California Environmental Protection Agency

Central Coast Regional Water Quality Control Board

Proposed Methodology to Derive Natural Conditions for Turbidity and Development of Site-Specific Water Quality Criteria for Turbidity in the Central Coast Region

Technical Project Report

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Abstract

Using methods cited in the *Nutrient Criteria Technical Guidance Manual* (USEPA, 2000a), the *Ambient Water Quality Criteria Recommendations, Rivers and Streams in Nutrient Ecoregion III* (USEPA, 2000b), and *A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document* (USEPA, 2015), staff defined and documented the development of natural conditions for turbidity in the Central Coast Region. These values can be used in conjunction with existing water quality objective (WQO) language in the *Water Quality Control Plan for the Central Coastal Basin* (Basin Plan), which currently relies on undefined natural conditions and states:

> Where natural turbidity is between 0 and 50 Nephelometric Turbidity Units (NTU), increases shall not exceed 20 percent. Where natural turbidity is between 50 and 100 NTU, increases shall not exceed 10 NTU. Where natural turbidity is greater than 100 NTU, increases shall not exceed 10 percent.

The derivation of natural conditions of turbidity will improve the ability of the Central Coast Water Board to implement and ensure compliance with current turbidity WQOs and is critical to protecting and restoring water quality.

The methods used herein draw from the three guidance documents above and include the following elements:

1. Stream classification based primarily on physical parameters. Staff assigned streams one of six classifications based on slope, system size, and substrate.
2. Designation of degree of relative impact to streams due to anthropogenic sources. Staff labeled streams that met selection criteria as “least impacted.”
3. Empirical statistical analysis to characterize the distribution of values for turbidity in both reference streams and the general population of streams to ascertain natural conditions. As recommend by USEPA (2000a) and USEPA (2000b), staff used a reference site approach in which data for a subset of sites that have experienced minimal human disturbance activities are accepted as representative of natural conditions. Reference streams for the purpose of this study are referred to as least impacted streams for the duration of this paper.
4. Proposed numeric interpretations of the existing Basin Plan turbidity criteria were then developed based on the values derived from the empirical statistical analysis, namely the 25^{th} percentile value for the general population of streams and the 75^{th} percentile value for the reference streams, and the current Basin Plan turbidity criteria. The resulting range of values are presented in Table 1 below.

Table 1: Proposed Seasonal Turbidity Criteria Endpoints

Class	Season	***Proposed Criteria (NTU)***: *General Population 25th Percentile + 20%*	***Proposed Criteria (NTU)***: *Reference Streams 75th Percentile + 20%*
head-high-unconsolidated	Wet	0.1	3.6
	Dry	0.1	1.8
head-low-unconsolidated	Wet	1.2	2.3
	Dry	1.1	0.8
head-low-vegetated	Wet	1.0	4.0
	Dry	0.7	2.7
medium-high-unconsolidated	Wet	0.00	3.0
	Dry	0.1	1.4
medium-low-unconsolidated	Wet	2.0	7.8
	Dry	1.6	2.9
medium-low-vegetated	Wet	5.4	4.3
	Dry	3.0	3.0

Staff completed data validation by comparing the proposed numeric criteria against seasonal data from representative monitoring stations across each of the six stream classes. Data support that the proposed criteria are both achievable for impaired streams and protective of water quality in least impacted streams, however upper and lower endpoints[1] may be applied differently based on classification of the stream reach. More specifically, data indicated that the upper endpoint of the proposed criteria are adequately protective of low gradient and low velocity streams, which includes medium-low-vegetated, medium-low-unconsolidated, and head-low-vegetated stream classes; whereas the lower endpoint of the proposed criteria are necessary to adequately protect higher velocity streams and those located in the upper reaches of watersheds, particularly those in head-low-unconsolidated, head-high-unconsolidated, and medium-high-unconsolidated streams classifications. However, given that the range of values for the two sets of proposed criteria — those based on the 25th percentile of the general population of streams and criteria based on the 75th percentile of reference streams — is narrow, ranging from 0 NTU to 5.8 NTU, uniformly applying criteria based on the 75th percentile turbidity values of reference streams may be preferable. Adopting criteria based on the 75th percentile turbidity values of reference streams is generally preferred by the USEPA and a uniform approach to adopting criteria would have the additional benefit of being easier to communicate to Central Coast Water Board members and

