APPENDIX B. Review of Existing Standards and Threshold Standards for Relevance to Assessment of Lake Tahoe Nearshore Desired Conditions

This appendix represents a preliminary effort by the Nearshore Science Team (NeST) to scientifically evaluate existing standards as prelude to developing a monitoring and evaluation plan, with an eye toward both relevancy for monitoring the nearshore environment and for management of desired conditions in the nearshore.

It is important to note that this appendix addresses only the existing standards that were provided for review by the agency working group for this project. That list contained 62 different entries in the form of numeric and narrative standards from both states (California and Nevada) as well as threshold standards from the TRPA. These entries were sorted and categorized on the basis of their similarity into 38 different parameter categories (as shown in Appendix A). These were then graded in terms of relevancy for both management and monitoring into three tiers, ranging from 1) important, to 2) relevant, to 3) less relevant for the nearshore of Lake Tahoe.

The primary focus of relevancy classification, however, was on the application of a particular parameter for assessment of nearshore condition, not on its use for regulatory purposes or for management objectives. For example, nutrient and sediment loading are particularly important for TMDL and management purposes because of the effects they exert on nearshore ecosystem processes, but they are only relevant to in-lake nearshore monitoring in terms of interpreting the direct measurements of nutrient and sediment concentrations and important ecosystem responses such as clarity or periphyton growth.

Several new metrics have been recommended as part of the NeST nearshore evaluation and monitoring plan presented in the main body of this report. In several cases these new metrics derive from or contain important elements of the standards reviewed here, and ultimately it may be desirable to revise or replace existing standards with new standards that link directly to these primary nearshore monitoring metrics. It is beyond the scope of this project, however, to provide the necessary level of analysis required by law to eliminate existing standards. Rather, we provide the scientific background that will help responsible management agencies decide where they may want to address changes that would target specific features and metrics of nearshore condition.

It is also important to note that there are certain nearshore metrics related toxicity, human and aquatic health, and aquatic invasive species that should be monitored as part of existing programs, rather than as a direct effort of the integrated nearshore monitoring and evaluation plan. They are represented in this plan simply as a first step toward integrating across multiple indicators for comprehensive nearshore assessment.

Table B-1 provides a summary of standards that were reviewed for assessment of nearshore condition and management of water resources, corresponding to categories shown in

Appendix A. Standards derive from (1) the Tahoe Regional Planning Agency: Goals and Policies, Attachment C - Resolution No. 82-11, (2) the California Regional Water Quality Control Board, Lahontan Region: Basin Plan (1975, amended 1995) and Regional Plan Update, 2012; (3) the Nevada Division of Environmental Protection: Chapter 445A for Water Controls contained in the Nevada Administrative Code.

Table B-1. Existing Standards Potentially Relevant to the Nearshore of Lake Tahoe.

ID #	Parameter Category	Nearshore Management	Nearshore Monitoring
1	Total Nitrogen	Important	Relevant
2	Total Soluble Inorganic Nitrogen	Important	Relevant
3	Ammonia	Less relevant	Less relevant
4	Nitrite	Less relevant	Less relevant
5	Dissolved Inorganic Nitrogen Loading	(see #8)	(see #8)
6	Total Phosphorus	Important	Relevant
7	Soluble Phosphorus	Important	Relevant
8	Biostimulatory Substances	Important	Relevant
9	Clarity	Important	Important
10	Pytoplankton	Important	Important
11	Algal Growth Potential	Relevant	Relevant
12	Biological Indicators (with Periphyton)	Important	Important
13	Suspended Materials	Important	Relevant
14	Settleable Materials	Less relevant	Less relevant
15	Suspended Sediment Loading	(see #13)	(see #13)
16	Total Dissolved Solids	Relevant	Less relevant
17	Conductivity	Relevant	Less relevant
18	pH	Relevant	Less relevant
19	Sodium Absorption Ratio	Less relevant	Less relevant
20	Chloride	Less relevant	Less relevant
21	Sulfate	Less relevant	Less relevant
22	Boron	Less relevant	Less relevant
23	Chemical Constituents	Less relevant	Less relevant
24	*E. coli*	Important	Important
25	Coliform Bacteria	Relevant	Relevant
26	Fecal Coliform	Relevant	Relevant
27	Temperature	Relevant	Relevant
28	Temperature Change	Relevant	Relevant
29	Dissolved Oxygen	Relevant	Relevant
30	Aesthetic Condition	(see #9 and #12)	(see #9 and #12)
31	Color	Less relevant	Less relevant
32	Taste and Odor	Relevant	Less relevant
33	Floating Materials	Less relevant	Less relevant
34	Oil and Grease	Less relevant	Less relevant
35	Toxicity	Important	Important
36	Radioactivity	Less relevant	Less relevant
37	Aquatic Communities and Populations	Important	Important
38	Nondegradation	Important	Less relevant

#1) Total Nitrogen

See NV-1 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and a relevant parameter for nearshore assessment. This would provide supplementary data as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - AA ≤0.25 mg/L; SV ≤0.32 mg/L.

CA - AA ≤0.15 mg/L.

3. Description of Standard

a) Narrative description of the standard(s):

Total Nitrogen (TN) represents the sum of total organic plus total inorganic nitrogen. It is determined by analyzing for Total Kjeldahl Nitrogen (TKN) as well as for nitrate-N + nitrite-N and then summing the two (TKN plus nitrate and nitrite). The TN represents nitrogen that has been taken up by algae, bacteria and other aquatic microorganisms (so present as particulate organic-N), plus that portion that has been released by all aquatic organisms as physiological side products or as the result of the decomposition of dead organic matter (both dissolved organic-N and dissolved inorganic-N, a form directly available to fuel algal growth). The organic nitrogen is composed of a large number of organic compounds including amines, amides, amino acids, proteins, and refractory humic compounds of low nitrogen content. The dissolved organic nitrogen (DON) fraction of lakes and streams is often 5-10 times greater than the particulate organic nitrogen contained in the plankton and seston, and the DON often constitutes over 50 percent of the total soluble N in fresh waters (Wetzel, 1975). In Lake Tahoe DON is generally about 60 percent of TN (Lahontan and NDEP 2010).

Much of the TN is dissolved organic matter as indicated above. The TN pool in the lake is much greater than the DIN pool; e.g., it was estimated that the DIN pool was 2900 metric tonnes and the TN pool was 14,000 metric tonnes in 1990 (Jassby *et al.*, 1992).

While TN, as a measure for water quality is very important with respect to waste water discharge, or for comparing lake of different trophic status (in regional analyses), its use as an independent indicator can be complicated. This is largely because science's understanding of how much of the total organic-N pool is, or can be, bioavailable for algal use. Organic nitrogen can be mineralized by bacteria to ammonium, and some algae can

use organic nitrogen directly as a source of nitrogen. Research in this area is generally limited. A study by Seitzinger *et al.* (2002) looking at nitrogen bioavailability in runoff from forest, pasture and urban land-uses in the northeastern United States found that from 0 to 73 percent of the DON could be used by algae. Similarly, working in a montane stream, Kaushal and Lewis (2005) reported that use of DON by algae ranged from 15 to 73 percent. These are complex studies that have not been conducted at Lake Tahoe.

It is important to note that while TN is used in the Tahoe TMDL (Lahontan and NDEP 2010), its incorporation into the Lake Clarity Model was done based on estimates of the N bioavailability for both the organic and inorganic pools. Without an approach for converting TN into bioavailable N (as done for the TMDL), TN is likely to have limited meaning with regard to evaluating the nearshore condition, unless organic-N loading or in-lake production changes dramatically.

b) What are reasonable reference conditions for this constituent:

Total N has traditionally been, almost exclusively, monitored in the open-water. Typical values for Lake Tahoe TN currently range from approximately 50-150 µg/L with a mean (±stdev) of 83±32 µg/L; n=150 (TERC unpub. data). TN was only measured in the nearshore between 1968-1972 (n=18) as part of the California Department of Water Resources monitoring (e.g. DWR 1973). At that time, the mean concentration in the open-water was 99±50 µg/L (n=36), and virtually identical to conditions today. DWR also measured TN in the nearshore during the entire period of record at five locations (near Tahoe Keys, Rubicon, near Incline Creek, Kings Beach and Zephyr Cove). TN (n=18) was identical at 126±75, 126±51, 126±70, 121±64 and 124±60 µg/L at these stations, respectively. Nearshore values exceeded 250 µg/L in three of the 126 samples and exceeded 200 µg/L in 13 of the 126 total samples. The ratio of nearshore to limnetic stations was approximately 25 percent.

Wetzel (1975) describes the following general ranges for lakes of different trophic status: ultra-oligotrophic TN <1-250 µg/L, oligo-mesotrophic 250-600 µg/L and meso-eutrophic TP 500-1100 µg/L. It may be useful to set bounds for TN in the nearshore based on the desired trophic state. A nearshore with ultra-oligotrophic characteristics should have TN <1-250 µg/L according to the values given by Wetzel.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

The existing standards of 150 µg/L TN (CA) and 250 µg/L (NV) are in the ultra-oligotrophic range. Both standards are consistent with a desired condition of ultra-oligotrophic nearshore; however, the CA standard is more reflective of historic conditions.

#2) Total Soluble Inorganic Nitrogen

See NV-2 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and a relevant parameter for nearshore assessment. This would provide supplementary data as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - AA ≤0.025 mg/L.

CA - None.

3. Description of Standard

a) Narrative description of the standard(s):

Dissolved inorganic nitrogen or DIN represents the sum of the soluble forms of nitrate, nitrite, and ammonium, and for the purpose of this discussion is taken to be synonymous with total soluble inorganic nitrogen (TSIN). Dissolved inorganic nitrogen (DIN) is a very important nutrient that often controls algal growth as these are the forms of nitrogen that are readily available for phytoplankton and periphyton uptake. Mean annual nitrate levels (15-20 µg N/L) and ammonium (1-2 µg N/L) account for approximately 25 percent of the total nitrogen in the lake's open water. The ratio of nitrate (+nitrite) to ammonium in the open-water is approximately 10:1. The average annual water column (mid-lake) concentration of nitrate-N is on the order of 18 µg N/L and has remaining uniform since 1980 (TERC 2012).

Goldman *et al.* (1993) examined the long-term set of 110 bioassays (1967-1992), that tested response to either nitrate or phosphate additions alone or in combination. These results are for open-water phytoplankton; limited if any data on nearshore response to N and P additions is available. The most outstanding feature of this record is a long-term shift from co-limitation by both N and P to predominant P limitation. In earlier tests (1967-1981), growth stimulation was observed in about 45 percent of the N bioassays and in about 25 percent of the P bioassays. In later tests (1982-1992), P stimulation was observed more frequently (nearly 90 percent of the P bioassays), while N stimulation was rare (occurring in six percent of the N bioassays). Jassby *et al.* (1995) attributed this shift to excessive DIN loading from atmospheric deposition.

More recently, phytoplankton response to nutrient addition for the period 2002-2011 is summarized in the UC Davis State of the Lake Report (TERC 2012). Between January and

April, algal growth was limited purely by phosphorus (P). From May to September, nitrogen (N) added by itself was more stimulatory, but the lake was co-limited, as shown by the greater response to adding both nutrients. Phosphorus was more stimulatory from October to December, but co-limitation was again the dominant condition. These results highlight the role of nutrients in controlling algal growth and underscore the synergistic effect when both are available.

Periphyton bioassays have been extremely limited with only six single tests run during a single study in 1986-1987 (Loeb 1987). Results were similar to those for phytoplankton in the sense that nitrate, phosphate, or N+P could be stimulatory. The data are insufficient to establish trends.

b) What are reasonable reference conditions for this constituent:

The earliest available data for ambient nitrate and ammonium concentrations in the nearshore date back to the DWR study (e.g. DWR 1973) when values were reported for the period July 1968 – December 1972. The mean open-water of limnetic value at a sampling depth near the surface was 2 µg N/L with a 0-4 µg N/L range. These DWR values are not directly comparable to the values from 1980-current (see below). DWR reported summary data for DIN (nitrate and ammonium) from five sites that had sufficient data over the period of record. Mean nitrate was on the order of 2-3 µg N/L with a 0-8 µg N/L range. Even though it is presented, the early DWR data for ammonium is considered unreliable as mean concentration at the nearshore sites was 10-13 µg N/L with very high maximum values at each site (19-39 µg N/L). The methodology for measuring low levels of ammonium in seawater and freshwater have significantly improved since 1968-1972 and the ammonium levels in Lake Tahoe have been found to be lower. Consequently, we focus on nitrate.

