstream end of the watershed. The watershed has seen urban development in recent decades, with a high degree of development occurring along portions of the main tributaries of Malibu Creek (Busse et al. 2006). Lower Malibu Creek also receives discharges from the Tapia waste-water treatment plant.

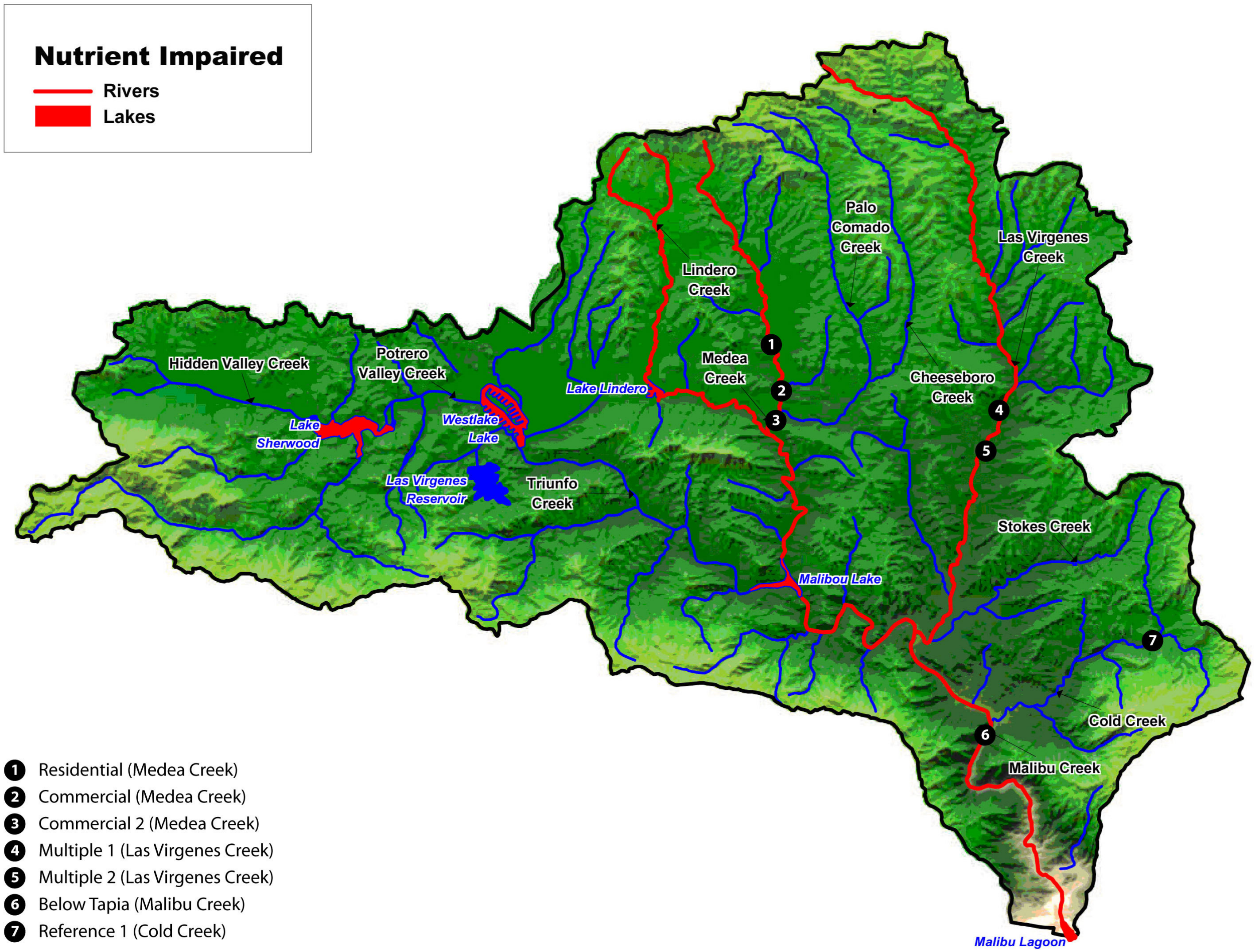

Figure 1. Map of the Malibu Creek watershed showing nutrient-impaired water bodies in red (Bowie et al., 2002). Also identified on this map are sampling locations near different land uses from Busse et al. 2003 that are part of the evaluation presented in Section 2 and 3.

1.2 BENEFICIAL USES AND IMPAIRMENT

The Malibu Creek watershed supports or potentially supports a total of 14 beneficial uses. Among them 10 beneficial uses are sensitive to nutrient inputs and related effects, including: REC1 (Water contact recreation), REC2 (Non-contact Recreation), WARM (Warm freshwater habitat), COLD (Cold freshwater habitat), EST (Estuarine habitat), MAR (Marine habitat), WILD (Wildlife habitat), RARE (Preservation of rare and endangered species), MIGR (Migration of aquatic organisms), and SPWN (Spawning, reproduction, and/or early development). Recreational uses of (REC1 and REC2) apply to all the listed water bodies. WARM is the existing use for all the impaired streams, except in Lower Medea Creek (reach 1) and Lindero Creek where WARM is intermittent use.