[1] The upper endpoint of the proposed criteria refers to the larger of the values presented in Table 1 for a given season and stream class (i.e., whichever is larger between the 25th percentile value for the general population of streams and 75th percentile for the least impacted streams, after accounting for a 20 percent increase for all values per the current Basin Plan WQO for turbidity) and the lower endpoint refers to the smaller of the two values.

stakeholders. Further, the effective difference of a 2 NTU versus 7.8 NTU water quality objective would offer comparable positive water quality outcomes given that the regionwide median for turbidity is more than 100 NTU.

The empirical statistical analysis conducted as part of this project to develop several types of effluent limits or in-stream thresholds. The type of threshold (e.g., seasonal median, single-sample maximum, or prohibition) included in a permit depends on the nature of the permitted discharge and the characteristics of the receiving water or conveyance thereto.

Introduction

This report documents a methodology to define and document natural conditions for turbidity in the Central Coast Region and presents values that could be proposed for site-specific numeric water quality objectives (WQOs)[2], or criteria, for turbidity in the Central Coast Region. The methodology proposed herein is based on guidance published by the United States Environmental Protection Agency (USEPA) as described in the *Nutrient Criteria Technical Guidance Manual* (USEPA, 2000a), the *Ambient Water Quality Criteria Recommendations, Rivers and Streams in Nutrient Ecoregion III* (USEPA, 2000b), and *A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document* (USEPA, 2015). The basis of the methodology employed for this project includes classifying streams using slope, system size, and substrate, then further using land use to ascertain a degree of relative impact due to anthropogenic sources. The methodology then applies an empirical statistical approach to characterize the distribution of turbidity values in two populations of streams: those deemed least impacted and the general population of streams. Staff used this distribution of values to ascertain natural conditions for turbidity. Staff then developed proposed numeric WQO values using the current Basin Plan turbidity criteria, which states:

> Where natural turbidity is between 0 and 50 Nephelometric Turbidity Units (NTU), increases shall not exceed 20 percent. Where natural turbidity is between 50 and 100 NTU, increases shall not exceed 10 NTU. Where natural turbidity is greater than 100 NTU, increases shall not exceed 10 percent.

Background

The Basin Plan contains regulations adopted by the Central Coast Water Board to control discharges of waste that might affect the quality of waters of the state in the Central Coast Region and serves as the basis for the Central Coast Water Board's regulatory programs. The current Basin Plan WQO for turbidity—which applies to all inland surface waters, enclosed bays, and estuaries of the region—allows increases from 10 to 20 percent over natural conditions. The Central Coast Water Board's is

[2] Water quality objectives found in the Basin Plan and are established to protect beneficial uses in the region's surface water. There are two types of objectives: narrative and numerical. Narrative objectives present general descriptions of water quality that must be attained through pollutant control measures and watershed management. Numerical objectives typically describe pollutant concentrations, physical/chemical conditions of the water itself, and the toxicity of the water to aquatic organisms.

limited in their ability to implement and enforce the turbidity WQO as it is currently written because natural conditions are unquantified and not well characterized. The methodology and proposed numeric criteria described in this document offer a scientifically defensible approach to deriving natural turbidity and interpreting the existing Basin Plan WQO and will provide staff with necessary tools to determine effluent and in-stream turbidity thresholds that are protective of beneficial uses, enforceable, and readily implementable. They will also serve to bring turbidity thresholds in line with the original intent of the 1975 Basin Plan, which is to limit exceedances of turbidity to between 10 and 20 percent of seasonally established norms, depending upon natural conditions. The functional result of improving implementation of the turbidity WQO includes the ability to more effectively regulate a broader range of turbid or turbidity-causing discharges that adversely affect beneficial uses, as well as improving regulatory consistency and efficiency. This will give the Central Coast Water Board additional regulatory and enforcement tools to address the cumulative impacts of turbidity-causing discharges.