The only comprehensive monitoring of nearshore DIN was during the period 1981-1985 in association with a series of littoral zone/periphyton projects (e.g., Loeb and Reuter 1983, Loeb *et al.*, 1986). Fixed stations at Sunnyside, Rubicon Point, Zephyr Point and six sites along the south shore, from Baldwin Beach to Stateline were sampled at a depth of 0.5 m. Between July 1981 and July 1982, mean nitrate concentrations at all the nearshore locations ranged from only 4-6 µg N/L. The Index Station and the Midlake Station also had a mean value of 5 µg N/L. Seasonality is evident in the data – both open-water and nearshore – as a direct result of lake mixing which brings nitrate enriched bottom waters to the surface.

During 1983-1985 nearshore and open-water nitrate was again measured throughout the year at an expanded set of stations to be more inclusive of whole-lake conditions. Data show that the mean of the open-water sites was 7 µg N/L while the nine nearshore sites,

exclusive of south shore stations, had a mean on the order of 5 µg N/L. The three south shore stations, showed a range from 6-9 µg N/L with the highest at Bijou.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

The historic average annual concentrations for DIN are all significantly less that the ≤25 µg N/L Nevada standard. Most individual DIN values for the 1983-85 data were also below the 25 µg/L DIN level, e.g. the 95th percentile level for DIN for all the 0.5m and 2m nearshore data were 18 and 19 µg/L respectively. Certainly, values above the 25 µg N/L value are undesirable.

However, as discussed elsewhere in this report, since algae in Lake Tahoe are nutrient limited, the in-lake concentrations of nutrients can be quite variable and ephemeral. Goldman *et al.* (1981) emphasized ambient nutrient concentration may not be a good specific indicator of algal growth under all circumstances. For example, they directly compared phytoplankton primary productivity during August of both 1978 and 1979 in Tahoe Keys, Emerald Bay and the deep-water pelagic zone of Lake Tahoe proper. Especially in 1978, where productivity ranged from 1.8 to 6.1 to 167.7 mg C/m^{-3}/day in the open-water, Emerald Bay, and Tahoe Keys, respectively, but nitrate levels only ranged between 2.2–2.3±1.4 in these three regions. Nutrient concentrations are very dynamic in that (1) large levels can be quickly reduced due to algal uptake, with an apparent inverse relationship, and (2) the use of recycled nutrients that are mineralized in the lake can fuel algal growth. Thus, measurements of nutrient response variables, such as phytoplankton chlorophyll or periphyton biomass, often are emphasized for evaluation of aquatic systems rather than focusing simply on nutrient concentrations, which can exhibit high levels of transient spatiotemporal variability.

#3) Ammonia

See NV-3 and CA-3 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Since ammonia is included in the soluble inorganic nitrogen sample data (#2), it would contribute supplementary data as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - SV ≤3.0 µg/L.

CA - One-hour and four-day temperature and pH dependent standards in Basin Plan.

3. Description of Standard

a) Narrative description of the standard(s):

Ammonia is soluble in water and its speciation is affected by a variety of environmental parameters, but especially pH and temperature. The relative concentrations of NH_3 (ammonia) and NH_4^+ (ammonium) is a specific function of temperature and pH (see Lahontan Basin Plan). For example, at a pH of 7.5 and a temperature of 15 °C 0.86 percent (0.0086) of the total ammonia pool ($NH_3 + NH_4^+$) occurs in the un-ionized form. It is the un-ionized form (NH_3) that can be toxic to freshwater aquatic life.

Data for calculated un-ionized ammonia is rarely, if ever reported for the ambient waters of Lake Tahoe. Given the typically low ambient concentrations for total ammonia ($NH_3 + NH_4^+$) there is virtually no risk that the un-ionized portion will be sufficient to affect aquatic life. However, ionized ammonia or ammonium is an algal growth nutrient. The impact of ammonium as a driver of eutrophication is addressed in the section on total dissolved inorganic nitrogen (#2).

b) What are reasonable reference conditions for this constituent:

As NeST was unable to locate nearshore specific data on ammonia concentrations in Lake Tahoe there is no basis to support reasonable reference conditions for this constituent, other than existing state standards intended to prevent ammonia toxicity in aquatic organisms.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

The current Lahontan and NDEP standards are based on a well-supported national recommendations based on toxicity to aquatic life, and are considered sufficient.

#4) Nitrite

See NV-4 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. But since nitrite is measured and included as part of nitrate sample analysis, it would still be represented in the total soluble inorganic nitrogen data. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - SV ≤0.06 mg/L.

CA - None.

3. Description of Standard

a) Narrative description of the standard(s):

Nitrite is a component of the dissolved inorganic-N pool along with nitrate an ammonium. Nitrite (NO_2) levels in natural lake water are typically extremely low as bacteria rapidly convert nitrite to nitrate under oxic conditions. Nitrite can increase under anoxic conditions in water polluted with very high levels of nitrogen.

Nitrites react directly with hemoglobin in human blood and other warm-blooded animals to produce methemoglobin and is there of concern in drinking water. Also, nitrites can produce a serious condition in fish called "brown blood disease."

b) What are reasonable reference conditions for this constituent:

Since nitrite is potentially a toxic compound, reference conditions based on historic or unpolluted conditions are not applicable.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

From the point of view of nitrogen, algal growth and eutrophication, the current standard is sufficient. It is beyond the scope of this project to evaluate standards with regard to public health. Given that nitrate is so low in Lake Tahoe, we suspect that under natural, ambient conditions, nitrite should not pose a public health issue; however, confirmation needs to be supplied by the states and local/regional drinking water supplier and public health departments.

#5) Dissolved Inorganic Nitrogen Loading

See TRPA-5 in parameter summary table (Appendix A)

Note: the review and discussion of DIN loading is included below under Biostimulatory Substances (#8).

#6) Total Phosphorus

See CA-6 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and a relevant parameter for nearshore assessment. This would provide supplementary data as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None .

NV - None.

CA - AA ≤0.008 mg/L.

3. Description of Standard

a) Narrative description of the standard(s):

Phosphorus is a major nutrient associated with increased algae and periphyton growth, and may be present as organic, inorganic, soluble and particulate forms. Total phosphorus represents the aggregate of these forms, with soluble reactive phosphorus (orthophosphate) being of most concern, reported on a molar or mass phosphorus basis. As part of the TMDL science program it was determined that particulate-P yielded 20-30 percent of it's phosphorus to the bioavailable pool. Similarly, 5-15 percent of the dissolved organic-P pool was bioavailable and 95 percent of the soluble reactive-P pool (Ferguson and Qualls, 2005; Sahoo *et al.*, 2009). Phosphorus and suspended sediments are related as phosphorus is commonly bound to soil particles.

Goldman *et al.* (1993) examined the long-term set of 110 bioassays (1967-1992), that tested response to either nitrate or phosphate additions alone or in combination. These results are for open-water phytoplankton; limited if any data on nearshore response to N and P additions is available. The most outstanding feature of this record is a long-term shift from co-limitation by both N and P to predominant P limitation. In earlier tests (1967-1981), growth stimulation was observed in about 45 percent of the N bioassays and in about 25 percent of the P bioassays. In later tests (1982-1992), P stimulation was observed more frequently (nearly 90 percent of the P bioassays). Recent data (2001-2011) shows that P stimulated algal growth in 95 percent of the experiments conducted in the period January-April, in 10 percent of the tests run in May-September and 40-45 percent of the test run in October-December. The combination of N plus P (both in soluble form) were always stimulatory.

b) What are reasonable reference conditions for this constituent:

The data for TP in the nearshore is very limited. As part of the *California – Nevada – Federal Joint Water Quality Investigation of Lake Tahoe* study, mean TP values were reported for the period July 1968 – December 1972 (typically two sampling dates per year). The mean (and range) for the open-water stations was reported at <7.5 µg/L (1-22 µg/L) (e.g. DWR 1973). This was nearly identical to the values reported from five nearshore stations: <8.1 µg/L (2-18 µg/L); <7.2 µg/L (2-20 µg/L); <5.9 µg/L (1-14 µg/L); <7.3 µg/L (1-18 µg/L) and <7.7 µg/L (1-18 µg/L).

It may also be useful to assess levels of TP in the nearshore relative to lake trophic states. Wetzel (1975) indicates the following general ranges for lakes of different trophic status: ultra-oligotrophic TP <1-5 µg/L, oligo-mesotrophic 5-10 µg/L and meso-eutrophic TP 10-30 µg/L.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

The California standard of 8 µg/L for TP appears reasonable. Additional, yet limited data on current TP levels in the nearshore will be useful as part of a supportive dataset to assess the full annual range.

#7) Soluble Phosphorus

See NV-7 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and a relevant parameter for nearshore assessment. This would provide supplementary data as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - AA ≤0.007 mg/L.

CA - None.

3. Description of Standard

a) Narrative description of the standard(s):

Phosphorus is a major nutrient associated with increased algae and periphyton growth, and may be present as organic, inorganic, soluble and particulate forms. Soluble reactive phosphorus (SRP) is essentially a measure of orthophosphate, the form of phosphorus most readily available to the algae. While the SRP method measures mostly orthophosphate, total hydrolzable P (THP) also typically measures small amounts of the less readily available condensed polyphosphates that may be hydrolyzed in part by the analytical method. In a comparison of SRP and THP from 65 samples from the open-water of Lake Tahoe the mean THP was 3.2 µg/L as compared to 2.2 µg/L for SRP. The historic data base from UC Davis in the 1980s for nearshore nutrients consisted of THP analysis while the DWR (e.g. 1973) measurements were as reactive phosphate.

b) What are reasonable reference conditions for this constituent:

Average reactive orthophosphorus in the open-water during the 1968-1972 DWR (e.g. 1973) study were 3.1-3.4 µg/L with a range of 0.1-10.0 µg/L. The five nearshore sites

were: 2.7 µg/L (0.8-8.0 µg/L); 3.3 µg/L (0.2-9.0 µg/L); 3.3 µg/L (0.2-7.0 µg/L); 3.4 µg/L (0.3-10.0 µg/L) and 3.7 µg/L (0.1-13.0 µg/L).

In the 1981-82 nearshore study (Loeb 1983) THP concentrations at nearshore sites along the west and south shore were generally close to levels at Mid-lake and Index stations. The overall mean concentrations for the one year study were also close (3-4 µg/L) at the pelagic stations and 3-6 µg/L at the nearshore stations. Individual THP values generally were below 8 µg/L, with only 4 out of 98 samples exceeding 8 µg/L. Nearshore THP data collected during periphyton monitoring 1983-85 (Loeb and Palmer, 1985; Loeb *et al.*, 1986) showed similar patterns. Average THP at pelagic sites was (3-4 µg/L) which was slightly lower than 1983-1985 averages for the nearshore sites which ranged from about 5-7 µg/L. The 90th and 95th percentile levels for all nearshore THP data were 8 and 9 µg/L, respectively, for sites at 0.5m and 10m, and 13 µg/L for sites at 2m.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Soluble orthophosphate is typically rapidly assimilated by algae and other biota in low nutrient waterbodies such as Lake Tahoe. Consequently, concentrations are usually very low in the photic zone where algal growth occurs. For this reason, concentrations of orthophosphate are not very diagnostic for evaluating phosphorus dynamics in aquatic ecosystems (Wetzel 1975).

A standard value of 7.0 µg/L appears to be an appropriate value.