Streams/lakes in the Malibu Creek watershed are susceptible to degradation in water quality because of continuing urban development. Data collected in the Malibu Creek watershed has shown elevated algal biomass and macroalgal cover in developed areas, as a result of increases in nutrient and light availability (Busse et al. 2006). Most of the water bodies in the Malibu Creek watershed have been listed under 303(d) for coliforms or algae/nutrient problems (Bowie et al. 2002; EPA Region IX, Table 1). Malibu Lagoon and Malibu Creek upstream of the lagoon, and several tributaries to Malibu Creek (Las Virgenes Creek, Medea Creek, and Lindero Creek) are major areas of concern. Malibu Beach adjacent to the lagoon must be closed occasionally due to high coliform measurements, and water from the lagoon has been implicated as a probable source of the contamination. Streams that feed into Malibu Creek were listed under 303(d) for either coliforms, algae/nutrients, or both problems, including Las Virgenes Creek, Stokes Creek, Medea Creek, Lindero Creek and Palo Comado Creek. In addition, four lakes in the watershed along the tributary stream have been listed for eutrophication problems (algae, nutrients, ammonia, low DO) - Malibou Lake, Lake Lindero, Westlake Lake, and Lake Sherwood.

Table 1. Malibu Creek Watershed 303(d) listed Waterbodies for Nutrients (streams = linear miles listed; lakes = acres listed) (from EPA Region IX)

Waterbody	Algae	Eutrophy	Scum/ Odors	Ammonia	Organic Enrichment	Dissolved Oxygen
Lake Sherwood (Acres)	213	213		213	213	213
Westlake Lake (Acres)	186	186		186	186	186
Lake Lindero (Acres)	14	14	14		14	
Las Virgenes Creek (Miles)	11.25		11.25			11.25
Lindero Creek (Miles)	6.56		6.56			
Medea Creek (Miles)	7.56					
Malibou Lake (Acres)	69	69			69	69
Malibu Creek (Miles)	8.43		8.43			
Malibu Lagoon (Acres)		33				

Currently, the Los Angeles Regional Water Quality Control Board has established bacteria TMDLs for the Malibu Creek. TMDLs for the algal/nutrient problems for the impaired water bodies in the watershed are under development.

1.3 Summary of the Existing Analysis

In 2002, Tetra Tech conducted nutrient and coliform modeling for the Malibu Creek watershed TMDL studies (Bowie et al. 2002). In the study, watershed model HSPF was used to model pollutant loading and transformation in the watershed, streams and the Lagoon, and water quality model BATHTUB was used to model the eutrophication in the four lakes. Pollutant loadings from various sources were estimated.

In the summer of 2001 and 2002, a survey of nutrient and algae in the Malibu Creek Watershed was conducted by University of California, Santa Barbara and Southern California Coastal Water Research Project members (Busse et al. 2003; Busse et al. 2006). In the study, algal biomass (both benthic and floating), nutrient levels (nitrogen and phosphorus), and physical conditions were surveyed in multiple streams with different surrounding land uses and habitat conditions, in order to identify factors and land uses that promote excessive algal growth. High algal levels were found at sites with human influence. The study indicated nutrient and light availability significantly affect algal composition and total algal biomass. The study also indicated that at several locations algal growth is saturated by high nutrient levels and is not nutrient limited.

1.4 Scope of This Effort

As indicated in the study by Busse et al. (2003, 2006), although nutrient concentrations explained a large portion of variation in algal density across sites, other physical parameters such as shading and current speeds also affect to algal growth. Sites downstream of commercial land uses with moderate nutrient concentrations can exhibit high benthic algal density due to high temperature and lack of shading. The availability of site specific data on nutrient levels, algal density, and physical parameters was used to develop site-specific NNE for the Malibu Creek watershed.

2 Data

2.1 Algal Response Data

In 2001 and 2002, algal biomass at different sites with a range of different land use patterns were surveyed by Busse et al. (2003, 2006). For the survey in 2002, benthic and floating algal density were measured separately and for each the sampling site, six sub-habitat types with different light level and current speeds that reflect shading and flow conditions were surveyed. The 2002 survey locations also contained more sites with human influence. Also for the 2002 survey, more complete data were available for August 2002 than June 2002. Therefore for our analysis, we mostly rely on data obtained in August 2002.

For the survey in 2002, seven locations along the main tributaries (Las Virgenes Creek, Medea Creek) and Malibu Creek were included. The sites include one reference site containing open space, one site with a high density residential area, two commercial sites, two sites with multiple land uses, and one site below the Tapia treatment plant. These sites are shown in Figure 1. The two multiple land use sites on Las Virgenes Creek were influenced by both residential development and historical sludge injection fields.

Within each site, six sub-habitat types with different combination of shading and flow conditions including shaded pools, shaded runs, shaded riffles, sun pools, sun runs and sun riffles were surveyed, if that sub-habitat type is available. For each sub-habitat type, three equally spaced cross-stream transects were established. Benthic algae were sampled at five evenly spaced locations along each transect. Chlorophyll a concentrations for benthic algae samples were averaged for each sub-habitat type. Besides chlorophyll a, ash free dry mass (AFDM) was also measured for each sample in the laboratory. Table 2 lists algal response data in the August 2002 survey. The observed chlorophyll a was highly variable among different sites and sub-habitats. Commercial 1 sun run site showed the highest average benthic chlorophyll a concentrations of 969.2 ± 482.5 mg/m^2. The chlorophyll a to AFDM ratio ranges from 2.7 to 14.3.

Table 2. Summary of benthic chlorophyll a and AFDM data from the August 2002 survey (Busse et al. 2003).

