Nutrient Numeric Endpoints for TMDL Development: Chorro Creek Case Study Review Draft

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1 Introduction

Tetra Tech, Inc. under contract to EPA Region 9 and the California State Water Resources Control Board developed an approach for calculating nutrient numeric endpoints (NNE) for use in California Water Quality Programs (Tetra Tech, 2006). California is taking a risk-based approach in which targets are developed for response variables (or secondary indicators) such as algal density. These response targets can then be converted to site-specific nutrient targets through use of modeling tools.

The California NNE approach recognizes that there is no clear scientific consensus on precise levels of nutrient concentrations or response variables that result in impairment of a designated use. To address this problem, waterbodies are classified in three categories, termed Beneficial Use Risk Categories (BURCs). BURC I waterbodies are not expected to exhibit impairment due to nutrients, while BURC III waterbodies have a high probability of impairment due to nutrients. BURC II waterbodies are in an intermediate range, where additional information and analysis may be needed to determine if a use is supported, threatened, or impaired. Tetra Tech (2006) lists consensus targets for response indicators defining the boundaries between BURC I/II and BURC II/III.

Tetra Tech (2006) also documents a set of relatively simple spreadsheet tools to assist in evaluating the translation between response indicators and nutrient concentrations or loads. These simplified tools provide a starting place, and should be superseded by calibrated site-specific models where available.

One important use of the NNE is for setting initial nutrient endpoints for waterbodies requiring nutrient TMDLs. Accordingly, USEPA under Contract GS-10F00268k issued a task order to Tetra Tech to apply the NNE method to develop nutrient endpoints for a selected set of California waterbodies requiring nutrient TMDLs. These case studies are intended to demonstrate the NNE process and to test and refine the accompanying tools. The fourth case study reported under this task order is for Chorro Creek.

1.1 SITE

Chorro Creek is a tributary to Morro Bay which discharges to the Pacific Ocean in San Luis Obispo County, CA (Figure 1). Major tributaries to Chorro Creek include San Bernardo, San Luisito, Walters, Pennington, and Dairy Creeks. The total drainage area at the mouth of Chorro Creek is approximately 43.2 square miles. The watershed is dominated by valley grassland, coastal scrub, and oak savanna with both public and private land owners. Private land uses include urban development and livestock rangeland. Public lands are managed for rangeland, recreation, military operations, and prison facilities. The California Men's Colony (CMC) operates a tertiary wastewater treatment plant that discharges to Chorro Creek just below the confluence with Pennington Creek.

The Chorro Creek Watershed has a Mediterranean climate, with characteristically warm, dry summers and cool, wet winters. Watershed elevation ranges from sea level at the mouth of the creek to 1,400 ft in the headwaters. Average annual rainfall near the coast is approximately 45 cm and near the ridge line is approximately 89 cm.