#8) Biostimulatory Substances

See TRPA-8, TRPA-5 and CA-8 in parameter summary table (Appendix A)

1. Relevancy: An important parameter with regard to management and water quality control, and relevant to nearshore assessment (but better represented by #1, #2, #6 and #7.) Data on nutrient loading monitored in the watersheds is contributory to interpretation of nearshore conditions. Retain or revise as part of the state standards for protection of nearshore water quality, with compliance monitoring of watershed inputs required to achieve load reductions for the Lake Tahoe TMDL.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - Reduce the loading of dissolved inorganic nitrogen, dissolved phosphorus, iron, and other algal nutrients from all sources to meet the 1967–1971 mean values for phytoplankton primary productivity (PPr) and periphyton biomass in the littoral zone.

TRPA - Reduce dissolved inorganic nitrogen loading to Lake Tahoe from all sources by 25 percent of the 1973-81 annual average. (Reduce dissolved inorganic nitrogen loads from surface runoff by approximately 50 percent, from groundwater approximately 30 percent, and from atmospheric sources approximately 20 percent of the 1973-81 annual average.)

NV - None.

CA - Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect the water for beneficial uses.

Note - The recent CA and NV Lake Tahoe TMDL calls for a 15 year reduction of total N by 4 percent and a 65 year target reduction of 10 percent total N. It also specifies a 15 year reduction of total P by 17 percent and a 65 year target reduction of 35 percent total P.

3. Description of Standard

a) Narrative description of the standard(s):

Load reduction of nitrogen, phosphorus and other biostimulatory substances is of prime importance at Lake Tahoe. Indeed, the goal of water quality restoration efforts over the past four decades has been focused on load reduction. This was most recently addressed in the Lake Tahoe TMDL where numeric targets for nutrient load reduction were developed.

Nitrogen loading to Lake Tahoe from the major sources was reported in the TMDL (Lahontan and NDEP 2010) with the following estimates in the order of importance: DIN annual load – 192 metric tons (MT); atmospheric deposition to lake surface – 148 MT (77 percent); groundwater – 32 MT (17 percent); urban runoff – 8 MT (4 percent) and; streamflow – 4 MT (2 percent). Total N loading to Lake Tahoe from the major sources was also reported in the TMDL (Lahontan and NDEP 2010) with the following estimates in the order of importance: total N annual load – 397 metric tons (MT); atmospheric deposition to lake surface – 218 MT (55 percent); urban runoff – 63 MT (16 percent) and; non-urban upland – 62 MT (16 percent) groundwater – 50 MT (14 percent).

Phosphorus loading to Lake Tahoe from the major sources was reported in the TMDL (Lahontan and NDEP 2010) with the following estimates in the order of importance: SRP annual load – 13.2 metric tons (MT); groundwater – 4.8 MT (36 percent); non-urban - 3.8 MT (29 percent); urban – 2.3 MT (17 percent) and atmospheric deposition to lake surface – 2.3 MT(17 percent). Total P loading to Lake Tahoe from the major sources was also reported in the TMDL (Lahontan and NDEP 2010) with the following estimates in the order of importance: total P annual load – 46 metric tons (MT); urban runoff – 18 MT

(39 percent); non-urban upland –12 MT (26 percent); atmospheric deposition to lake surface – 7 MT (15 percent) and groundwater – 7 MT (15 percent).

b) What are reasonable reference conditions for this constituent:

It is difficult to establish a reference condition for DIN and SRP loading – from all major sources – since there is inadequate data on loading during the late 1960s – early 1970s, a period which forms the basis for the existing algal growth, periphyton and phytoplankton biomass and clarity standards. Comprehensive estimates of whole-lake loading only began to become available in the 1990s (Reuter *et al.*, 2003), which led to a detailed estimate of DIN and SRP loading as part of the TMDL (Lahontan and NDEP 2010).

The TMDL modeled the loading for N and P that would result in the 29.7 m standard for open-water transparency (measured as Secchi depth). However, there are three important caveats, (1) the 29.7 m transparency standard is not directly linked to the nearshore, (2) TMDL load reduction was for TN and TP with a set of bioavailability factors included in the Lake Clarity Model and (3) because of the importance of fine sediment particles in controlling Secchi depth transparency in the open-water, the relative importance of N and P is less than the NeST would expect for the nearshore where periphyton and other algae impact beneficial uses.

While it was significantly outside the scope of this project, modeling of the nearshore (as was done for the open-water TMDL), could be used to estimate reference loading conditions for N and P. At this time, science does not know the quantitative level of nutrient reduction that would be needed to meet nearshore periphyton and phytoplankton standards. An assumption is made that load reduction that will improve pelagic clarity will also be of significant benefit to the trophic status of the nearshore environment. While this may or may not be true for specific nearshore locations, it is a reasonable expectation for the nearshore taken as a whole.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Yes, in the general sense that desired conditions are well represented by a narrative standard that requires loading reductions in DIN, dissolved phosphorus (DP) and iron as necessary to meet 1967-1971 mean values for phytoplankton PPr and periphyton biomass. However, specific guidance is given only for a numeric loading reduction in DIN to Lake Tahoe (25 percent), which was based on limited data from the period 1973-1981. While this numeric standard was forward-thinking in the 1970s to early 1980s, over 30 years of new monitoring and research now needs to be considered. At the time these thresholds standards were developed and adopted, phytoplankton bioassay results suggested the overwhelming importance of nitrogen for growth stimulation. Conditions have changed (Goldman *et al.*, 1993) and the overwhelming importance of the combination of nitrogen and phosphorus in the stimulation of algae is now apparent. There seems to be but little

evidence to support the historic selection of numeric DIN load reductions required from the various sources, as well as the total. Again, these were forward-thinking at the time, and in fact served as a precursor to the Lake Tahoe TMDL with its pollutant reduction requirements, but numeric water quality threshold standards must account for specific reductions in both nitrogen and phosphorus loading.

The Lake Tahoe TMDL attempted to address this issue, at least for the open-water. Furthermore, research found that fine sediment particles, in addition to nitrogen and phosphorus, affected deep lake clarity, with the fine particles as the most important factor (Swift *et al.*, 2006). Based on the open-water conditions, the TMDL established a nutrient load reduction requirement of 4 percent N and 17 percent P as a 15-year target from their 2004 baselines, with a 65-year target of 10 percent N and 35 percent P reduction to meet the desired transparency value of 29.7 m as the annual average. Note that while the N and P reduction requirements are stated in terms of TN and TP, they represent the bioavailable forms.

Both the TRPA threshold standards and the Lake Tahoe TMDL load reduction requirements are specifically focused on water clarity in the deep, open-water portion of the lake. Given the importance of periphyton in the nearshore, these regulatory requirements may not be specifically applicable to the nearshore. This is especially the case for periphyton, where benthic algae are not much affected by fine sediment particles, but by nitrogen and phosphorus. Consequently, the loading of these nutrients will have a much great level of importance in the nearshore than it does in the open-water. N and P load reductions to protect the nearshore will require a much greater emphasis than is required for transparency in the open-water. However, NeST fully agrees that any reduction in nutrients entering the lake via the watershed should have a beneficial, yet at this time unquantifiable, impact on the nearshore condition.

The exclusion of biostimulatory substances as a metric to evaluate nearshore condition is NOT based on the assumption that these substances (especially nitrogen and phosphorus) are not important and do not greatly affect littoral zone trophic status. Rather, the inclusion of phytoplankton and benthic algae as response metrics serves to provide a more reliable assessment since both communities are in part controlled by nutrient availability. The measurement of nitrogen, phosphorus and other biostimulatory substances could be critical in understanding the dynamics of phytoplankton and benthic algae, and as supporting data for interpreting water quality management policy and actions.

Even though biostimulatory substances may not be the most appropriate metric for evaluating a nearshore trophic status indicator, the pursuit of nutrient load reduction is certainly an important management standard.

At this time NeST does not see any reason to maintain the iron portion of the TRPA standard. While iron and other trace metals can stimulate algal growth (e.g., Lane and Goldman 1984), NeST does not consider a focus on iron reduction to be necessary, as controls for fine sediment particle reduction will help in iron load reduction.

#9) Clarity

See TRPA-9, TRPA-30, NV-9 and CA-9 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and an important parameter for nearshore assessment. This has been categorized as one of the primary metrics for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality. Consideration of revisions to the standards may be appropriate at this time, or after additional data have been collected as part of a standardized nearshore monitoring and evaluation program.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - Decrease sediment load as required to attain turbidity values not to exceed three NTU. In addition, turbidity shall not exceed one NTU in shallow waters of the Lake not directly influenced by stream discharges.

TRPA - Improve nearshore aesthetic quality such that water transparency and the biomass of benthic algae are deemed acceptable at localized areas of significance.

NV - Vertical extinction coefficient (VEC) < 0.08/m when measured at any depth below first meter. Turbidity must not exceed 3 NTU at any point too shallow to determine reliable VEC.

CA - Waters shall be free of changes in turbidity that cause nuisance or adversely affect the water for beneficial uses. Increases in turbidity shall not exceed natural levels by more than 10 percent.

3. Description of Standard

a) Narrative description of the standard(s):

Water clarity is represented by conditions of light absorption, diffraction and scattering. Transmissivity and turbidity measurements are both required as they interpret water clarity conditions differently. Transmissometers measure both absorption and scattering processes and read full scale, i.e. 100 percent, when in pristine water, thereby providing reliable readings at low particle concentrations. Turbidimeters measure a subset of scattering processes and read full scale at high turbidity values when transmissometers are less

effective. The turbidimeter readings are more variable and less stable in high clarity conditions characteristic of undisturbed area in Lake Tahoe. Therefore, light transmissometers are more suitable for long-term measurements at background clarity levels, whereas turbidity is appropriate for shorter-term measurements of non-background conditions. Transmissivity profiles would be relevant for interpreting subtle changes in clarity conditions over depth, and UV transmissivity is important to community composition.

b) What are reasonable reference conditions for this constituent:

Turbidity values of less than 0.14 NTU represent the cleanest conditions in the Lake Tahoe nearshore zone as assessed by whole-lakeshore surveys. Impacted waters commonly increase above 1 NTU, and have been infrequently observed to exceed 10 NTU, with areas of decreased water quality associated with areas of greater on-shore urbanization Taylor *et al.* (2003). Turbidity values in the absence of major disturbance vary around the nearshore from about 0.15 to 0.3 NTU. The most pristine conditions, found along 31 percent of the lakeshore perimeter, had a 0.12 NTU mean of mean turbidities and 5.3 percent mean for CVs. Areas that were less pristine accounted for 54 percent of the lakeshore perimeter and were characterized by a slightly higher 0.14 NTU mean of mean for turbidities and twice the mean of CVs of 10.6 percent. Therefore, a reasonable turbidity reference condition between 0.12 and 0.14 NTU would be consistent with historical data. It must be noted that this reference condition is specifically based on irregularly repeated measurements taken between 2000 and 2012 produced by a Hach 2000 turbidimeter using a flow-through system. Turbidity measurements taken utilizing other turbidimeter models, from other manufacturers, and different collection systems will require calibration to this reference system.

Measurement of low turbidity values represented by the reference condition are difficult and require research-grade equipment and methodology to carry out in a repeatable manner over time. Light transmissivity is more suitable to quantifying changes near the reference conditions. Transmissivity values are higher (e.g. 97 percent) in the cleanest conditions and decrease to below 80 percent in degraded waters, but is only infrequently found at less than 60 percent. The most pristine conditions, found along 33 percent of the lakeshore perimeter, had a 96.4 percent mean of mean transmissivities and a 0.3 percent mean for CVs. Areas that were less pristine accounted for 25 percent of the lakeshore perimeter and were characterized by a slightly more degraded 94.9 percent mean of mean for transmissivities and twice the mean of CVs of 0.6 percent. Therefore, a reasonable light transmissivity reference condition between 96.4 and 94.9 would be consistent with historical data. This reference condition is considered to be an interim value and must be reviewed as more data are collected as part of a dedicated nearshore monitoring program. The interim status is due to the much more limited amount of available data and the

development and testing of a finalized standard operating procedure that prioritizes the use of this sensor for measurements in pristine areas.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

No. The current California nearshore standard does not permit turbidity to exceed natural levels by more than 10 percent. Although the best theoretical accuracy for the research grade turbidimeters is considered to be 2 percent, this accuracy was determined under perfect laboratory conditions over a NTU range considerably higher than observed in the nearshore zone. A 10 percent change in readings in the range typical of undisturbed conditions (from 0.1–1 NTU) cannot be easily measured using a turbidimeter. However, the same relative difference in clarity can be quantified using a light transmissometer.