Creek	Land Use	Sub-Habitat	Average Benthic chlorophyll a (mg/m^2)	Maximum Periphyton chlorophyll a (mg/m^2)	Average Ash Free Dry Mass (g/ m^2)	Chlorophyll a/AFDM ratio
Medea Creek	Residential 1	Sun Riffle	165.1	194	34.8	5.0
Medea Creek	Residential 1	Shade Riffle	50.0	62.4	10.7	4.8
Medea Creek	Commercial 1	Sun Run	969.2	1628	210.3	4.1
Medea Creek	Commercial 1	Sun Riffle	110.9	245.5	44.9	2.7
Medea Creek	Commercial 2	Sun Pool	133.1	257	40.6	3.2
Medea Creek	Commercial 2	Sun Run	73	194	29.2	3.5
Medea Creek	Commercial 2	Sun Riffle	66.9	134	24.6	3.7
Las Virgenes	Multiple 1	Shade Run	383.9	566	45.7	8.0
Las Virgenes	Multiple 1	Shade Riffle	504.0	670.9	53.5	9.3
Las Virgenes	Multiple 2	Sun Run	102.6	151.9	85.3	3.1
Las Virgenes	Multiple 2	Shade Run	531.1	701.7	79.9	6.7
Las Virgenes	Multiple 2	Shade Riffle	255.9	264.4	21.5	12.5
Malibu Creek	Below Tapia	Shade Run	341	717.4	32.9	14.3
Malibu Creek	Below Tapia	Sun Riffle	230.3	345.6	40.4	5.9
Malibu Creek	Below Tapia	Shade Riffle	258.1	337.7	25.9	10.2

2.2 CHEMICAL WATER QUALITY DATA

Water samples at each site were collected downstream of transect. For each sample, ammonium (NH_4), nitrate (NO_3), soluble reactive phosphorus (SRP), total phosphorous and total nitrogen (TN) concentrations were measured. Table 3 shows the nutrient concentrations obtained in the August 2002 survey. Nitrate concentrations were generally low (below 0.2 mg/L) for residential and commercial sites, while multiple site 1 and 2 (sites with historical sludge injection) exhibit high nitrate concentrations of 2.8 and 3.8 mg/L, respectively. Total N ranged from 0.68 mg/L to 3.8 mg/L among sites.

Table 3. Water Quality data obtained from August 2002 survey (Busse et al. 2003).

Land Use	Sub-Habitat	NO3-N (mg/L)	NH4-N (mg/L)	TN (mg/L)	SRP (mg/L)	TP (mg/L)
Residential 1	Sun Riffle	0.018	0.043	0.686	0.123	0.186
Residential 1	Shade Riffle	0.018	0.043	0.686	0.123	0.186
Commercial 1	Sun Run	0.127	0.05	1.203	0.077	0.137
Commercial 1	Sun Riffle	0.127	0.05	1.203	0.077	0.137
Commercial 2	Sun Pool	0.072	0.063	1.418	0.053	0.087
Commercial 2	Sun Run	0.072	0.063	1.418	0.053	0.087
Commercial 2	Sun Riffle	0.072	0.063	1.418	0.053	0.087
Multiple 1	Shade Run	2.804	0.025	2.748	0.268	0.296
Multiple 1	Shade Riffle	2.804	0.025	2.748	0.268	0.296
Multiple 2	Sun Run	3.869	0.071	3.806	0.301	0.326
Multiple 2	Shade Run	3.869	0.071	3.806	0.301	0.326
Multiple 2	Shade Riffle	3.869	0.071	3.806	0.301	0.326
Below Tapia	Shade Run	0	0.050	0.686	0.293	0.363
Below Tapia	Sun Riffle	0	0.050	0.686	0.293	0.363
Below Tapia	Shade Riffle	0	0.050	0.686	0.293	0.363

The main source of water quality data for the four listed lakes is a study by UC Riverside for the Los Angeles Regional Water Quality Control Board in 1992-1993 (Lund et al., 1994). Water quality data were collected on a monthly basis at several depths for a one-year period from July 1992 to July 1993 (Table 4). For the purpose of the analysis that follows, annual averages of these concentrations were used based on the finding that there was little consistent inter-seasonal change in concentration.

Table 4. Nutrient Measurements in Malibu Creek Watershed Lakes by UC Riverside for 1992-1993 (Mean and Ranges, Lund et al. 1994)

Lake	NO3-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TN (mg/L)	PO4-P (mg/L)	TP (mg/L)	Chlorophyll a (µg/L)
Sherwood	0.5 <0.1-1.2	0.8 <0.1-2.2	1.7 0.5-3.0	2.23 0.6-4.2	0.25 <0.1-0.5	0.25 <0.1-0.5	16 1-52
Westlake	0.3 <0.1-1.3	0.4 0.1-1.0	1.3 0.7-2.3	1.69 0.8-3.6	0.16 <0.1-0.3	0.16 <0.1-0.3	14 2-35
Lindero	0.4 <0.1-1.3	0.1 <0.1-0.5	1.1 <0.1-2.0	1.58 0.2-4.3	0.09 <0.1-0.2	0.13 <0.1-0.2	23 2-56
Malibou	0.5 <0.1-1.9	0.1 <0.1-0.3	1.2 <0.1-2.7	1.78 0.2-4.6	0.13 <0.1-0.3	0.14 <0.1-0.4	44 2-185

2.3 PHYSICAL DATA

Table 5 summarizes the observed physical conditions including velocity, percent open canopy and water temperature for the selected locations surveyed in August 2002. Velocity for the selected locations ranged from 0.02 to 0.36 m/s. Percent open canopy is around 90% under sun light condition and around 1-2% under shade condition, with only a few exceptions. Temperature is generally below or around 20 degrees, except at commercial site 1, where temperature is around 30 degrees.