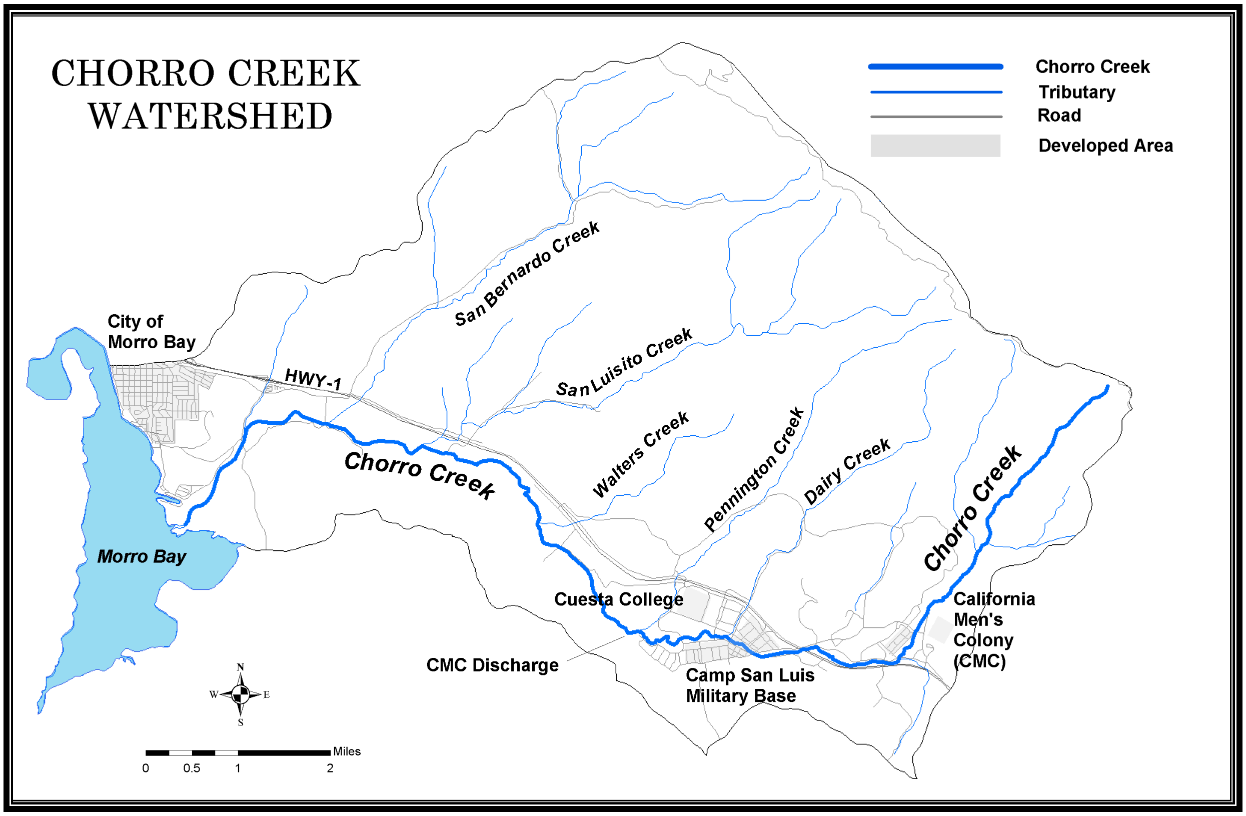

Figure 1. Chorro Creek Watershed (from CCRWQCB, 2006)

1.2 Beneficial Uses and Impairment

The beneficial uses of Chorro Creek are designated by the Central Coast Regional Water Quality Control Board (CCRWQCB, 2006) and include

MUN: Domestic and municipal water supply

AGR: Agricultural supply

GWR: Groundwater recharge

REC1: Water contact recreation

REC2: Non-contact water recreation

MIGR: Migration of Aquatic Organisms

SPWN: Spawning, reproduction, and/or early development

BIOL: Preservation of biological habitats of special significance

FRSH: Freshwater replenishment

WARM: Warm freshwater habitat

COLD: Cold freshwater habitat

WILD: Wildlife habitat

RARE: Preservation of rare and endangered species.

Chorro Creek is listed as impaired for nutrients on the 1998 California 303(d) list and for dissolved oxygen on the draft 2006 303(d) list. The nutrient impairment is based on violation of the narrative water quality objective for biostimulatory substances: "Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses." The CCRWQCB (2006) considers algal biomass coverage in excess of 40 percent to constitute nuisance levels. Measurements of algal cover exceeded the 40 percent threshold in 57 percent of observations.

The dissolved oxygen listing is based on concentrations observed below the water quality standard for COLD habitats: 29 percent of samples were below the 7 mg/L standard. According to the source assessment presented in the TMDL (CCRWQCB, 2006), dissolved oxygen excursions occur in the lower reaches of Chorro Creek due to excessive biostimulatory factors.

1.3 Summary of Existing Analyses

Several studies involving Chorro Creek and its receiving water, Morro Bay, have been completed over the past decade. This section summarizes the existing analyses and their uses for application of the NNE tool.

In 1998, Tetra Tech completed a habitat characterization and assessment study for the Morro Bay Estuary (Tetra Tech, 1998). Lower Chorro Creek was included in the assessment along with other major tributaries to the Bay. The primary study objectives were determination of sediment transport and hydraulic capacity. No estimates of nutrient loading or measurements of benthic algal biomass were included. Hydraulic characteristics were described for typical to high flow events during which the majority of sediment transport occurs. The data are not useful for defining Summer low flow conditions when benthic algae reach nuisance levels.

In 1999, Tetra Tech continued the analysis of the Morro Bay Estuary with a study on nutrient loading and circulation (Tetra Tech, 1999). The mouth of Chorro Creek was monitored on a bi-weekly basis in the dry season and weekly during the wet season for nitrate and phosphate, as well as other general water quality parameters. Higher median nitrate and phosphate concentrations were observed in the lower reaches of Chorro Creek at the Canet Road and Twin Bridges sampling locations, which are downstream of the California Men's Colony wastewater treatment plant. The study estimated that 86 percent of nitrogen loading to Morro Bay and 94 percent of phosphorus loading comes from Chorro Creek. More comprehensive nutrient monitoring was recommended for development of a full eutrophication model of the Bay. As a result, an extensive volunteer monitoring effort was initiated by the Morro Bay National Estuary Program (MBNEP, 2000).