Existing near-shore thresholds are static and do not provide exemptions to account for unusual or infrequent events, although the TRPA does permit turbidity up to 3 NTU in areas of the nearshore directly influenced by stream discharge. This standard recognizes that stream discharges can have a negative impact on nearshore clarity. However, the actual delineation of stream-affected areas around the lake is not a trivial exercise and may require focused studies in areas where urban and stream outfalls are near each other.

Recognition of urban influences separately from pristine areas would provide greater protection for the more pristine areas around the lake in the sense that nearshore clarity in un-impacted areas should not be reflective of areas with urban runoff. For example, current thresholds permit degradation in water clarity of up to 1 NTU at pristine areas like Bliss and Sand Harbor State Parks – a change that would degrade clarity from current levels down to a visibility of only 3-6 m (Taylor *et al.*, 2003). The low variability in turbidity characteristic of these pristine areas indicates that such events are highly uncommon compared to urban areas that routinely exceed 1 NTU in response to hydrologic events. A regional approach that separates out low variability pristine areas from highly variable urban areas may be necessary to meet the public's expectations of clarity.

Numeric standards could be similar to those currently in place, but should include new standards for light transmittance and perhaps more stringent requirements for the relatively pristine areas. Localization of clarity metrics could also include a temporal component that allows a greater percentage exceedance off-shore from urban areas but be more restrictive near pristine areas. Local factors such as land use, bathymetry, and nearshore currents may be important to consider when developing regional threshold values for different zones around the lake.

In nearshore waters >20 m in depth, NeST agrees that existing standards for the vertical extinction coefficient appear to be appropriate.

#10) Phytoplankton

See CA-10 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and an important parameter for nearshore assessment. This has been categorized as one of the primary metrics for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality. Consideration of revisions to the standards may be appropriate at this time, or after additional data have been collected as part of a standardized nearshore monitoring and evaluation program.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - Counts: Jun-Sep average ≤100 per mL; SV ≤500/mL.

CA - Counts: mean annual average ≤100 per mL; max ≤500/mL.

3. Description of Standard

a) Narrative description of the standard(s):

Three measures of phytoplankton abundance that are frequently used are 1) cell counts, 2) biovolume and 3) chlorophyll *a* concentrations, each with advantages and disadvantages (Dolan *et al.*, 1978). Cell counts is used to study species composition, and quantify number of organisms and diversity. Perhaps the most critical disadvantage is that by only reporting the number of organisms present; cell number does not consider cell size and differences in biomass. For concerns such as food webs, levels of algal biomass, clarity, color, nuisance species, etc., cell counts by themselves does not provide adequate information. Additionally, phytoplankton cell counting is very laborious and time consuming. For these reason, the measurement as chlorophyll *a* became an accepted surrogate for algal biomass in the late 1960s and 1970s.

b) What are reasonable reference conditions for this constituent:

Nearshore phytoplankton was monitored in the late 1960s to early 1970s, which was done as part of the California-Nevada-Federal Joint Water Quality Investigation of Lake Tahoe (e.g. DWR 1973). Cell counts were made near the surface (1.5 m) at both littoral and pelagic stations; the data in the reports included counts of individual species and total cells per ml. Sites with violations of the above standards were identified. There were some years when many sites violated the standards and some when few sites violated the standards. There was no site that consistently violated the standards. High phytoplankton counts were not always linked in this monitoring with consistently impaired regions.

Cell biovolume takes cell size into account to calculate the volume of phytoplankton material. Using the density of phytoplankton cell material - on the order of just over 1 mg/L = 1 mm^3/L – biovolume can be converted to biomass. The suggested range for phytoplankton biomass values in water of varying tropic status are defined by Wetzel (2001) from a compilation of published studies. For maximum average biomass (mg/m^3) these include: ultra-oligotrophic - <50, oligotrophic – <100, oligo-mesotrophic - <200, mesotophic - <300, and eutrophic - >300. For Lake Tahoe's open-water the range of average annual values range on the order of 50-150 mg/m^3 with individual values between 40-<250 mg/m^3. The only data for nearshore phytoplankton biomass in Lake Tahoe is from a 1981-82 investigation that found values of 40-60 (Loeb *et al.*, 1984). In 1982 the annual average open-water value was approximately 60 mg/m^3 (note that the open-water values includes water taken from the deep chlorophyll maximum which is not found in the nearshore. Therefore, nearshore phytoplankton biomass in the early 1980s was largely in the ultra-oligotrophic range.

Historical chlorophyll *a* data are quite sparse for the nearshore in Lake Tahoe (refer to discussion of this metric in the nearshore report for an update and summary of recent nearshore chlorophyll data). An exception to this is the *California-Nevada-Federal Joint Water Quality Investigation of Lake Tahoe*. In 1971-1972 the mean±stdev of chlorophyll *a* at the 12 nearshore sites was 0.18±0.04 µg/L. According to Wetzel (1975) this is well within the 0.01-0.5 µg/L range for ultra-oligotrophic lakes. This is also well below the <0.95 µg/L value applied for oligtrophic conditions by Carson and Simpson (1996).

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Cell number (counts) alone is typically not an effective means of expressing phytoplankton abundance. While cell number may be adequate to distinguish between trophic status on the large scale (large differences expected between oligotrophic and eutrophic waterbodies), its application for the nearshore of Lake Tahoe is limited as changes in cell number may not be significant enough for this feature to serve as a good standard. We suggest instead that the nearshore metric for phytoplankton be expressed as cell counts that identify both the species composition and their abundance.

#11) Algal Growth Potential

See CA-11 in parameter summary table (Appendix A)

1. Relevancy: A relevant parameter for nearshore management, and a relevant parameter for nearshore assessment. Since AGP will be included as supplementary data to the nearshore phytoplankton evaluation, it will be included as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality. Consideration of revisions to the standards

may be appropriate after additional data have been collected as part of a standardized nearshore monitoring and evaluation program.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - None.

CA - Mean Algal Growth Potential at any point ≤ 2x times the mean annual AGP at limnetic reference station.

3. Description of Standard

a) Narrative description of the standard(s):

The algal growth potential (AGP) bioassay has its history in the early studies of cultural eutrophication. It largely reflects the ability of natural populations of phytoplankton to grow in ambient water, and is a function of original biomass, species composition and nutrient availability, among other things. In this regard AGP is an integrative measure. AGP is extremely useful in that it allows for comparisons between potential growth at different locations. This latter application forms the basis for the existing California standard. Tracking the absolute response from the AGP over time can also be informative with respect to the ability an aquatic area to support increasing or decreasing crops of algae.

The only readily available data NeST could find for AGP tests at lake Tahoe come from the California-Nevada- Federal Joint Water Quality Investigations in 1969-1974. The AGP assay procedure used in the DWR (e.g. 1973) studies involved an incubation of 1.8 L of lake water collected from each nearshore station, incubated in a growth chamber at 20°C and a light intensity of approximately 125 μE m^{-2} sec^{-1} (~10 percent of full sunlight). Change in algal abundance was measured over a two-week period by periodically subsampling for chlorophyll analysis. The peak chlorophyll value during the incubation was considered the algal growth potential of the water. This was then compared to the AGP from pelagic or open-water reference samples from mid-lake.

The algal nutrient stimulation bioassays that have been performed at Lake Tahoe to date (e.g. Goldman *et al.*, 1993) differ from AGP in the sense that the former provide information on which nutrient is most stimulatory to algal. The algal nutrient stimulation bioassays have not focused on nearshore condition, but rather open-water condition.

b) What are reasonable reference conditions for this constituent:

The most reasonable reference conditions come from the California-Nevada- Federal Joint Water Quality Investigations in 1969-1974 conducted by the California Department of

Water Resources. Between 1971-1972, most of the nearshore stations did not exceed the 2.0 times background standard. Three of 12 stations had values in in the range of 2.5-3.75 times background

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

The California standard appears to be reasonable. Additional data is needed to assess current conditions relative to the historical measurements.

#12) Biological Indicators (with Periphyton)

See TRPA-30, CA-12 and CA-38 in parameter summary table (Appendix A)

1.Relevancy: An important nearshore parameter for management purposes, and an important parameter for nearshore assessment. Periphyton has been categorized as one of the primary metrics for nearshore assessment (features relevant to phytoplankton standards were discussed in #10 and #11 above). Retain or revise as part of the state standards for the protection of nearshore water quality. Consideration of revisions to the standards related to periphyton would be appropriate at this time, and periphyton should be recognized as an independent standard and/or raised to the level of a threshold or standard where it is not.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - Improve nearshore aesthetic quality such that water transparency and the biomass of benthic algae are deemed acceptable at localized areas of significance.

NV - None.

CA - Lake Tahoe algal productivity and biomass of phytoplankton, zooplankton, and periphyton shall not be increased beyond the levels recorded in 1967-71, based on statistical comparison of seasonal and annual means. *The "1967-71 levels" are reported in the annual summary reports of the "California-Nevada-Federal Joint Water Quality Investigation of Lake Tahoe."*

CA - The State Board designated Lake Tahoe an Outstanding National Resource Water (ONRW) in 1980, both for its recreational and its ecological value, and stated: "Viewed from the standpoint of protecting beneficial uses, preventing deterioration of Lake Tahoe requires that there be no significant increase in algal growth rates. Lake Tahoe's exceptional recreational value depends on enjoyment of the scenic beauty imparted by its clear, blue waters. ...Likewise, preserving Lake Tahoe's ecological value depends on

maintaining the extraordinarily low rates of algal growth which make Lake Tahoe an outstanding ecological resource."

3. Description of Standard

a) Narrative description of the standard(s):

This standard is inclusive of the whole lake, which includes the nearshore. It is targeted at controlling the cultural eutrophication and maintaining plankton and attached algae abundance at levels commensurate with ultra-oligotrophy and conditions in Lake Tahoe in the late 1960s and early 1970s.

Periphyton or attached algae is arguably one of the most important metrics to assess Desired Conditions for nearshore trophic status. It is visually noticeable to even the most casual of those who use the nearshore for recreation, aesthetic enjoyment and both water and non-water contact activities. At certain locations in Lake Tahoe the contrast between the blue water and thick carpets of attached algae – at times up to six inches in length – is striking.

Studies of nearshore attached algae at Lake Tahoe began as early as the 1970s as scientists appreciated to link between periphyton abundance and regional nutrient input (e.g., Goldman *et al.*, 1982; Loeb and Reuter, 1984; Loeb, 1986). These studies occurred over the period 1981-1985 (Loeb *et al.*, 1986). Routine monitoring was re-initiated in 2000 and has continued through the present (e.g., Reuter *et al.*, 2001; Hackley *et al.*, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). Periphyton biomass in the shallow waters of the nearshore (0 – 1 m in depth) is largely related to the degree of land development and enhanced nutrient loading. Long-term studies at Lake Tahoe have shown portions of the shoreline to be virtually periphyton-free year-round while others support significant seasonal blooms. In this regard periphyton is a very sensitive metric for nearshore trophic status.

b) What are reasonable reference conditions for this constituent:

Discussion of the periphyton metric in our nearshore report provides significant detail on suggestions for reference conditions – the reader is referred to that section. These suggestions are based on a comprehensive analysis of the long-term Lake Tahoe data. NeST believes that the historic data base is quite sufficient to recommend reasonable reference conditions for periphyton.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

NeST is appreciative of the integrative nature of this standard, focusing on managing cultural eutrophication. Attainment of this standard will support Desire Conditions; however, Desired Condition must be defined and might not be the same as Reference Conditions. At this time NeST sees no reason to include zooplankton for the application of

this standard in the nearshore. Zooplankton may be a key constituent of a supportive database and would be sampled if the status/trend of the recommended nearshore metrics warrant further investigation.