Table 5. Physical conditions of survey sites in August 2002 survey (Busse et al. 2003)

Creek	Land Use	Sub-habitat	Velocity (m/s)	% Open Canopy	Water Temperature (deg C)
Medea Creek	Residential 1	Sun Riffle	0.28	90	23
Medea Creek	Residential 1	Shade Riffle	0.12	14.9	19.2
Medea Creek	Commercial 1	Sun Run	0.24	89.6	30.3
Medea Creek	Commercial 1	Sun Riffle	0.36	90.9	30.5
Medea Creek	Commercial 2	Sun Pool	0	74.5	28.6
Medea Creek	Commercial 2	Sun Run	0.18	91.1	18.1
Medea Creek	Commercial 2	Sun Riffle	0.23	88.9	20.8
Las Virgenes	Multiple 1	Shade Run	0.1	0.2	20.1
Las Virgenes	Multiple 1	Shade Riffle	0.13	0.2	20.2
Las Virgenes	Multiple 2	Sun Run	0.02	29.7	16.8
Las Virgenes	Multiple 2	Shade Run	0.09	1.6	16.6
Las Virgenes	Multiple 2	Shade Riffle	0.14	2.3	16.7
Malibu Creek	Below Tapia	Shade Run	0.04	0	19.4
Malibu Creek	Below Tapia	Sun Riffle	0.12	54.7	20
Malibu Creek	Below Tapia	Shade Riffle	0.2	1.8	19.6

3 NNE Tools Application - Streams

3.1 PARAMETER SPECIFICATION

Depth and Velocity

Velocity for each location was measured during the survey and therefore was directly used in the analysis. For August 2002, the depth for surveyed streams is 15.2 (± 8.53) cm (L. Busse, personal communication). In our analysis, we assumed a depth of 0.2 m.

Solar Radiation

Solar radiation was estimated for the summer period (June-August) based on the latitude, using the routine embedded in the Benthic Biomass Spreadsheet. Percent canopy openness measured during the survey was directly used in the analysis.

Light Extinction Coefficient

Light extinction coefficient can be calculated as a function of turbidity. An approximate linear relationship of light extinction to turbidity is expected in streams. Regression relationship (Walmsley et al. 1980), Ke (PAR) = 0.1T + 0.44, where Ke (PAR) is the extinction rate of photosynthetically active radiation (PAR, per meter) and T is nephelometric turbidity (NTU). Stream turbidity for Las Virgenes Creek, Medea Creek and Malibu Creek below Tapia were monitored by the Heal the Bay Stream team (http://www.healthebay.org/streamteam/). Turbidity for these streams during summer (July-September) generally ranges around 1 NTU. Based on the equation, the estimated light extinction coefficients for these streams are around 0.54 m^{-1}.

Days of Accrual

The days of accrual can be used to adjust maximum algal density based on days of accrual, on top of the estimated value from revised QUAL2K method (see more detailed description in Tetra Tech, 2006a). The days of accrual for Malibu Creek were estimated from daily flow data of 1988-1998 from Los Angeles County Department of Public Works (LACDPW), using the count of hydrological events exceeding the three times the median flow. The estimated days of accrual for Malibu Creek at Tapia are 93.4 days. Daily flow data were not available for the Las Virgenes Creek and Medea Creek. Survey data from Busse et al. (2003) indicated stream velocity during summer and fall of 2001 and 2002 were generally below 0.35 m/s. Welch and Jacoby (2004) noted that significant scour usually does not begin until flow velocities reach about 0.7 m/s (2.3 ft/s). Therefore it is expected during summer and fall, no storm events exist to cause significant scour of benthic algae and a value of 100 days was assumed for the days of accrual for Las Virgenes and Medea Creek.

3.2 Model Results

The NNE Benthic Biomass Predictor tool provides a variety of empirical and simplified parametric model approaches to predict benthic algae response to ambient conditions. Here results from standard QUAL2K, revised QUAL2K, revised QUAL2K with accrual adjustment and Dodds et al. (2002) model were presented (Table 6). Generally the tool was able to predict the observed maximum benthic chlorophyll a concentrations in various locations reasonably well. Dodds et al. (2002) method, which is based on regression relationship of TN and TP, was generally able to predict the higher observed maximum chlorophyll a at sites with multiple land use (Las Virgenes Creek) and lower observed maximum chlorophyll a at residential land use site (Medea Creek). However without the consideration of physical parameters, Dodds et al. (2002) method can not predict the variability exhibited in different sub-habitat condition for the same land use. The parametric (QUAL2K) methods therefore performed better in capturing the variation in observed maximum chlorophyll a among different sub-habitats. For example, for the residential 1 site (Medea Creek), the standard QUAL2K methods were able to predict the higher chlorophyll a concentrations under sun riffle sub-habitat and the lower chlorophyll a concentration under the shade riffle sub-habitat.