In 2001, the Coastal San Luis Resource Conservation District completed a habitat assessment of Chorro Creek in support of the Morro Bay Watershed Steelhead Restoration Planning Project (CSLRCD, 2001). Habitat inventories and bank erosion assessments were conducted over approximately 8.5 miles between Morro Bay and the Chorro Reservoir Dam. Several elements of the inventory were used to develop the NNE application at the Twin Bridges (310TWB) and Canet Road (310CAN) sampling locations: stream width, depth, and velocity at low flow (approximately 3.5 cfs) and percent canopy cover.

In 2006, the Central Coast Regional Water Quality Control Board completed a Chorro Creek TMDL report for nutrients and dissolved oxygen (CCRWQCB, 2006). The source assessment listed growth of benthic algae in the lower reaches as the primary cause of low DO concentrations in addition to summer low flow, high temperature conditions, decreased slope in these reaches, and salinity. Diurnal DO data collected at the lower two monitoring stations show fluctuations of 5 to 10 mg/L per cycle. The upstream sites had a fairly constant DO concentration over the course of a day with no excursion of the DO standard.

Benthic algae is present in the Chorro Creek watershed even at background nutrient concentrations (CCRWQCB, 2006). The CCRWQCB concluded that nutrients alone are not causing the high densities of benthic algae and subsequent low dissolved oxygen concentrations. High densities of benthic algae at these sites are also attributed to low flow, high temperature conditions that are favorable for photosynthesis.

The TMDL report also attributes high densities of benthic algae to a lack of stream shading. At the Twin Bridges monitoring location, the reported canopy cover is 2 percent and the benthic algae coverage is 99 percent. Data collected at several other locations along Chorro Creek indicate that a canopy cover of at least 70 percent is required to control nuisance benthic algae growth. Lack of shading not only provides additional light for photosynthesis, but also results in increased water temperatures which 1) result in higher rates of photosynthesis and 2) reduce the solubility of oxygen.

1.4 Scope of this Effort

According to the nutrient and dissolved oxygen TMDL recently completed by the CCRWQCB (2006), nutrient concentrations alone are not responsible for the dense growth of benthic algae. Even at sites along the creek with near background levels of nitrogen and phosphorus, coverages of 80 to 90 percent have been observed. Other contributing factors are low flow, high temperature, salinity, and lack of shading. Though the CMC is contributing additional salinity and nutrients to the system, it does not appear to impact temperature relative to solar radiation.

The 2006 TMDL plan requires decreased nutrient and salinity loading from the CMC as well as stream restoration efforts to increase canopy cover and shading. Use of the NNE tool for Chorro Creek will help determine the nutrient concentrations required to reduce benthic algae in the lower reaches to acceptable levels once the canopy cover has been restored.

2 Data

2.1 Algal Response Data

Quantitative measures of algal density (either as dry weight or chlorophyll *a* concentration per area of stream bottom) are not available for Chorro Creek. However, there have been frequent measurements of algal percent cover. The 20006 TMDL (CCRWQCB, 2006) notes that benthic algal biomass greater than 150 mg/m^2 is considered to be a nuisance in a stream, and approximately correlates this to areal coverage of algae (USEPA, 2000), concluding "cover of algae exceeding 40% to be evidence of an excursion of the biostimulatory substances objective."

In 21 measurements of algal cover in Chorro Creek, 12 (or 57 percent) exceeded the 40%-coverage target. As a result, the Central Coast Regional Water Quality Control Board concluded that Chorro Creek was impaired relative to the basin plan narrative criteria for biostimulatory substances. Unfortunately, percent coverage is an inexact measure of impairment, as the implications of a greater percent coverage by a dense filamentous green algae such as *Cludophora* are likely quite different from the same percent coverage by a thin film of diatoms.