For many decades, however, an important gap in the water quality standards and environmental thresholds programs at Lake Tahoe has been the virtual exclusion of numeric values for periphyton. Neither the TRPA nor the State of Nevada have specific provisions for periphyton in Lake Tahoe. The current California water quality standard for periphyton in Lake Tahoe, as stated on page 3-9 of the Water Quality Control Plan [Biologic Indicators] states "for Lake Tahoe, algal productivity and biomass of phytoplankton, zooplankton, and periphyton shall not be increased beyond the levels recorded during the period 1967-71, based on statistical comparison of seasonal and annual means." Very recently in the TRPA Regional Plan Update that was adopted on December 12, 2012 it also states in a new Management Standard that the TRPA will "Implement policy and management actions to reduce the areal extent and density of periphyton (attached algae) from Lake Tahoe's nearshore."

Hackley *et al.* (2004) suggested that this definition be re- considered in that (1) the 1967-71 data was collected on artificial substrates that do not mimic actual ambient conditions and (2) there is significantly more data upon which to base a numeric value. NeST believes that sufficient data is now available to move beyond a narrative or management standard make a recommendation for a numeric standard for periphyton.

As discussed in Hackley *et al.* (2004), the following approaches should be considered in the development a periphyton standard: (1) literature definitions for nuisance levels of attached algae, (2) single annual maximum values, (3) average annual values, (4) exceedence of baseline conditions, (5) statistical value based on the distribution of existing data and how often it exceeds a chosen value and (6) level of acceptance based on public perception. The results of this analysis are presented in detail in the metric section of this nearshore report on periphyton. Numerous scenarios are presented there for consideration as new periphyton standards.

#13) Suspended Materials

See CA-13 and CA-15 in parameter summary table (Appendix A)

1. Relevancy: An important parameter with regard to management and water quality control, and relevant to nearshore assessment. This would provide supplementary data as part of a supportive database for nearshore assessment. Retain or revise as part of the state standards for protection of nearshore water quality, with compliance monitoring of watershed inputs required to achieve load reductions for the Lake Tahoe TMDL.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - None.

CA - Waters shall not contain suspended materials in concentrations that cause nuisance or that adversely affects the water for beneficial uses. For natural high quality waters, the concentration of total suspended materials shall not be altered to the extent that such alterations are discernible at the 10 percent significance level.

CA - The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect the water for beneficial uses.

Note - The recent CA and NV Lake Tahoe TMDL calls for 15 year reduction of fine sediment particles (<16 µm) of 32 percent, and a 65 year target of 65 percent.

3. Description of Standard

a) Narrative description of the standard(s):

Suspended sediment can contribute to numerous ecological and environmental issues in lakes. These include, but are not limited to loss of clarity, increased turbidity, reduced visual capacity of fish and other aquatic organisms, gill and digestive clogging, transport of phosphorus and other undesirable chemicals, and once the material is settled it can affect benthic life forms. Suspended materials are transported into a waterbody from various sources, most notably the watershed, although atmospheric contributions also occur. Sediment particles can also be resuspended from the lake bottom via waves and/or human activities (e.g. boat traffic).

Increasing fine particle concentrations directly affect lake clarity. This has been demonstrated in pelagic waters of Lake Tahoe where suspended particulates less than 16 µm in diameter remain in suspension long enough and effect light scattering and absorption sufficiently as to affect mid-lake clarity (Jassby *et al.*, 1999; Swift, 2004; Swift *et al.*, 2006). A similar size break for particles in the nearshore is assumed for clarity purposes, but under some high-energy hydrodynamic conditions it is possible that larger particles contribute significantly to clarity loss in the nearshore. Of equal importance is the particle size distribution of sediment loading to the lake. Material that is composed mainly of fine silts and clays or is high in organic content can influence community composition and aesthetic conditions in the nearshore environment. Rates and patterns of shoreline erosion contribute to this nearshore benthic structure.

Nearshore clarity loss is a function of both increasing planktonic algae and suspended sediment concentrations. Suspended sediment concentrations are expected to be quite variable in time and spatial distributions around the lakeshore, dependent on storm runoff, seasonal snowmelt, resuspension due to wave action and recreational activities.

b) What are reasonable reference conditions for this constituent:

In the absence of reliable monitoring there is currently no existing data to support the development of reference conditions for this constituent. Nearshore reference conditions could be reflect some value(s) in proportion to pelagic lake concentrationsm, but this is not recommended without preliminary data to support the development of such a relationship.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Existing standards are likely to be sufficiently protective as long as the concentrations of suspended sediments can be measured accurately. Unfortunately, the typical nearshore concentrations are so low that standard methods (TSS and SSC) do not provide the resolution needed for discerning changes important to clarity loss at the ten percent significance level. New methods are in development for addressing this issue.

#14) Settleable Materials

See NV-14 and CA-4 in parameter summary table (Appendix A)

1. Relevancy: It is a less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - Waters must be free from substances attributable to domestic or industrial waste or other controllable sources that will settle to form sludge or bottom deposits in amounts sufficient to be unsightly, putrescent or odorous or in amounts sufficient to interfere with any beneficial use of the water.

CA - Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or that adversely affects the water for beneficial uses. For natural high quality waters, the concentration of settleable materials shall not be raised by more that 0.1 milliliter per liter.

3. Description of Standard

a) Narrative description of the standard(s):

Settleable solids are that portion of the suspended solids that are of sufficient size and weight to settle in a given period of time, usually one hour (e.g. in an Imhoff Cone). The results are reported as milliliters of settled solids per liter of wastewater. Settleable solids are approximately 75 percent organic and 25 percent inorganic. In domestic wastewater, the organic fraction is generally of animal or vegetable life, dead animal matter, plant tissue or organisms, but may also include synthetic (artificial) organic compounds. Settleable solids is a consitituent most commonly associated with wasterwater and industrial waste.

b) What are reasonable reference conditions for this constituent:

Insufficient data to establish reference conditions based on previous observations, however, given that the primary source(s) of settleable materials is wastewater and industrial effluent, it is reasonable to expect that a condition of no settleable solids would be an appropriate reference condition.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

We believe so, however, the states of California and Nevada would need to officially make this determination. Standards for settleable materials derive principally from wastewater treatment discharge management objectives. Wastewater is no longer discharged into Lake Tahoe.

#15) Suspended Sediment Loading

See CA-15 in parameter summary table (Appendix A)

Note: the review and discussion of suspended sediment loading is included above under Suspended Materials (#13).

#16 and #17) Total Dissolved Solids and Conductivity

See NV-16, CA-16, NV-17 and CA-17 in parameter summary table (Appendix A)

1. Relevancy: A relevant parameter for nearshore management, but a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

a) Existing Standards for TDS:

TRPA - None.

NV - AA ≤60.0 mg/L; SV ≤70.0 mg/L.

CA - 60/65 mg/L.

b) Existing Standards for Conductivity:

TRPA - None.

NV - AA ≤95 µmhos/cm; SV ≤105.0 µmhos/cm.

CA - ≤95 µmhos/cm at 50°C at any location in the Lake.

3. Description of Standard

a) Narrative description of the standard(s):

The electrical conductivity (EC) of a solution is directly proportional to its ion concentration. Conductivity and total dissolved solids (TDS) usually demonstrate a strong linear relationship because the greater the dissolved solids content of water the greater the electrical conductance of that water as a medium, and vice versa. *In situ* monitoring of EC can be a proxy for more costly laboratory TDS analyses.

Conductivity (or electrical conductivity, EC) is a relatively consistent and buffered indicator in the nearshore zones of Lake Tahoe, apart from during runoff events such as snowmelt. In this respect, conductivity and total dissolved solids are a good diagnostic of runoff events. This could be useful in monitoring urbanized areas for stormwater contributions that affect nearshore clarity and health, and may be relevant as an indicator of conditions more conducive to nearshore invasive species, such as largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*).

b) What are reasonable reference conditions for this constituent:

Specific conductance ranged between 600 and 7000 µS cm-1 at urban runoff sites in South Lake Tahoe, while remaining below 100 µS cm-1 at the Upper Truckee River (Susfalk, Fitzgerald, 2010). At Rosewood Creek in Incline Village, spring and summer electrical conductivity values ranged from 200-300 µS cm-1 and fall and winter values ranged from 75-150 µS cm-1 (Susfalk, Fitzgerald, 2009). Conductivity values within the lake nearshore zone are typically near 92 µS cm-1.

Clearly, there are large differences in conductivity values between outfall culverts, natural streams and rivers, and the lake proper. Conductivity may be an indicator that provides a localized determinant of high-impact nearshore events.

From a lake perspective, the mixing of higher level of TDS inputs with background 92 µS cm-1 lake water will dilute the effect, but provides retrospective information about inputs and mixing effects. The background threshold should stay at ≤95 umhos/cm, near outfalls this number would need to be evaluated by future monitoring efforts to determine if any latitude is warranted.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

While the ecological impacts are not considered extreme for the levels of conductivity/TDS found at Lake Tahoe, this indicator can be a proxy for other runoff-related water quality constituents. The numeric standards, as background thresholds, are sufficient. But, if this constituent is to be implemented as an indicator of road runoff and BMP effectiveness then more consideration is needed regarding the appropriateness of relaxing these standards near inflows into the lake.

#18) pH

See NV-8 and CA-18 in parameter summary table (Appendix A)

1. Relevancy: A relevant parameter for nearshore management, but a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - SV 7.0–8.4.

CA - In fresh waters with designated beneficial uses of COLD, changes in normal ambient pH levels shall not exceed 0.5 pH units; single value, 7.0–8.4.

3. Description of Standard

a) Narrative description of the standard(s):

The pH is usually defined as the logarithm of the reciprocal of the concentration of H^+ ions. The pH of most natural waters falls in the range of 4.0-9.0, but much more often in the range of 6.0-8.0. The majority of freshwaters have a somewhat alkaline pH because of the presence of carbonate and bicarbonate. pH is of interest for many reasons including, but not limited to, reflection of microbial/biologic activity, pollution, acid rain indicator, relationship to hardness and metals toxicity, health of aquatic life.

b) What are reasonable reference conditions for this constituent:

Chang *et al.* (1992) and UC Davis – TERC (unpublished data) have reported Lake Tahoe pH in the range of 7.3-8.0 for open-water.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Yes, they appear protective.

#19) Sodium Absorption Ratio

See NV-19 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - AA ≤8.0.

CA - None.

3. Description of Standard

a) Narrative description of the standard(s):

High levels of sodium may be toxic to plant cells and the sodium absorption ratio (SAR) evaluates the suitability of water for use in agricultural irrigation. Elevated concentrations of sodium ions create a plant growth hazard, which is measured by one of two methods. The more common method, the Sodium Adsorption Ratio (SAR), is the proportion of sodium (Na) ions compared to the concentration of calcium (Ca) plus magnesium (Mg).

b) What are reasonable reference conditions for this constituent:

Given the negligible use of Lake Tahoe's oligotrophic waters water for irrigation, establishing reference conditions at this time is not pertinent. NeST was unable to locate water quality data for ambient SAR in Lake Tahoe.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

It appears to be; however, analysis of the adequacy of the SAR standard for irrigation purposes was outside the scope of this project.

#20) Chloride

See NV-20 and CA-20 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - AA ≤3.0 mg/L; SV ≤5.0 mg/L.

CA - 3.0/4.0 mg/L.

3. Description of Standard

a) Narrative description of the standard(s):

Chloride is one of the four major anions in freshwater, and together the lake's anions and cations usually constitute total ionic salinity. At Lake Tahoe, in the general absence of anthropogenic sources of chloride, this ion can be used as a conservative tracer that indicates road salt, sewage leaks, etc. Shallow lakes with reduced volume and urban/industrial source can show increases in chloride, which may have an impact on lake biota. Chloride can increase with a significant lowering of lake level.

b) What are reasonable reference conditions for this constituent:

Chloride is not typically monitored in Lake Tahoe due to its ultra-oligotrophic status. Average chloride during the period 1968-1972 was very similar at both the open-water and nearshore station with a mean of 1.8-2.2. mg/L and a range of 0.4-5.3 mg/L. In the mid-1970s, chloride concentrations in Lake Tahoe ranged from 1.6-1.8 mg/L (EPA 1977).