The QUAL2K methods predict biomass as ash free dry mass (AFDM) and rely on a chlorophyll a to AFDM ratio to convert AFDM to chlorophyll a. Here site specific chlorophyll a to AFDM ratio is available (Table 2). With site-specific nutrient concentrations, physical conditions of canopy closure, stream temperature and current velocity as well as site-specific chlorophyll a to AFDM ratios, QUAL2K methods generally reproduced the variation in chlorophyll a concentrations very well, although the methods slightly under-predicted the maximum chlorophyll a at a few locations with extremely high observed maximum chlorophyll a concentrations of over 700 mg/m^2 (shade run of Multiple 2 site, and sun run of commercial 1). Overall, the QUAL2K methods provide more flexibility than the Dodds et al. (2002) method. QUAL2K runs without adjustment to the parameters performed well at reproducing the maximum benthic chlorophyll a concentrations.

Table 6. Predicted and Observed Maximum Benthic Chlorophyll a (mg/m^2)

Creek	Name/ Land use	Habitat	Standard QUAL2K	Revised QUAL2K	Revised QUAL2K with Accrual Adjustment	Dodds et al. 2002	Observed Maximum
Medea Creek	Residential 1	Sun Riffle	195	372/237*	305/194*	188	194.1
Medea Creek	Residential 1	Shade Riffle	83	159/101*	130/83*	188	62.4
Medea Creek	Commercial 1	Sun Run	520	690/527*	565/471*	217	1628
Medea Creek	Commercial 1	Sun Riffle	350	458/350*	323/247*	217	245.5
Medea Creek	Commercial 2	Sun Pool	287	473/293*	388/240*	208	257
Medea Creek	Commercial 2	Sun Run	171	286/174*	234/143*	208	194
Medea Creek	Commercial 2	Sun Riffle	175	292/179*	237/147*	208	134
Las Virgenes	Multiple 1	Shade Run	559	579	474	354	566
Las Virgenes	Multiple 1	Shade Riffle	653	676	588	354	670.9
Las Virgenes	Multiple 2	Sun Run	173	219	179	438	151.9
Las Virgenes	Multiple 2	Shade Run	867	567	446	438	710.7
Las Virgenes	Multiple 2	Shade Riffle	243	307	267	438	264.4
Malibu Creek	Below Tapia	Shade Run	867	567	446	243	717.4
Malibu Creek	Below Tapia	Sun Riffle	516	338	266	243	345.6
Malibu Creek	Below Tapia	Shade Riffle	627	410	323	243	337.7

* use inorganic nitrogen in revised QUAL2K methods

The tool can be used to predict nutrient targets to achieve a specified maximum algal density. Tetra Tech (2006a) recommends a target maximum benthic chlorophyll a concentration of 100 mg/m^2 for the BURCI/II boundary (below which conditions may be deemed acceptable) and 150 mg/m^2 for the BURC II/III boundary (above which conditions are deemed unacceptable) for COLD and SPAWN uses. For WARM uses, Tetra Tech (2006a) recommends a BURC I/II boundary of 150 mg/m^2 and a BURC II/III boundary of 200 mg/m^2. For Las Virgenes Creek, Medea Creek and Malibu Creek, COLD and SPAWN are the potential and existing uses. Proposed TMDL target for chlorophyll a in streams is also at150 mg/m2 for the Malibu Creek Watershed.

The tool was used to predict target nutrient concentrations in order to meet target maximum benthic algal density of 150 mg/m^2 (BURC II/III for COLD uses and BURC I/II for WARM uses). The revised QUAL2K methods predict target concentrations for N or P, either one of which will achieve the target (Figure 2; Table 7). The standard QUAL2K method is based on inorganic nutrient concentrations, and the total nutrient limits shown in the table are those that would be required to at the existing average inorganic fraction of nutrient concentrations. The Dodds et al. (2002) methods is based on co-limitation of TN and TP, and therefore results shown in Table 7 are the TN levels required to achieve target under current TP level or required TP concentrations at the existing average TN concentrations.

Predicted TN targets vary under different land uses and different habitat conditions (Table 7). The predicted large variation in TN targets is a direct result of the highly variable maximum chlorophyll a concentration observed among these sites. Although highly variable, predicted TN targets for the impaired streams are generally around or below 1 mg/L. Predicted TN targets are 0.15-1.6 mg/L for the high density residential site in Medea Creek, 0.09-1.15 mg/L for the commercial sites, 0.05-1.6 mg/L for sites with multiple land uses, and 0.06-0.24 mg/L for Malibu Creek. These values are generally in agreement with the proposed TMDL target values for nitrogen (1 mg/L), however suggesting lower nutrient target values are needed for sections of the streams with poor habitat integrity (loss of riparian zone) or high loading of nutrients as a result of high degree of human influence in the surrounding watersheds.

For Malibu Creek watershed, the models suggested very low total phosphorus target values if to achieve control of benthic algal growth by phosphorus (at many cases below 0.01 mg/L, ranging from 0.0014 mg/L to 0.0084 mg/L, Table 7). Therefore to attain benthic algal growth target based on total phosphorus alone might not be achievable at these low levels and reductions in total nitrogen or the combination of the TN and TP reduction become the preferred management targets.