Methods

The development of baseline turbidity conditions is based on the methodology published by the United States Environmental Protection Agency (USEPA) as described in the *Nutrient Criteria Technical Guidance Manual* (USEPA, 2000a), the *Ambient Water Quality Criteria Recommendations, Rivers and Streams in Nutrient Ecoregion III* (USEPA, 2000b), and *A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document* (USEPA, 2015).

Nutrient Criteria Technical Guidance Manual

USEPA (2000a) provides scientifically defensible technical guidance to assist states in developing regionally based numeric nutrient and algal criteria for river and stream systems. It presents an approach in which rivers and streams are first classified by type and then criteria are developed based on least impacted stream conditions. This method provides a detailed framework for criteria development and some region-specific criteria recommendations. USEPA created these documents for the development of nutrient criteria; however, they also “provide methodologies for developing criteria for four primary variables: total nitrogen, total phosphorus, chlorophyll a, and a measure of turbidity.”

USEPA (2000a) outlines three general approaches to criteria development:

1. Identification of least impacted streams for each stream class using best professional judgment (BPJ) or percentile selections of data plotted as frequency distributions,
2. Use of predictive relationships (e.g., trophic state classifications, models, and biocriteria), and
3. Application and/or modification of established nutrient/algal thresholds (e.g., nutrient concentration thresholds or algal limits from published literature).

The methodology described herein is based on approach 1, in which reference streams for each stream class are identified using percentile selections of data (the other method described in approach 1, using best professional judgment, is not explored here). A reference stream or reach is "a least impacted waterbody within an ecoregion[3] that can be monitored to establish a baseline to which other waters can be compared. Reference reaches are not necessarily pristine or undisturbed by humans" (USEPA, 2000a). Reference streams for the purpose of this study are referred to as "least impacted" streams.

Ambient Water Quality Criteria Recommendations, Rivers and Streams in Nutrient Ecoregion III

USEPA (2000b) presents a set of recommendations for determining criteria for two causal variables (total nitrogen and total phosphorus) and two early indicator response variables (chlorophyll a and some measure of turbidity). The technical guidance manual describes a process for developing criteria that involves a body of qualified specialists, historical information, reference conditions, theoretical or empirical models, and assessment of downstream effects.

A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document

USEPA (2015) presents a framework for identifying and characterizing natural conditions to inform the development of site-specific criteria for temperature, dissolved oxygen, and pH for the protection of aquatic life. The framework considers that some degree of human disturbance is generally widespread, data have a high degree of temporal and spatial variability, and sources of pollution may be natural or anthropogenic. This framework defines natural conditions as pollutant levels due only to non-anthropogenic sources.

There are five major parts to this framework.

1. Determine whether a natural background criterion is appropriate;
2. Determine whether non-attainment of the water quality criterion is due to natural processes;
3. Determine the spatial and temporal boundaries of the natural background criterion;
4. Calculate a natural background criterion; and
5. Adopt natural background criterion.

USPEPA (2015) states that a single generalized beneficial use may result in inconsistencies between water quality and biological assessment results in complex natural ecologies. Assessment of certain water quality criteria in a waterbody may inaccurately suggest impairment or compliance with the criteria depending upon natural

[3] Ecoregions are areas where ecosystems (and the type, quality, and quantity of environmental resources) are generally similar. This ecoregion framework is derived from Omernik (1987) and from mapping done in collaboration with USEPA regional offices and state and federal agencies. Ecoregions are critical for structuring and implementing ecosystem management strategies. A map of USEPA ecoregions can be viewed online at: https://www.epa.gov/eco-research/ecoregions.

processes at the site and climatic variability. As a result, statewide water quality criteria adopted to protect the generalized beneficial use should be further refined through adoption of site-specific criteria, to protect unique characteristics inherent to a specific waterbody.