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Given that values of <3 mg/L are often considered background, the current standards appear adequate.

#21) Sulfate

See NV-21 and CA-21 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - SV ≤2.0mg/L.

CA - 1.0/2.0 mg/L.

3. Description of Standard

a) Narrative description of the standard(s):

As with chloride, sulfate is considered on of the four major anions. Sulfates are discharged into the aquatic environment in wastes from industries that use sulfates and sulfuric acid,

such as mining and smelting operations, paper and pulp mills, textile mills and tanneries. Sulfates are also released during blasting and the deposition of waste rock in dumps at metal mines. The burning of fossil fuels is also a major source of sulfur to the atmosphere. Emissions of sulfur to the atmosphere can be loaded into lakes through atmospheric deposition. Sulfate fertilizers can also be a major source of sulfate to ambient waters.

b) What are reasonable reference conditions for this constituent:

It is not uncommon for sulfate concentrations to range between about 2 and 30 mg/L. In 1977 the sulfate concentrations in Lake Tahoe ranged from 1.5-3.6 mg/L

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Yes, given the limited historic data, both sets of state standards appear protective.

#22) Boron

See CA-22 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - None.

CA - 0.01 mg/L.

3. Description of Standard

a) Narrative description of the standard(s):

Boron is an element of concern with regard to drinking water, irrigation, livestock and aquatic life among possible beneficial uses.

b) What are reasonable reference conditions for this constituent:

Data from Lake Tahoe is virtually non-existent.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

They appear to be protective.

#23) Chemical Constituents

See NV-23 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - Wastes from municipal, industrial or other controllable sources containing arsenic, barium, boron, cadmium, chromium, cyanide, fluoride, lead, selenium, silver, copper and zinc that are reasonably amenable to treatment or control must not be discharged untreated or uncontrolled into the waters of Nevada. In addition, the limits for concentrations of the chemical constituents must provide water quality consistent with the mandatory requirements of the 1962 Public Health Service Drinking Water Standards.

CA - None.

3. Description of Standard

a) Narrative description of the standard(s):

A generalized standard that applies to all of Nevada. Heavy metals should be represented in Nevada's regulations for the U.S. EPA Priority Pollutants that include organic compounds as well.

b) What are reasonable reference conditions for this constituent:

The current database for these constituents is very limited and not adequate to determine reference conditions. As the chemicals operate within a toxicity framework, environmental reference conditions are not applicable, rather they are driven by aquatic life and human health bioassay tests for toxicity. These are typically evaluated by the U.S. EPA for use by the states.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

They appear to be protective.

#24, #25, and #26) E. Coli, Coliform Bacteria, and Fecal Coliform

See NV-24, CA-25, NV-26 and CA-26 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and an important parameter for nearshore assessment. This has been categorized as one of the

primary metrics for nearshore assessment, with compliance monitoring directed by appropriate regulatory and management agencies as well as public heath departments. Refer to U.S. EPA for current recommendations (*E. coli* strongly recommended). Retain as part of the state standards for the protection of nearshore water quality and human health.

2. Existing Numeric, Narrative, or Threshold Standard

a) Existing Standards for E. coli:

TRPA - None.

NV - SV ≤ 126 colonies/100 ml.

CA - None (although scheduled for adoption 2015/2016).

b) Existing Standards for coliform bacteria:

TRPA - None.

NV - Concentration during any 30-day period shall not exceed a log mean of 20/100 ml, nor shall more than 10 percent of all samples collected during any 30-day period exceed 40/100 ml.

CA - Waters shall not contain concentrations of coliform organisms attributable to anthropogenic sources, including human and livestock wastes.

c) Existing Standards for fecal coliform:

TRPA - None.

NV - A density not greater than the values shown in the following table (MPN/100mL):

	Median	Maximum
Undeveloped Lake Front Areas		
10 yards offshore.....	5.0	32.0
100 yards offshore.....	3.0	15.0
Developed Lake Front Areas		
10 yards offshore.....	240.0	700.0
100 yards offshore.....	15.0	64.0
Directly Influenced by Streams		
10 yards offshore.....	240.0	700.0
100 yards offshore.....	32.0	240.0

CA - Concentration during any 30-day period shall not exceed a log mean of 20/100 ml, nor shall more than 10 percent of all samples collected during any 30-day period exceed 40/100 ml.

3. Description of Standard

a) Narrative description of the standard(s):

Coliform is a type of bacteria that is present in the environment and in the feces of all warm blooded animals and humans. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff. They are also found in plant and soil material. There is evidence that of *E. coli* may arise from nonpoint sources originating within the beach area (e.g., birds, sand, and sediment storage) or from nearby inputs (riparian and wetland runoff) (Whitman *et al.*, 2003). Coliforms themselves do not always cause serious illness but are rather used as an indicator of sanitary quality of foods and water. The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply. *E. coli* is the major species in the fecal coliform group. Of the five general groups of bacteria that comprise the total coliforms, only *E. coli* is generally not found growing and reproducing in the environment. Consequently, *E. coli* has traditionally been considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens.

According to the U.S. EPA (http://water.epa.gov/type/rsl/monitoring/vms511.cfm; 2012), members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms, fecal coliforms and fecal streptococci instead.

In addition to the possible health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand.

b) What are reasonable reference conditions for this constituent:

Not applicable in the sense that levels are set by risk to human health. These regulatory levels should remain the same regardless of the water body.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Perhaps, however, both states and responsible public health agencies should further investigate the U.S. EPA 2012 guidance cited above: “if your state is still using total or fecal coliforms as the indicator bacteria and you want to know whether the water meets

state water quality standards, you should monitor fecal coliforms. However, if you want to know the health risk from recreational water contact, the results of EPA studies suggest that you should consider switching to the *E. coli* or enterococci method for testing fresh water".

#27 and #28) Temperature and Temperature Change

See NV-27, NV-28 and CA-28 in parameter summary table (Appendix A)

1. Relevancy: A relevant parameter for nearshore management, and a relevant parameter for nearshore assessment. This would provide supplementary data as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

a) Existing Standards for temperature:

TRPA - None.

NV - SV ≤10.0 Oct-May and ≤20.0 Jun-Sep. Waters must be free from high temperature, biocides, organisms pathogenic to human beings, toxic, corrosive or other deleterious substances attributable to domestic or industrial waste or other controllable sources at levels or combinations sufficient to be toxic to human, animal, plant or aquatic life or in amounts sufficient to interfere with any beneficial use of the water. Compliance with the provisions of this subsection may be determined in accordance with methods of testing prescribed by the Department. If used as an indicator, survival of test organisms must not be significantly less in test water than in control water.

CA - None.

b) Existing Standards for temperature change:

TRPA - None.

NV - 0°C (increase above natural receiving water temperature).

CA - 0°C (increase above natural receiving water temperature).

3. Description of Standard

a) Narrative description of the standard(s):

Aquatic organisms are generally ectothermic and have specific temperature tolerance ranges and optimal temperature preferences for growth and reproduction. Therefore, an altered thermal regime will have direct impacts on aquatic organisms' fundamental

biological processes, potentially affecting their fitness and competitiveness (Poff *et al.*, 2002; Lockwood *et al.*, 2007). For example, given the availability of sufficient resources, the growth and development of aquatic organisms with wide thermal tolerances could increase with a warmer climate, thus giving these species a competitive advantage over coldwater species (Hill and Magnuson 1990, Adrian *et al.*, 2009). This is relevant to studies of competitive advantage between native and non-native species. Further, many biological and chemical processes proceed at faster rates with increasing temperature, which may directly affect rates of nutrient cycling in the lake.

There has been an observed warming trend in the shallow and very deep pelagic-profundal waters that is largely attributed to increased daily air temperatures and a slightly positive trend in downward long-wave radiation (Coats *et al.*, 2006, TERC 2012). This altered thermal regime measured in the open water has altered the lake's stability and resulted in a shift in the phytoplankton community structure (Winder *et al.*, 2009). Long-term measurements for nearshore temperature are lacking. Snapshot studies of nearshore temperature exist, but continuous data is needed to understand the variance and longer-term trajectories of nearshore temperature. Continuous data are used to obtain daily, weekly, or seasonal averages and variation, and to determine trends and compare differences between locations.

b) What are reasonable reference conditions for this constituent:

The UN Reno Aquatic Ecosystems Laboratory has analyzed temperature from nearshore thermal probes placed in embayments, nearshore (<3 m deep), and marinas in 2003. In 2006 they monitored nearshore epilimnetic temperatures (1 – 2 m deep) at approximately 3 hour intervals in the field by thermistors at 20 in situ nearshore sites. Weekly averages were computed for the May to October 2006 study period to determine variability of thermal attributes in the nearshore of Lake Tahoe. Analysis of the thermistor time series indicated regional specific patterns in nearshore thermal properties; however, monitoring locations need to be selected carefully, since embayments and marinas may act very different in physical structure than the main part of the lake. Nearshore temperatures in Lake Tahoe are above 10°C from early May to November and above 15°C between late May through early September (Ngai 2008). Nearshore temperature estimates indicate that the entire nearshore reaches a thermally suitable temperature for non-native largemouth bass that have been introduced in the lake. This finding corroborates with prior estimates made by Ngai (2008).

Observed temperature gradients of 1-2 °C indicate that southern lake regions are more thermally preferable to warm-water non-native fishes. In addition, the onset of reproduction and the duration of suitable conditions for reproduction may vary across regions within the lake. Recent research also suggests that the lake's latest nearshore invader, Asian clam, is likely limited in reproduction and growth by temperature (Denton

et al., 2012). Increases in thermal attributes of that extend the growing season for clam can result in the thousands of young clams produced from populations each year leading to increased expansion (Wittmann *et al.*, 2012).

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

The existing standards are adequate when considered over the short term. The temperature of Lake Tahoe is largely beyond the control of the basin management agencies as it is linked to climate change. Since a number of standards are linked to temperature (e.g. algal growth potential and biological indicators) it is important to track nearshore temperature into the future. At this time it is too early to establish a numeric or qualitative standard.

#29) Dissolved Oxygen

See NV-29 in parameter summary table (Appendix A)

1. Relevancy: A relevant parameter for nearshore management, and a relevant parameter for nearshore assessment. This would provide supplementary data as part of a supportive database for nearshore assessment. Retain as part of the state standards for the protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - SV ≥90%.

CA - Dissolved oxygen concentration, as percent of saturation, shall not be depressed by more than 10 percent, nor shall the minimum dissolved oxygen concentration be less than 80 percent of saturation. With designated beneficial uses of Cold and Spawning, Lake Tahoe is also subject to the following standards: 7-day mean = 9.5 mg/L (6.5 mg/L intergravel) and 1-day minimum = 8.0 mg/L (5.0 intergravel).

3. Description of Standard

a) Narrative description of the standard(s):

Dissolved oxygen is one of the fundamental parameters in lakes affecting whole-lake metabolism as well as the survival and health of aquatic life. Solubility of oxygen is affected non-linearly by temperature, increasing considerably in cold water. Altitude will also affect the absolute concentration of dissolved oxygen in water but not the relative measure of percent saturation. At Lake Tahoe's elevation the absolute concentration of dissolved oxygen will be 0.79 of that under identical conditions at sea level.

b) What are reasonable reference conditions for this constituent:

Nearshore dissolved oxygen was measured near the surface in the California-Nevada-Federal Joint Water Quality Investigations (e.g. DWR 1973). Levels were very near 100 percent saturation at all stations, ranging from approximately 95-110 percent. Values from the open-water were the same. Routine monitoring of nearshore dissolved oxygen has not been emphasized as the ultra-oligotrophic waters of Lake Tahoe are typically rich in dissolved oxygen.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Yes, they appear to be protective.

#30) Aesthetic Condition

See TRPA-30, NV-30 and CA-30 in parameter summary table (Appendix A)

Note: the review and discussion of aesthetic condition has been included above under Clarity (#9) and Biological Indicators (#12).

#31) Color

See CA-31 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - None.