The availability of site-specific data allows the model to calculate site-specific nutrient targets based on nutrient levels and physical condition. The results suggested that calculated targets vary largely among different land uses and sub-habitats, even for the same stream. For residential site sun riffle and shade riffle conditions, with similar ambient nutrient concentrations, shade riffle sub-habitat has higher target TN and TP values, suggesting the impact of physical condition (in this case shading). The shade riffle sub-habitat offers more canopy cover for light limitation and therefore results in lower water temperature and lower algal density as was observed (Table 2 and Table 3). As a result, higher nutrient targets are allowed for the shade riffle sub-habitat. The Commercial 1 site has high percentage of open canopy (90 % open canopy) and higher water temperature (over 30 deg C), which favor benthic algae growth and therefore the calculated nutrient targets for the site is low to moderate. For the Multiple 1 and Multiple 2 sites, high nutrient concentrations result in algae growth even under shade conditions. Therefore TN and TP values at these sites need to be reduced to very low levels in order to limit the algal growth. It was found that some diatoms are able to adapt to low light conditions. As indicated in Busse et al. (2003, 2006), the composition of algae vary among sites, with thick diatom and macroalgae dominating in more human influenced sites (Multiple sites, below Tapia). These sites also show higher chlorophyll a to AFDM ratios. Therefore, algal community structure is another factor influencing allowed nutrient targets. Overall lowest TN/TP target values were calculated at Multiple 1 sites and sites below Tapia.

Table 7. Total Nitrogen Goal (mg/L) for Target of 150 mg/m^2 maximum Chlorophyll a

Creek	Name/ Land Use	Habitat	Standard QUAL2K		Revised QUAL2K		Dodds et al. 2002	
			TN	TP	TN	TP	TN	TP
Medea Creek	Residential 1	Sun Riffle	0.49	0.0027	0.15/0.2*	0.0019	0.4	0.064
Medea Creek	Residential 1	Shade Riffle	1.6	0.009	0.62/1.4*	0.0115	0.4	0.064
Medea Creek	Commercial 1	Sun Run	0.22	0.0023	0.09	0.0014	0.5	0.026
Medea Creek	Commercial 1	Sun Riffle	0.35	0.0038	0.19/0.13*	0.0023	0.5	0.026
Medea Creek	Commercial 2	Sun pool	0.59	0.0038	0.20/0.3*	0.0024	0.6	0.020
Medea Creek	Commercial 2	Sun Run	1.15	0.007	0.49/0.9*	0.0084	0.6	0.020
Medea Creek	Commercial 2	Sun Riffle	1.11	0.007	0.45/0.9*	0.0064	0.6	0.020
Las Virgenes	Multiple 1	Shade Run	0.07	0.0028	0.28	0.003	0.3	<0.01
Las Virgenes	Multiple 1	Shade Riffle	0.05	0.002	0.21	0.0024	0.3	<0.01
Las Virgenes	Multiple 2	Sun Run	0.70	0.026	1.6	0.0275	0.3	<0.01
Las Virgenes	Multiple 2	Shade Run	0.65	0.012	0.47	0.0185	0.3	<0.01
Las Virgenes	Multiple 2	Shade Riffle	0.35	0.013	1.1	0.0019	0.3	<0.01
Malibu Creek	Below Tapia	Shade Run	0.038	0.0016	0.09	0.0015	0.25	0.042
Malibu Creek	Below Tapia	Sun Riffle	0.07	0.0031	0.24	0.0027	0.25	0.042
Malibu Creek	Below Tapia	Shade Riffle	0.056	0.0024	0.17	0.0021	0.25	0.042

*use inorganic nitrogen in revised QUAL2K method

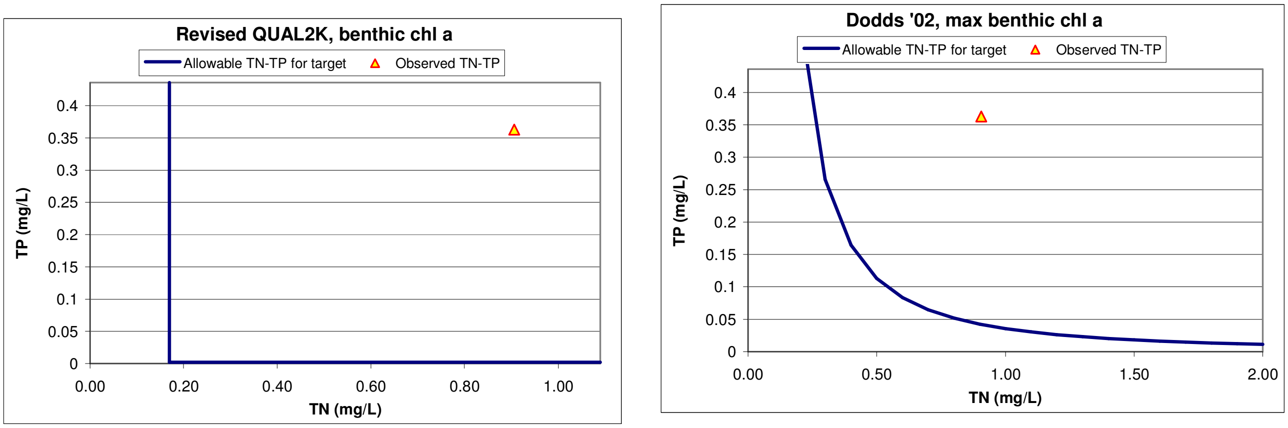

Figure 2. Revised QUAL2K and Dodds et al. 2002 Tool Results for a Target Maximum of 150 mg/m2-Chlorophyll a at Malibu Creek Shade Riffle Sub-habitat

USEPA (2000) suggested eco-regional criteria applicable to this area. Model results are compared to the USEPA criteria and the summary of Region IX RTAG water quality monitoring in Table 8. The targets derived from the CA NNE Scoping Tool for Malibu Creek are in the same range as the USEPA eco-regional criteria, but with some important caveats. The calculated TN targets from the Scoping Tool generally fall below the median value of the impaired waters due to nutrients (0.7 mg/L) suggested by Regional IX RTAG water quality monitoring data, with only a few exceptions (mostly for sites with good shading). For a few highly human influenced sites (Multiple 1 and below Tapia), the calculated TN targets are generally below the median of the minimally impacted waters (0.25 mg/L). The calculated TP targets generally fall below the median and average value of the minimally impacted waters of 0.08 mg/L.