Dissolved oxygen (DO) concentrations in Chorro Creek also frequently fall below the COLD minimum of 7 mg/L (29 percent of summer samples reported in CCRWQCB (2000) are below 7 mg/l). 40-hr continuous DO monitoring at four sites in September 2003 showed consider diurnal variability at sites

310CAN (Chorro Creek at Canet Road) and 310TWB (Chorro Creek at South Bay Boulevard), with morning concentrations below the 7 mg/L standard (see 0). Average benthic algal cover at these sites was greater than 99 % and 95 %, respectively. The diurnal variation at 310 TWB (the downstream site) was almost 10 mg/L, which, coupled with measurements of algal cover greater than 99 percent, indicates impairment associated with benthic algal growth. This finding is supported by diurnal variability in pH, which is also associated with daylight photosynthesis and nighttime respiration of algae.

Algal cover measurements are useful in evaluation of stream conditions, but do not provide a quantitative index of algal density. In this report, we apply the simplified tools developed for the CA NNE program to provide further evidence as to whether expected algal densities in Chorro Creek present a threat to attaining water quality standards.

2.2 CHEMICAL WATER QUALITY

The Central Coast Regional Water Quality Control Board of the California Environmental Protection Agency conducts regional water quality monitoring through its Central Coast Ambient Monitoring Program (CCAMP). Extensive nutrient data and habitat information for use with the NNE tool is available at two sites on Chorro Creek mainstem: 310TWB (Chorro Creek at South Bay Boulevard) and 310CAN (Chorro Creek at Canet Road). Both sites are located downstream of the California Men's Colony (CMC) discharge, the effluent of which often dominates flow in Chorro Creek during the summer and early fall seasons.

Statistics for summer season results (June – September) were extracted from the CCAMP database. As periphyton is expected to have a moderately long response time to ambient nutrient concentrations, extreme values may not be particularly relevant. Therefore, the central tendency and range of the ambient data were described by the mean, median (50th percentile), 25th percentile, and 75th percentile (Table 1). Site locations are shown in 0.

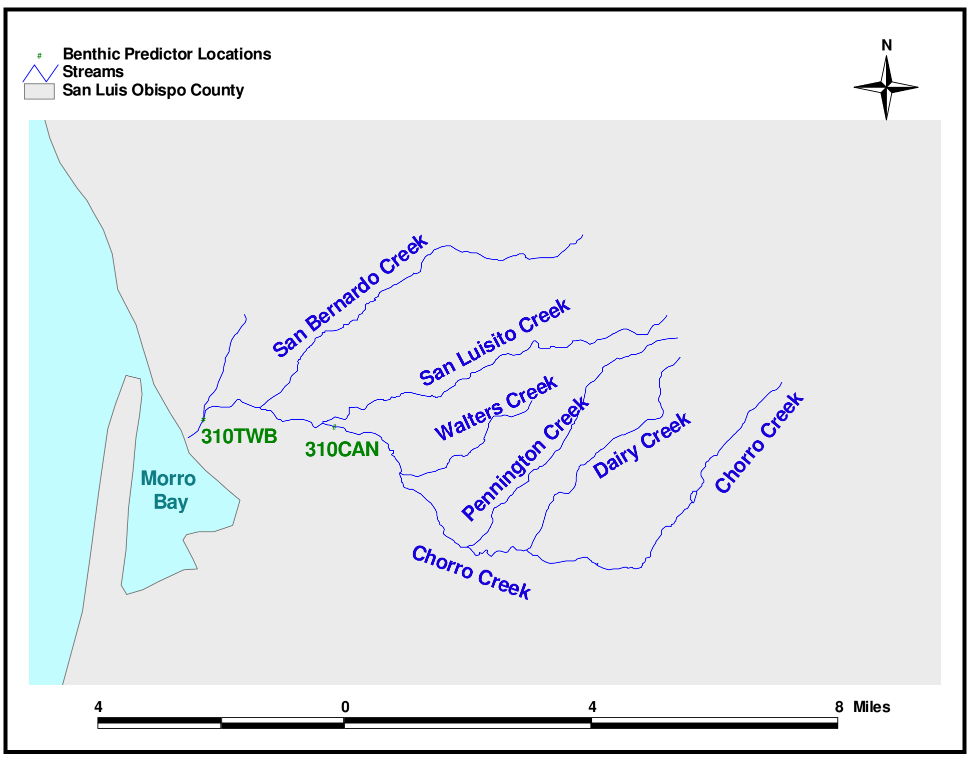

Figure 2. Water Quality Stations on Chorro Creek Used for NNE Tool Application

Table 1. Chorro Creek Water Quality Data, 1993-2006 Summer (June-September)