CA - Waters shall be free of coloration that causes nuisance or adversely affects the water for beneficial uses.

3. Description of Standard

a) Narrative description of the standard(s):

Lake Tahoe is known for both its deep clarity and its cobalt blue color. A number of color scales have been used in limnology to empirically compare the true color of lake (after filtration) various combinations of inorganic chemicals in serial dilution prepared in the laboratory (Wetzel 1975). Among these scales, platinum units (Pt units) and the Forel-Ule color scale are widely used in the United States and Europe, respectively.

The use of these types of color scales is most relevant when engaged in regional comparisons of multiple waterbodies, within a single waterbody to distinguish basins and bays of different water quality, or when there is significant seasonal variation. Lake Tahoe is much too dilute for this test to be of much practicality for assessing lake condition over the short term.

Lake color can also be measured using sophisticated underwater light sensors or spectral radiometers. Only Smith *et al.* (1973) and Watanabe *et al.* (2012) have directly measured color in the deep waters of Lake Tahoe using this instrumentation. No published measurements have been made in nearshore waters.

b) What are reasonable reference conditions for this constituent:

Given the lack of data on color conditions in the nearshore, there is nothing to support reasonable reference conditions for this constituent.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

At this time NeST considers color as less relevant for assessing nearshore condition, vis-à-vis, clarity and light transmission. Reasons including: measurement based on chemically created color scales is too insensitive for meaningful use in Lake Tahoe, the spectral radiometer approach is too labor intensive and costly. Nearshore color will change very quickly due to stream inflow, direct inflow from the land, complex currents/circulation patterns, and anthropogenic activities. In addition because of the influence of depth to the bottom (e.g. shallow south shore and deep east shore) the bottom substrate characteristics (aquatic plants, boulders, sand, etc.), visual perception of nearshore water color may be quite different from that obtained using the measurement approaches presented above.

The existing CA water quality standard is protective on a state-wide basis, but less relevant to conditions in Lake Tahoe. The standards for clarity (#9) are generally more applicable except in the case of localized sources of coloration in the nearshore such as spills, pipe leaks, urban runoff and other organic and inorganic compounds.

#32) Taste and Odor

See NV-32 and CA-32 in parameter summary table (Appendix A)

1. Relevancy: A relevant parameter for nearshore management, but a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality. Taste and odor, in addition to other constituents required by state, federal and local drinking water regulations, should be monitored by water suppliers.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - Waters must be free from materials attributable to domestic or industrial waste or other controllable sources in amounts sufficient to produce taste or odor in the water or detectable off-flavor in the flesh of fish or in amounts sufficient to change the existing color, turbidity or other conditions in the receiving stream to such a degree as to create a public nuisance or in amounts sufficient to interfere with any beneficial use of the water.

CA - Waters shall not contain taste or odor producing substances in concentrations that impart undesirable tastes or odors to fish or other edible products of aquatic origin, that cause nuisance, or that adversely affect the water for beneficial uses. For naturally high quality waters, the taste and odor shall not be altered.

3. Description of Standard

a) Narrative description of the standard(s):

Taste and odor can enter water in a variety of manners. Surface water sources can become contaminated through algal blooms or through industrial wastes or domestic sewage introducing taste- and odor-causing chemicals into the water. The algae can be either planktonic or benthic/attached forms. Accumulation and decomposition of organic materials and products may also contribute to changes in taste and odor.

b) What are reasonable reference conditions for this constituent:

Not applicable.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Taste and odor are not specific metrics of ecological condition of the nearshore. While taste and odor problems may be indicative of problems in the nearshore, such as increased growth of algae or specific species of algae, parameters which more directly measure such growth should generally be a better ecological metric. It is important to stress, however, that taste and odor problems are a real concern of water purveyors and users around the lake, so should be retained as a standard for water supply.

#33) Floating Materials

See CA-33 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - None.

CA - Waters shall not contain floating material, including solids, liquids, foams, and scum, in concentrations that cause nuisance or adversely affect the water for beneficial uses. For natural high quality waters, the concentrations of floating material shall not be altered to the extent that such alterations are discernable at the 10 percent significance level.

3. Description of Standard

a) Narrative description of the standard(s):

The types of floating materials of concern are noted in the California standard (above). Typically, these floating materials are of anthropogenic origin, although certain types of biological constituents may constitute floating materials under this standard.

b) What are reasonable reference conditions for this constituent:

The reference conditions in Lake Tahoe should reflect pristine conditions.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

This standard is diffuse as floating material may be of natural origin, or associated with human activities, or both. In addition, there may be a range of natural levels of floating materials associated with different lake conditions and different regions of the lake. This can create uncertainty and ambiguity in interpretation of the use of floating materials as a nearshore indicator. For instance, naturally produced materials may include: woody debris contributed from streams, pollen, wind-blown particles, some foam (i.e. that associated with natural dissolved organic carbon in the water), some sheens. Storms may input large amounts of woody debris from the tributaries, creating a nuisance level of floating debris nearshore. The presence of algal scum on the surface, oil sheens or plant clippings may indicate deteriorated ecological health in the nearshore.

Agencies should consider the inclusion of dead aquatic invasive species, excessive plant material resulting from accelerated eutrophication (e.g. phytoplankton, attached algae,

macrophytes), fish kills or other dead aquatic life resulting from violation of other water quality standards as floating material.

The California standard states that "concentrations of floating material shall not be altered to the extent that such alterations are discernable at the 10 percent significance level". This portion of the standard is vague in the sense that there appears to be no protocol for determining the 10 percent level of significance.

#34) Oil and Grease

See NV-34 and CA-34 in parameter summary table (Appendix A)

1. Relevancy: A relevant parameter for nearshore management, and a relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of nearshore water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - Waters must be free from floating debris, oil, grease, scum and other floating materials attributable to domestic or industrial waste or other controllable sources in amounts sufficient to be unsightly or in amounts sufficient to interfere with any beneficial use of the water.

CA - Waters shall not contain oils, greases, waxes or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect the water for beneficial uses. For natural high quality waters, the concentration of oils, greases, or other film or coat generating substances shall not be altered.

3. Description of Standard

a) Narrative description of the standard(s):

The concentration of dispersed oil and grease (OG) is an important parameter for water quality and safety. OG in water can cause surface films and shoreline deposits leading to environmental degradation, and can possibly lead to human health risks when discharged in surface or ground waters. OG also can be damaging to aquatic life and to organisms that feed or other wise use freshwaters.

b) What are reasonable reference conditions for this constituent:

Defined within the California standard.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

The current standards for oil and grease appear appropriate for the nearshore of Lake Tahoe, and are particularly relevant for marinas and launch areas, and areas receiving stormwater runoff from roadways and other paved land uses. However, standards could be made more protective by broadening the definition to include total petroleum hydrocarbons, PAH and possibly other hydrocarbons as deemed relevant,

#35) Toxicity

See NV-35 and CA-35 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes, and an important parameter for nearshore assessment. This has been categorized as one of the primary metrics for nearshore assessment, with compliance monitoring directed by appropriate regulatory and management agencies as well as public heath departments. Retain as part of the state standards for the protection of nearshore water quality and human health.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - Waters must be free from high temperature, biocides, organisms pathogenic to human beings, toxic, corrosive or other deleterious substances attributable to domestic or industrial waste or other controllable sources at levels or combinations sufficient to be toxic to human, animal, plant or aquatic life or in amounts sufficient to interfere with any beneficial use of the water. Compliance with the provisions of this subsection may be determined in accordance with methods of testing prescribed by the Department. If used as an indicator, survival of test organisms must not be significantly less in test water than in control water.

CA - All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life. *Compliance with this objective will be determined by use of indicator organisms, analyses of species diversity, population density, growth anomalies, bioassays of appropriate duration and/or other appropriate methods as specified by the Regional Board. The survival of aquatic life in surface waters subjected to a waste discharge, or other controllable water quality factors, shall not be less than that for the same water body in areas unaffected by the waste discharge, or when*

necessary, for other control water that is consistent with the requirements for "experimental water" as defined in Standard Methods for the Examination of Water and Wastewater (American Public Health Association, et al., 1998).

3. Description of Standard

a) Narrative description of the standard(s):

Numerous organic and inorganic chemicals can be toxic to all forms of aquatic life and human health. In ultra-oligotrophic waterbodies such as Lake Tahoe this is typically not problematic unless there is a spill, unexpected discharge or a source in the watershed that is transported along with surface and/or groundwater flow. Toxicity can take many forms including, but not limited to, interference with reproduction, acute or chronic interference with normal physiological processes, or in the extreme, death.

b) What are reasonable reference conditions for this constituent:

Applicable in the sense that under reference conditions, no toxicity would be expected.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

They appear to be protective.

#36) Radioactivity

See NV-36 and CA-36 in parameter summary table (Appendix A)

1. Relevancy: A less relevant parameter for nearshore management, and a less relevant parameter for nearshore assessment. Retain as part of the state standards for the general protection of water quality.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - None.

NV - Radioactive materials attributable to municipal, industrial or other controllable sources must be the minimum concentrations that are physically and economically feasible to achieve. In no case must materials exceed the limits established in the 1962 Public Health Service Drinking Water Standards (or later amendments) or 1/30th of the MPC values given for continuous occupational exposure in the "National Bureau of Standards Handbook No. 69." The concentrations in water must not result in accumulation of radioactivity in plants or animals that result in a hazard to humans or harm to aquatic life.

CA - Radionuclides shall not be present in concentrations which are deleterious to human, plant, animal, or aquatic life nor which result in the accumulation of radionuclides in the food web to an extent which presents a hazard to human, plant, animal, or aquatic life. Waters designated as MUN shall not contain concentrations of radionuclides in excess of the limits specified in Table 4 of Section 64443 (Radioactivity) of Title 22 of the California Code of Regulations which is incorporated by reference into this plan. This incorporation-by-reference is prospective including future changes to the incorporated provisions as the changes take effect.

3. Description of Standard

a) Narrative description of the standard(s):

The California standard provides sufficient description for this constituent.

b) What are reasonable reference conditions for this constituent:

Background values for radioactivity in Lake Tahoe should be low as there has been no previous cause for concern. Most likely any monitoring would be precipitated by a known or suspected discharge.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

Yes, they appear to be protective.

#37) Aquatic Communities and Populations

See TRPA-37 and CA-37 in parameter summary table (Appendix A)

1. Relevancy: An important nearshore parameter for management purposes and nearshore assessment. This is one of the primary metrics for nearshore assessment. Retain as part of the state standards, but it needs significant revision for direct application to nearshore management.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - Prevent the introduction of new aquatic invasive species into the region's waters and reduce the abundance and distribution of known aquatic invasive species. Abate harmful ecological, economic, social and public health impacts resulting from aquatic invasive species.

NV - None.

CA - All wetlands shall be free from substances attributable to wastewater or other discharges that produce adverse physiological responses in humans, animals, or plants; or which lead to the presence of undesirable or nuisance aquatic

life. All wetlands shall be free from activities that would substantially impair the biological community as it naturally occurs.

3. Description of Standard

a) Narrative description of the standard(s):

This standard protects all aquatic life with a focus on pelagic and benthic macroinvertebrates, fish and plants that are native to Lake Tahoe, commensurate with its cold water, ultra-oligotrophic status.

b) What are reasonable reference conditions for this constituent:

Macroinvertebrates - There have only been two major sampling events for macroinvertebrates across the nearshore to profundal areas of Lake Tahoe. The first extensive collection of benthic invertebrates occurred in 1962-63 and revealed the existence of 10 endemic benthic invertebrate species (Frantz and Cordone 1966, Frantz and Cordone 1996) including two species of blind amphipod (*Stygobromus tahoensis* and *S. lacicolus*), and the Tahoe stonefly (*Capnia lacustra*). These surveys also established the relationship between several invertebrate taxa with deepwater macrophyte beds in Lake Tahoe. A second sampling occurred in the late 2000's and suggests lakewide-weighted densities of taxa endemic to Lake Tahoe have declined by 80-100 percent percent and is likely due to invasive species (signal crayfish- *Pacifascticus lenisculous* and Asian clam- *Corbicula fluminea*) and the changes in clarity which has resulted in the decline of deepwater algal-plant (Caires *et al.*, 2013).