Table 8. Comparison of Model Results to USEPA Eco-regional Nutrient Criteria Recommendations and Region IX RTAG Water Quality Monitoring Data

Chemical	Stream Type	Proposed USEPA 304(a) Criterion	Region IX RTAG Water Quality Monitoring Data (Tetra Tech, 2004)				
			Median	Average	Lower Quartile	Upper Quartile	No. of Data points
TN	Minimally Impacted		0.25	0.31	0.13	1.20	156
(mg/L)	Unimpaired		0.40	1.01	0.20	42.70	1425
	Impaired (nutrient)		0.7	1.06	0.40	11.00	868
	Impaired (other)		0.6	0.97	0.30	33.00	1486
	EPA 401(a) (US EPA 2000)	0.50					10
	CA NNE scoping tool	0.05-1.6					
TP	Minimally Impacted		0.08	0.08	0.03	0.30	34
(mg/L)	Unimpaired		0.07	0.36	0.01	24.80	633
	Impaired (nutrient)		0.13	0.77	0.05	7.94	525
	Impaired (other)		0.07	0.34	0.03	45.10	1069
	EPA 401(a) (US EPA 2000)	0.03			0.02		23
	CA NNE scoping tool	0.0014-0.028					

4 Suggested Targets - Streams

The California NNE approach is a risk-based approach, with ultimate focus on supporting designated uses. The general NNE guidance and accompanying tools provided initial, scoping-level estimate of nutrient reduction targets that can be used as a starting point for a TMDL. The results may be superseded by detailed watershed models if these become available in future.

4.1 Response Targets

The California NNE approach (Tetra Tech, 2006a) recommends setting response targets for benthic algal biomass in streams based on maximum density as mg/m^2 chlorophyll a. For the COLD and SPWN beneficial uses, the recommended BURC I/II boundary is 100 mg/m^2, while the BURC II/III boundary is 150 mg/m^2. Existing conditions in the Malibu Creek and its tributaries are clearly often above the BURC II/III boundary, indicating impairment of these uses. For Las Virgenes and Medea Creek, COLD and SPWN are not the existing uses but are potential uses. The WARM use boundary of 150 mg/m^2 for

BURC I/II can be applied. Therefore a target maximum benthic chlorophyll a of 150 mg/m^2 should be appropriate response target for the Malibu Creek and its tributaries.

4.2 NUTRIENT TARGETS

As shown in Table 7, application of the tool to Malibu Creek watershed using site specific data yields variable results in TN/TP target for various land uses and sub-habitat, suggesting the large influence of land use and habitat conditions on algal growth. Therefore suggesting a single target for a particular stream is difficult given the large influence of land use and physical condition on benthic algae growth and the high variability in observed benthic chlorophyll a concentrations. One approach is to suggest the lowest calculated target values possible. Or alternatively to consider different target values for different stream sections. Application of California NNE tool at the 150 mg/m^2 chlorophyll a target yielded a total nitrogen goal of 0.15 to 1.6 mg/L for the residential site of the Medea Creek, 0.09 mg/L to 1.15 mg/L for commercial sites of the Medea Creek, 0.05 to 1.6 mg/L for multiple land uses of Las Virgenes Creek, and 0.06-0.24 mg/L for Malibu Creek, respectively, according to the results from the revised QUAL2K method. Results from the Dodds et al. (2002) method generally suggest total nitrogen target values of 0.4 mg/L for residential site in Medea Creek, 0.5-0.6 mg/L for the commercial sites in the Medea Creek, 0.3 mg/L for the multiple land uses and 0.25 mg/L for the Malibu Creek. The results suggest that although a total nitrogen target of 1 mg/L might be suitable for protecting most of the stream segments, lower nutrient target values (ranging from 0.09 to 0.86 mg/L depending on land uses) are needed for sections with human influence. For stream sections with good habitat condition (e.g. good shading, healthy community structure) higher nutrient targets may be allowed. However, some critical sections with poor habitat condition (e.g. lack of shading, unhealthy community structure), very low nutrient targets are required. Particularly when these critical stream sections are downstream, the low target nutrients at these sections may also have an impact on the nutrient loading from upstream that is allowed to deliver to this section. Because the predicted TP target levels in many cases are below background levels, the focus for managing nutrient loads should initially be nitrogen or the combination of reducing nitrogen and phosphorus.

5 NNE Tool Application - Lakes

Four lakes of the Malibu Creek watershed were listed for eutrophication problems (algae, nutrients, ammonia, low DO) – Malibou Lake, Lake Lindero, West Lake, and Lake Sherwood. All these lakes have existing or intermittent beneficial uses of REC1, REC2, WILD, and WARM. Among the four lakes, Malibou Lake has the highest observed Chlorophyll a of 44 µg/L, exceeding the endpoint for REC2 and WARM uses. Here the BATHTUB spreadsheet tool was applied to all four lakes. The nitrogen and phosphorous loads to the lake as the required inputs to the spreadsheet tool were estimated as the total of loads coming from inflow tributaries and atmospheric deposition to lake surfaces. The predicted nutrient and chlorophyll a concentrations in the lakes compared well with the observed values (Table 9).