Parameter	Count	Mean	Median	25th Percentile	75th Percentile
310TWB: Chorro Creek at South Bay Boulevard					
PO_4-P (mg/L)	16	0.67	0.38	0.34	0.83
ORG-P (mg/L)	55	0.37	0.36	0.32	0.46
TP (mg/L)	3	0.57	0.51	0.49	0.63
NO_3-N (mg/L)	64	1.81	1.61	1.21	2.14
NH_3-N (mg/L)	18	0.04	0.03	0.02	0.04
ORG-N (mg/L)	19	0.32	0.30	0.26	0.36
TKN (mg/L)	19	0.36	0.30	0.30	0.40
TN (mg/L)	19	2.6	2.5	2.1	3.1
Turbidity (NTU)	69	1.8	1.6	0.8	2.3
310CAN: Chorro Creek at Canet Road					
PO_4-P (mg/L)	2	1.25	1.25	1.23	1.28
ORG-P (mg/L)	123	1.00	0.92	0.59	1.48
TP (mg/L)	6	1.41	1.38	1.38	1.45
NO_3-N (mg/L)	124	2.96	2.73	2.13	3.65
NH_3-N (mg/L)	6	0.03	0.04	0.02	0.04
ORG-N (mg/L)	8	0.79	0.67	0.63	0.79
TKN (mg/L)	8	0.81	0.69	0.66	0.80
TN (mg/L)	8	3.7	3.6	3.3	4.2
Turbidity (NTU)	70	2.1	1.7	1.3	2.4

2.3 PHYSICAL DATA

In 2001, the Coastal San Luis Resource Conservation District completed a comprehensive habitat survey over approximately 8.5 miles of Chorro Creek, starting 1.6 miles upstream of the mouth of Chorro Creek and ending at the Chorro Reservoir Dam (CSLRCD, 2001). The surveyed reach contains Site 310TWB as well as channel upstream of Site 310CAN (0). Unfortunately, the channel segment containing Site 310CAN was not able to be surveyed due to access restrictions on private property.

HEC-2 profiles developed for the Morro Bay Habitat Characterization and Assessment Study (Tetra Tech, 1998) are also available for the lower Chorro Creek reaches, but the low flow estimates of velocity and depth are likely inaccurate compared to field data since HEC-2 is primarily a flood event model. Thus, the estimates of flow, depth, width, and resulting average velocity as measured during the habitat assessment when flows were near 3.5 cfs will be used to estimate channel hydraulics for use with the NNE tool.

3 NNE Tools Application

The NNE tool was applied at Stations 310TWB and 310CAN on Chorro Creek. Parameter specification is described next, followed by results of the modeling exercise.

3.1 Parameter Specification

Depth and Velocity

Measured stream flow during the 2001 habitat assessment was approximately 3.5 cfs (CSLRCD, 2001). Average widths and depths were recorded at each assessment location. Habitat assessment data from the beginning of Reach 1 for a distance upstream of approximately 1.1 miles was used to estimate the hydraulic parameters for Site 310TWB. The next 2.9 miles of surveyed reach were used to estimate the parameters for Site 310CAN. Table 2 summarizes the hydraulic parameters estimated for the two sites.

Table 2. Average Hydraulic Characteristics Assumed for Two NNE Application Sites

Site	Flow (cfs)	Average Width (ft)	Average Depth (ft)	Average Velocity (fps)
310TWB	3.5	18	1	0.19
310CAN	3.5	13	1	0.27

Light Extinction Coefficient

Light extinction in the water column was estimated from turbidity. In general, light extinction is a function of water itself, dissolved colored organic material, phytoplankton, and inanimate particulate matter (Effler et al., 2005), and occurs through a combination of adsorption and scattering. In flowing streams, scattering by inorganic particulates is usually the dominant factor in light extinction, while scattering in the water column is directly measured by a nephelometric turbidity meter as NTU (Gallegos, 1994). Therefore, an approximately linear relationship of light extinction to turbidity is expected in streams. Rather than implementing a complete optics model, we therefore rely on the simple empirical relationship of Walmsley et al. (1980), who established a regression relationship $K_e(PAR) = 0.1\ T + 0.44$, where $K_e(PAR)$ is the extinction rate of photosynthetically active radiation (PAR, per meter) and T is nephelometric turbidity (NTU). The relationship will vary according to the nature of suspensoids (Kirk, 1985), but is similar to results of other authors who suggest slopes of K_e relative to turbidity in the range of 0.06 to 0.12. Because turbidity has only a small effect on available light at the depths analyzed, the Walmsley relationship appears acceptable. The extinction coefficient was then estimated based on median turbidity as 0.6 m^{-1} for station 310TWB and 0.61 m^{-1} for station 310CAN.