Changes to the eulittoral nearshore (1-5 m) suggest highly variable densities today compared with historical data. In some cases, native taxa such as oligochaetes and pea clams have increased, possibly due to eutrophication or invasions by other taxa, while others are highly variable and may be decreasing (midges, ostracods).

Benthic invertebrates have long been used as environmental, ecological, and biodiversity indicators of water quality because of their ubiquitous distribution, relatively sedentary nature, and long life spans (Metcalfe 1989). One particular group of benthic invertebrates, non-biting midges, Chironomidae, has been commonly used as an environmental indicator in lake assessments (Charvet *et al.*, 1998). Since chironomids are found in most types of lakes, they are an excellent candidate for biomonitoring. A biological indicator taxon should be wide spread so that its absence in biological monitoring due to natural variation is not mistaken as an indication of impact or impairment (Gibson *et al.*, 1996). Chironomidae have over 4,000 documented species and can be very diverse in lakes with diversity estimates exceeding 180 species in individual lentic systems (Ferrington 2008). Spatial and temporal patterns in chironomid communities have long been successfully used in biological monitoring of many different types of aquatic ecosystem (Rosenberg 1992).

Furthermore, individual species within the family are indicative of trophic status of lakes (Saether 1979) and provide an easy way of monitoring human impacts on lentic systems.

Chironomidae collected from grab samples from the lake bottom have traditionally been used in lake typology (e.g. determining lake type by trophic status such as oligotrophic versus eutrophic sensu Saether 1979), but recently the cast off exoskeletons have been used to effectively monitor lake condition (Raunio *et al.*, 2007; Ruse 2010). The chironomids rest on their pupal skins at the surface of the water as they pump their wings full of blood prior to flying off to mate. The skins remain on the surface of the water for up to 48 hours and accumulate along the shores of lakes (Langton 1995). The skins are valuable tools in biomonitoring because they have taxonomically informative characters for ready identification and they require little to no expense for collecting, processing, and sorting because they can be collected using a simple dip net or drift net along the shore (Ruse 2010, Langton 1995). Also, the pupal skins, hereafter called pupal exuviae, represent the whole lake chironomid biota. Benthic grab sample sites are randomly selected, but they may miss much of the diversity in lake (Raunio *et al.*, 2007). The pupal exuviae come from all parts of an ecosystem so that when collected they represent most of the diversity present (Langton 1995). Even though specific depths are not linked to the samples of pupal exuviae, we can still identify indicator taxa associated with specific depths and trophic status of the lake (Raunio *et al.*, 2007).

Non-biting midge communities in Lake Tahoe indicate a shift over the past 50 years from oligotrophic- to eutrophic-tolerant taxa. In addition, preliminary research from the University of Nevada, Reno suggests that smaller lakes midge biodiversity may related to the clarity or nutrient status of the lake with the exception Echo Lake. This preliminary indication suggests that it may be possible to utilize midge communities for assessing longer-term health of Tahoe or neighboring lakes with differing nutrient and production status.

We propose two attributes for nearshore monitoring that will track the status of the lake over time related to nutrient conditions. First the midge community is analyzed to determine the proportion and trophic status of the nearshore. Second, the proportion of nonnative to native taxa is determined as a way of understanding the influence of invasive species to the benthic condition and community structure of the lake.

Macrophytes – Prior to development, pre-European conditions in the nearshore of Lake Tahoe likely contained a minimal amount of aquatic plants, both in terms of composition and areal distribution. The nearshore had few rooted-aquatic plants species, which largely inhabited the embayments and wetland margins prior to development. Over time the modification of the shoreline and establishment of marinas, along with increased propagule pressure from boat launching and the dumping of aquaria plants, have led to the

establishment of invasive plants. The establishment of Eurasian watermilfoil (*Myriophyllum spicatum*) in Lake Tahoe was formally confirmed by experts in 1995, but is thought to have been introduced to south Lake Tahoe sometime after an early 1960's installation of a 740-acre residential development (the Tahoe Keys). Severe impacts from aquatic plants were observed in the Tahoe Keys by the 1980's, and at this time a mechanical harvesting program was initiated to remove nuisance plant growth and to easier permit boater navigation within the Keys and out into the lake. In 2010, Eurasian watermilfoil was abundant throughout the entirety of the Tahoe Keys, and has since spread to over 30 locations lakewide. Another invasive macrophyte, curly leaf pondweed (*Potamogeton crispus*) was first observed in 2003 in a few small discrete locations along the south shore and has since rapidly increased its range to an approximate 20 km2 area along the southern shoreline of Tahoe. Macrophyte assemblages are also thought to contribute to the increased spread of warmwater fishes that prefer these plants for habitat. Currently there is an active program to manage plants and it is believed that a coordinated and active effort could reduce populations and reverse the trend of expansion if done properly. We propose developing a measurement that utilizes the 1995 plant survey conducted by Anderson and colleagues (USDA ARS) as the baseline conditions. The rate of expansion from this survey period and proportion of nonnative to native plants per location would be used as a numerical measurement for this attribute.

Mobile Consumers - Chandra *et al.* (2010) suggest modifying the existing indicators for fisheries and evaluating specific, quantifiable mechanisms that contribute to fish production and fish density and composition. Traditional indicators used in other ecosystems (e.g. species composition, density, growth, condition, and spawning potential) will allow for a direct measurement of changes the lake over time. Chandra *et al.* (2010) examined these data to detect mid and long-term changes in Lake Tahoe nearshore fishery. In 1991-1994 and 2008-2009, the predominant fish species caught in the nearshore minnow traps were Lahontan reside shiners (*Richardsonius egregious*) and speckled dace (*Rhinichthys osculus robustus*). However, current catch of these and other species have declined. Overall, nearshore fish densities have undergone general decrease (58 percent of historically sampled sites) between 1988-89 and 2009. In particular, Lahontan redside shiner densities have declined (25-100 percent) at 42 percent of the historically sampled sites. No significant change in speckled dace summer condition was observed between 1994 and 2008-2009. Lahontan redside shiners summer condition was poorer in recent years than in 1994. Tahoe suckers fall condition in 2008 increased when compared to conditions in 1994. Zooplankton, including cladoceran and copepods, and true flies are the most commonly utilized food items by Lahontan reside shiners and speckled dace, both historically and presently. Lahontan reside shiners are consuming a wider range of food types and relying more on surface food sources than before. These changes may be due to

nearshore habitat modifications, which alter the food availability or clarity. Alternatively, predation from game fish (e.g. lake trout) may also contribute to the decline when native fishes move offshore in the winter. Changes in spawning activities (spawning behavior and egg presence) and condition of spawning habitats (substrate types) were observed in 30 percent (6/20) of the sites when compared to historical data collected by Allen and Reuter (1996). Changes observed can potentially be attributed to changes in substrate types at various spawning sites as a result of decrease in lake water levels.

Two novel indicators (trophic niche and UV) to measure long- and short-term changes in nearshore fishery were also proposed. In the study changes in trophic niche were found. All fish species examined, except Tahoe sucker (*Catostomus tahoensis*), have demonstrated greater reliance on pelagic food source, while all fish species have reduced trophic position. UV exposure and in situ incubation experiments show that UV transparency of nearshore sites significantly impacts the survival of warmwater fish larvae, and influences whether these potentially invasive fish species are able to establish in nearshore Lake Tahoe. Native fish larvae (Lahontan redside shiner) were at least six times more tolerant of UV exposure than non-native warmwater fish larvae (bluegill and largemouth bass). The observed difference in UV tolerance in native versus non-native fish was used to develop a UV attainment threshold (UVAT, i.e. a water clarity threshold based on water transparency to UV) that is lethal to non-native fish larvae with no observed effect on native fish larvae. Measurements of UV transparency around the lake showed that more than half of the sites sampled were in non-attainment of the UVAT, suggesting the potential for widespread warmwater fish establishment.

Crayfish were introduced multiple times into Lake Tahoe and were established by 1936. Since 1967, crayfish densities have doubled in Lake Tahoe in 2008, as measured from a single monitoring site. Crayfish are known to be an aggressive benthic consumer (Lodge *et al.*, 2004) and can alter foodwebs (Light 2003), and are a food source for largemouth bass and other warm-water fish that are established in Lake Tahoe (Kamerath *et al.*, 2008). Crayfish data analysis is pending, however it is possible to achieve a numerical standard based on historical sampling events collected in 1967.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

No. The inclusion of wetlands only in this standard is much too restrictive. The current standard is not sufficient to support the desired condition for ecological integrity (native species and function) of the nearshore environment. For example, it does not include the parameters needed to support fish growth and production within Tahoe's nearshore margin. Instead the assumption is that maintenance of "habitat" will result in viable fish populations, which is not necessarily true for Lake Tahoe due to the increasing stress on the biological community from new nonnative species introduction with slight alterations

to the thermal regime. In addition, while the management standard recently adopted by the TRPA for aquatic invasive species (AIS) is a good start, further protect may be warranted.

In the nearshore report, NeST proposes a new indicator called Community Structure. This indicator is comprised of the biological community that can be quantitatively measured in the nearshore, which includes macroinvertebrates, macrophytes, and mobile consumers (fishes and crayfish), both native and non-native. NeST suggests using empirically derived measurements of these biological groups since it will reduce the uncertainty associated with more descriptive factors such as "habitat" and provide a quantitative numeric understanding of changes in either distribution within the landscape or biological composition at specific locations over time. Finally, it also incorporates evaluations of effects from larger disturbances occurring in the nearshore due to nonnative species introductions and establishment. Community composition of the nearshore is an important metric, but target numeric values must be developed specifically for the nearshore reflecting desired conditions.

#38) Nondegradation

See TRPA-38, NV-38 and CA-38 in parameter summary table (Appendix A)

1. Relevancy: An important parameter for management purposes, but a less relevant parameter for nearshore assessment. Retain as part of the state standards. However, specific monitoring is not necessary for this standard as nondegradation is often interpreted as a narrative integration of all relevant standards.

2. Existing Numeric, Narrative, or Threshold Standard

Existing Standards:

TRPA - It shall be the policy of the TRPA Governing Body in development of the Regional Plan to preserve and enhance the high quality recreational experience including preservation of high quality undeveloped shorezone and other natural areas. In developing the Regional Plan, the staff and Governing Body shall consider provisions for additional access, where lawful and feasible, to the shorezone and high quality undeveloped areas for low density recreational uses.

NV - The specified standards are not considered violated when the natural conditions of the receiving water are outside the established limits, including periods of extreme high or low flow. Where effluents are discharged to such waters, the discharges are not considered a contributor to substandard conditions provided maximum treatment in compliance with permit requirements is maintained.

CA - Lake Tahoe is subject to State Board Resolution 68-16, which establishes a Nondegradation Objective, requires continued maintenance of existing high quality waters. Additionally, in reference to Lake Tahoe's designation as an ONRW, our Basin Plan reads: The State Board designated Lake Tahoe an Outstanding National Resource Water (ONRW) in 1980, both for its recreational and its ecological value, and stated: "Viewed from the standpoint of protecting beneficial uses, preventing deterioration of Lake Tahoe requires that there be no significant increase in algal growth rates. Lake Tahoe's exceptional recreational value depends on enjoyment of the scenic beauty imparted by its clear, blue waters. Likewise, preserving Lake Tahoe's ecological value depends on maintaining the extraordinarily low rates of algal growth which make Lake Tahoe an outstanding ecological resource." Section 114 of the Federal Clean Water Act also indicates the need to "preserve the fragile ecology of Lake Tahoe."

3. Description of Standard

a) Narrative description of the standard(s):

These standards are intended to provide a description of the desired conditions.

b) What are reasonable reference conditions for this constituent:

Not applicable, as the nondegradation standards are intended to reflect reference conditions.

c) Is the current standard (or set of standards) sufficient to support Desired Conditions:

It would be appropriate for the three regulatory agencies to collectively develop independent nondegradation statements (or a single statement) that address the nondegradation of Lake Tahoe nearshore condition specifically.