Table 9. Predicted and observed nutrient and chlorophyll a concentrations in lakes.

Constituents	Sherwood		West Lake		Lindero		Malibou	
	Observed	Predicted	Observed	Predicted	observed	Predicted	Observed	Predicted
Chlorophyll a (µg/L)	16	32.1	14	27.3	23	32.3	44	42.6
P Concentration (mg/L)	0.25	0.46	0.16	0.21	0.13	0.17	0.14	0.17
N Concentration (mg/L)	2.23	2.88	1.69	1.6	1.58	1.48	1.78	1.71

6 Suggested Targets - Lakes

The suggested nutrient numeric endpoints for planktonic algal biomass in lakes are 20 µg/L for REC1 and 25 µg/L for REC2 and WARM for BURC II/III boundary, and 10 µg/L for BURC I/II boundary. Here the tool was used to estimate TN/TP loadings and target TN/TP concentrations to meet a chlorophyll a target of 20 µg/L.

Table 10 listed the predicted probability of exceeding the Chlorophyll a target of 20 µg/L and the calculated TN loadings (under current TP loadings) and TP loadings (under current TN loadings) needed to meet the target. The target can be achieved by either reducing TN loadings or TP loadings.

Table 10. Predicted probability of exceeding Chlorophyll a target and calculated TN/TP loadings to meet targets

	Sherwood	West Lake	Lindero	Malibou
Probability of exceeding	42.8%	38.8%	30.3%	49.3%
Calculated TN loading (kg/yr)	12970	20000	2000	21500
Calculated TP loading	890	1656	140	1300
TN target (mg/L)	1.10	0.93	0.77	0.54
TP target (mg/L)	0.06	0.07	0.06	0.03

For a chlorophyll a target of 20 µg/L, the tool predicted that for Malibou Lake, 49.3% of the time the target will be exceeded. The predicted nitrogen load to meet the target of 20 µg/L (while P load remains the same at 7190 kg/yr) is about 21,500 kg/yr, a 70% reduction from current load of 75390 kg/yr. The reduction in N load results in predicted chlorophyll a concentration of 19.3 µg/L and TN concentrations of 0.54 mg/L, comparable to the proposed TMDL target value of 1 mg/L. The target can also be achieved by reducing TP load. The reduction of TP load to calculated load will result in a chlorophyll a concentration of 19.6 µg/L and TP concentration of 0.03, lower than the TMDL target of 0.1 mg/L. Generally, the average TN and TP target concentrations for all the lakes are comparable to the TMDL target of 1 mg/L for TN and 0.1 mg/L for TP, although there are substantial lake-to-lake differences that are reflective of their individual assimilative capabilities. The predicted targets for TN generally compare well to the median and average of unimpaired waters and are lower than the third quartile concentrations recommended in EPA guidance (Table 11). Calculated TP targets were more consistent with the median and average of the unimpaired waters than TN targets.

Table 11. Comparison of Model Results to RTAG Criteria

Chemical	Stream Type	Median	Average	First Quartile	Second Quartile	Third Quartile	Fourth Quartile	No of Data points
NO_3	Unimpaired	0.10	0.43	0.10	0.10	1.00	4.52	190
(mg/L)	Impaired (other)	0.70	1.88	0.23	0.70	2.60	15.81	28
TKN	Unimpaired	0.50	0.73	0.20	0.50	1.00	5.40	315
(mg/L)	Impaired (other)	0.50	0.96	0.30	0.50	0.80	9.40	107
TN	Unimpaired	0.60	1.16	0.30	0.60	2.00	9.92	
(mg/L)	Impaired (other)	1.20	2.84	0.53	1.20	3.40	25.21	
TN (mg/L)	CA NNE Scoping Tool				0.54-1.1			
TP	Unimpaired	0.03	0.08	0.03	0.03	0.08	3.00	252
(mg/L)	Impaired (other)	0.03	0.03	0.01	0.03	0.04	0.11	81
	CA NNE Scoping Tool				0.03-0.07			

7 Summary

The California NNE method and tools were successfully applied to the analysis of periphyton in the Malibu Creek watershed. The standard and revised QUAL2K methods appeared to provide a reasonable fit to observed maximum periphyton density (as chlorophyll a). The application however suggested highly variable nutrient targets under different land uses and habitat conditions. To meet a target maximum algal density of 150 mg/m^2, predicted total nitrogen targets are highly variable under different land uses and habitat conditions. Generally lower than 1 mg/L total nitrogen targets are required for stream segments with human influence in the surrounding watershed (ranging from 0.05 mg/L to 0.9 mg/L). It is noted that NNE tool provides a scoping-level analysis of nutrient targets, and should be superseded by a site-specific calibrated nutrient model where available. The California NNE tools use site-specific information, with the consideration of physical condition and linkage to beneficial uses and therefore are generally appropriate for developing numeric nutrient endpoints. The proposed nutrient TMDL for Malibu Creek watershed (USEPA Region IX) with target total nitrogen value of 1mg/L and phosphorous value of 0.1 mg/L is generally at the upper bound of the predicted total nitrogen target values for this watershed. The application of the BATHTUB spreadsheet to the four lakes also suggested that the target TN value of 1 mg/L and TP value of 0.1 mg/L are generally comparable to the calculated targets by the tool.

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