Canopy Cover

The 2001 habitat assessment also estimated the percent canopy cover at each survey location. Again, the first 1.1 miles of assessment data were used to estimate the canopy cover at Site 310TWB, and the next 2.9 miles of surveyed reach were used to estimate the canopy cover at Site 310CAN. Average percent canopy coverage at the two stations were 65 percent and 80 percent, respectively. Note that the TMDL report for Chorro Creek lists the canopy cover at site 310TWB as only 2 percent under existing conditions (CCRWQCB, 2006).

Days of Accrual

The scoping model provides an option to evaluate effects on expected maximum algal density based on days of accrual (d_a), using the relationship of Biggs (2000), where accrual time is defined as the number of days between events three-times the median flow. Flows in excess of this value are assumed to scour out a large percentage of the benthic algal biomass, limiting density.

Investigations by CCRWQCB (2006) on San Luis Obispo Creek, adjacent to Chorro Creek, demonstrate the importance of days of accrual, with increasing algal cover strongly correlated to days since the winter high flow period. The relationship posed by Biggs, however, appears ill-suited for many California coastal streams, in which the median flow may be very close to summer base flow. Instead, it is more appropriate to evaluate the time between flows of scouring potential – regardless of their relationship to median flow. True scouring flows are most likely to occur during the winter rainy season, and are rare or non-existent during the summer. For evaluation of maximum potential benthic algal growth, in late summer limitation by scouring flows cannot be counted upon, and an appropriate measure of days of accrual appears to be on the order of 6 months.

3.2 Model Results

The NNE Benthic Biomass Predictor tool provides a variety of empirical and simplified parametric model approaches to predicting benthic algal response to ambient physical and chemical conditions. The tool was first used to predict maximum benthic chlorophyll *a* at each of the sites. As discussed in Tetra Tech (2006), benthic algal density is highly variable in time and space, and simplified models generally seem to do a better job of predicting maximum benthic algal density. The tool provides access to multiple predictions, but only three are presented here. Of the empirical approaches, we present the revised version of the Dodds model (Dodds, 2002), and, of the parametric approaches, we present the standard and revised QUAL2K models (which are tuned to correspond to the Dodds' results on small streams).

Results, shown in Table 3, calculated at median nutrient concentrations, are given for both 80 percent canopy closure and no canopy closure. The two QUAL2K methods are approximately consistent, while the Dodds results (which do not depend on light availability) tend to fall between the QUAL2K predictions with 80 percent and 0 percent canopy closure. No measured data are available to validate these predictions; however, the relatively high predicted maxima are in qualitative agreement with observations of high percentage algal cover.

Table 3. Predicted Maximum Benthic Chlorophyll *a* (mg/m^2)

Station	80 % Canopy Closure			0 % Canopy Closure		
	Standard QUAL2K	Revised QUAL2K	Dodds (2002)	Standard QUAL2K	Revised QUAL2K	Dodds (2002)
310CAN	211	239	294	392	398	594
310TWB	204	164	377	375	303	377

Note: Revised QUAL2K results are calculated with a days-of-accrual adjustment.

The tool can then be used to predict nutrient concentration targets needed to achieve a specified maximum algal density. For the COLD uses, Tetra Tech (2006) recommends that the target for maximum benthic chlorophyll *a* should generally be between 100 mg/m^2 (BURC I/II boundary below which conditions may be deemed acceptable) and 150 mg/m^2 (BURC II/III boundary above which conditions are deemed unacceptable). For the WARM uses, Tetra Tech (2006) recommends a BURC I/II boundary of 150 mg/m^2 and a BURC II/III boundary of 200 mg/m^2.

Given that predicted maxima are far above the recommended range, analysis was made at the BURC II/III boundaries. In addition, 80 percent canopy closure was assumed for evaluating target values, consistent with the ongoing habitat improvement projects to establish good riparian cover along most of the Chorro Creek mainstem. (The TMDL goal establishes a goal of 70 percent closure; however, this value is not available for use in the NNE Tool. On the other hand, it appears likely that the NNE Tool may somewhat underestimate the effects of canopy closure; therefore, evaluation at a specified value of 80 percent appears to provide a good basis for scoping analysis.)

Results for the 200 mg/m^2 WARM target and the 150 mg/m^2 COLD target for maximum benthic chlorophyll *a* are shown in Table 4 and Table 5. In these tables, the Revised QUAL2K method directly predicts total nutrient concentrations for N and P, either of which will achieve the target. The Standard QUAL2K method is based on inorganic nutrient concentrations, and the total nutrient limits shown in the tables are those that would be required at the existing average inorganic fraction of nutrient concentrations. The Dodds (2002) method is based on total nutrient concentrations but always yields co-limitation, such that the target may be obtained by any point along a frontier of Total N and Total P concentrations (see 0). The results shown in the tables are the required concentrations of Total N at the existing average Total P concentration and the required concentration of Total P at the existing average Total N concentration. .

Table 4. Summer Nutrient Concentrations to Meet WARM Use Maximum Benthic Chlorophyll *a* Target of 200 mg/m^2 (80% Canopy Closure)

Station	Standard QUAL2K		Revised QUAL2K		Dodds (2002)	
	Total N (mg/L)	Total P (mg/L)	Total N (mg/L)	Total P (mg/L)	Total N (mg/L)	Total P (mg/L)
310CAN	1.92	0.11	2.9	0.045	0.18	0.016
310TWB	1.67	0.11	2.8	0.044	0.20	0.043

Table 5. Summer Nutrient Concentrations to Meet COLD Use Maximum Benthic Chlorophyll *a* Target of 150 mg/m^2 (80% Canopy Closure)

Station	Standard QUAL2K		Revised QUAL2K		Dodds (2002)	
	Total N (mg/L)	Total P (mg/L)	Total N (mg/L)	Total P (mg/L)	Total N (mg/L)	Total P (mg/L)
310CAN	0.50	0.029	1.6	0.028	0.085	0.005
310TWB	0.46	0.032	1.6	0.027	0.091	0.012

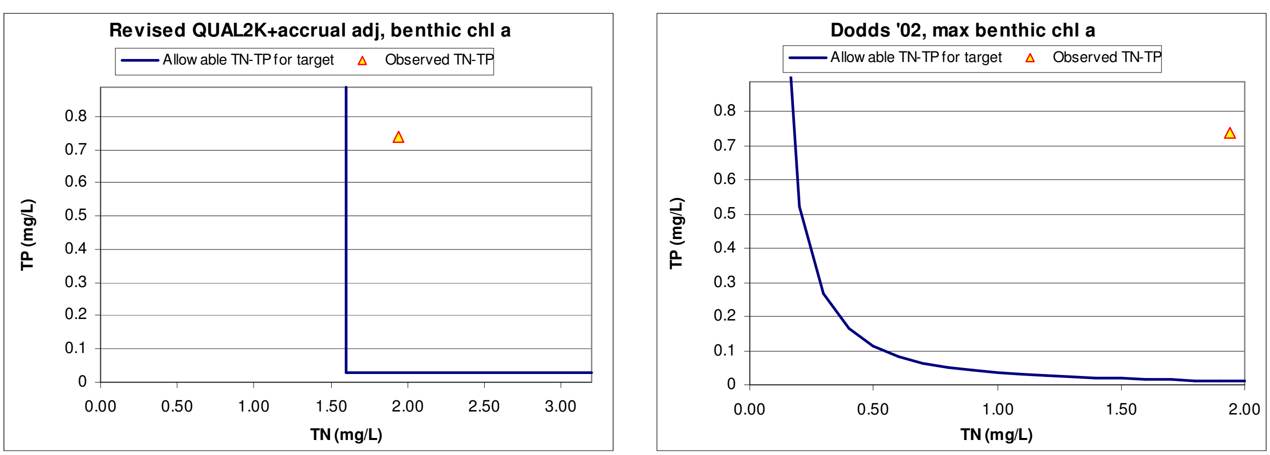

Figure 3. Revised QUAL2K and Dodds 2002 Tool Results for a Target Maximum of 150 mg/m^2-Chlorophyll *a* at Station 310TWB

Comparison of Table 4, Table 5, and Table 1 reveals that current conditions in Chorro Creek are elevated relative to the BURC II/III boundary for both WARM and COLD uses, especially for phosphorus.

USEPA (2000) suggested ecoregional criteria applicable to this area. Model results are compared to the USEPA criteria and the summary of Region 9 RTAG water quality monitoring data in Table 6. The targets derived from the CA NNE Scoping Tool for Chorro Creek are generally similar to the USEPA ecoregional criteria.

Table 6. Comparison of Model Results to USEPA Ecoregional Nutrient Criteria Recommendations and Region 9 RTAG Water Quality Monitoring Data

Chemical	Stream Type	Proposed USEPA 304(a) Criterion	Region 9 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	0.46 – 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	0.005 – 0.032					

Monitoring conducted for the Morro Bay National Estuary Program includes sampling from nine streams in the watershed that are upstream of any point source discharges, cropland, or urban development (but typically downstream of grazing areas). Average nitrate-N concentrations at these stations ranged from 0.2 to 0.4 mg/L, while average phosphorus-P concentrations ranged from 0.03 to 0.14 mg/L. The NNE targets for TN are thus apparently above background levels (given that above 80 percent of the nitrogen in the system is present as nitrate under median summer conditions at 310TWB and 310CAN), while the TP targets may be greater than normal background. This suggests that uses may best be attained through nitrogen control, which would also be beneficial to the health of the estuary.

4 Suggested Targets

The California NNE Approach (Tetra Tech, 2006) recommends setting response targets for benthic algal biomass in streams based on maximum density as mg/m^2 chlorophyll *a*. For the COLD beneficial uses, the recommended BURC I/II boundary is 100 mg/m^2, while the BURC II/III boundary is 150 mg/m^2. While quantitative measures of benthic algal density are not available, existing conditions in Chorro Creek appear to be above the BURC II/III boundary, suggesting impairment of these uses.

4.1 Response Targets

The California NNE Approach (Tetra Tech, 2006) recommends setting response targets for benthic algal biomass in streams based on maximum density as mg/m^2 chlorophyll *a*. For the COLD beneficial uses, the recommended BURC I/II boundary is 100 mg/m^2, while the BURC II/III boundary is 150 mg/m^2. While quantitative measures of benthic algal density are not available, existing conditions in Chorro Creek measured as percent algal cover suggest impairment of these uses.

Of particular importance for water quality in Chorro Creek, the risk of nuisance growth of *Cladophora* increases with increasing maximum benthic chlorophyll *a*. Welch et al. (1988) found that 20 percent or more cover by filamentous green algae was correlated with maximum benthic chlorophyll *a* greater than 100 mg/m^2, while Horner et al. (1983) concluded that biomass levels greater than 150 mg/m^2 often occurred with enrichment and when filamentous forms were more prevalent.

Another response target relevant to nutrients in Chorro Creek is dissolved oxygen (DO). The TMDL report (CCRWQCB, 2006) identifies biostimulation as a major contributor to depressed DO in Chorro Creek.

Protection of Morro Bay is also a relevant response target for management of nutrients in Chorro Creek, which was estimated to contribute 86 percent of the watershed nitrogen load and 94 percent of the watershed phosphorus load going to Morro Bay. While responses in the estuary likely depend more on net annual loading of nutrients than on concentrations in the creek, achieving full support of uses in the estuary may require further reductions in nutrient concentrations in the river. The NNE approach for estuaries, however, is still under development and targets based on estuarine response are not considered in this case study.

4.2 Nutrient Targets

The NNE Benthic Biomass Predictor spreadsheet can be used to translate the response targets into nutrient concentration goals. The model applications shown in Section 3.2 suggest that reductions in existing nutrient concentrations are necessary to meet response targets in Chorro Creek. However, the tool application is uncalibrated at this time, and different models and options in the tool lead to different predictions of nutrient targets. Development of quantitative nutrient targets based on benthic algal response in Chorro Creek should include the collection of appropriate data on existing benthic algal density to allow examination and calibration of model predictions. Ultimate nutrient concentration targets in Chorro Creek may also be constrained by loading limits necessary to support uses in Morro Bay.

5 Summary

The NNE benthic biomass tool was successfully applied to Chorro Creek and suggests the need for lowering existing nutrient concentrations to support uses based on benthic algal response. At the same time, efforts to improve riparian cover will limit light availability and decrease algal response – essentially increasing the assimilative capacity of the creek for nutrients. Unfortunately, no quantitative monitoring data on benthic chlorophyll *a* in the system is available; however, percent cover information does suggest that uses in the river are threatened by excess benthic algal growth

The California NNE approach is a risk-based approach, with ultimate focus on supporting designated uses. The general NNE guidance and accompanying tools provide initial, scoping-level estimates of nutrient reduction targets that can be used as a *starting* point for a TMDL or nutrient management plan. More sophisticated site-specific nutrient targets can be derived from the response targets through the use of calibrated, site-specific models. Calibration of the benthic algal component of such a model will require collection of data on periphyton densities.

6 References

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