The methods used herein draw from the three guidance documents described above and include the following elements:

1. Stream classification based primarily on physical parameters. Streams were given one of six classifications based on slope, system size, and substrate.
2. Designation of degree of relative impact to streams due to anthropogenic sources. Streams for which selection criteria were met were labeled “least impacted.”
3. Empirical statistical analysis to characterize the distribution of values for turbidity in both least impacted streams and the general population of streams to ascertain natural conditions. As recommend by USEPA (2000a) and USEPA (2000b), staff took a reference site approach, which use data for a subset of sites that have experienced minimal human disturbance activities and are accepted as representative of natural conditions.
4. Proposed numeric interpretations of the existing Basin Plan turbidity criteria were then developed using the values derived from the empirical statistical analysis, namely the 25th percentile value for the general population of streams and the 75th percentile value for the reference streams, and the current Basin Plan turbidity criteria.

Stream Classification

The purpose of stream classification is to identify groups of rivers or streams that have similar characteristics (i.e., similar biological, ecological, physical, and/or chemical features). Classification of streams and rivers allows for the comparison and extrapolation of data from different streams or rivers in an ecoregion. Comparing similar streams may help to predict the behavior of one stream based on data and observations from another (USEPA, 2000a). Classification minimizes the variability of stream-related measures (e.g., physical, biological, or water quality variables) within classes and maximizes variability between different classifications. Grouping streams with similar properties will aid in setting criteria for specific stream system types.

The *Nutrient Criteria Technical Guidance Manual* (USEPA 2000a) presents a two-phased approach to stream classification. The first phase of stream classification is based primarily on physical parameters associated with regional and site-specific characteristics including climate, geography, substrate features, slope, canopy cover, flow, size, and channel morphology. The combination of attributes used depends on regional applicability, data availability, the desired balance of flexibility, and scalability. Phase two involves further classification using additional parameters, such as turbidity, and may also include land use and other human disturbance parameters, such as point source discharges.

Existing Classification Systems

There are several existing classification systems that are based primarily on physical parameters and watershed characteristics that can be used in stream classification. These include the USEPA Ecoregional Classification, Rosgen Classification, Strahler Stream Order Classification, and the Cowardin Classification.

USEPA Ecoregional Classification

USEPA developed ecoregional classification for evaluating and managing natural resources (USEPA, 1987). It is based on geology, soils, geomorphology, dominant land uses, and natural vegetation and results in distinct geographically contiguous units. Ecoregions are relatively homogenous areas with respect to ecological systems and can occur as broad-scale ecoregions or at more refined scales. The classification system comprises four hierarchically nested levels corresponding with continental (Level I), subcontinental (Level II), regional (Level III), and sub-regional (Level IV) spatial scales. GIS data of ecoregional boundaries are available for download (USEPA, 1987).

Strahler Stream Order Classification

The Strahler Stream Order Classification can be used for stream monitoring and assessment. It is based on the sequential ordering of streams within a drainage network—headwaters are first order streams, a merger of two first order streams results in a second order stream, a merger of two second order streams results in a third order stream, and so on. Stream order is a rough surrogate for system size and complexity. This system has the disadvantage that disparities in hydrological conditions may exist among the same order streams since numerous lower order streams may enter a higher order stream without changing the stream order (USEPA, 2000a). If needed, researchers can compare stream order to estimated or measure flow data to identify and address disparities in hydrological conditions. Resource managers using stream order as a classification system should ensure that topographic maps used to identify watershed boundaries all utilize the same scale.

The Strahler Stream Order Classification has been incorporated into National Hydrography Dataset (NHD), and Central Coast Region data are available for download (USGS, 2019).

Cowardin Classification

The United States Fish and Wildlife Service (USFWS) developed the Cowardin classification to map and inventory wetland habitat (USFWS, 1979). Cowardin classification is applicable to streams that are less than 2 meters deep as well as deep-water habitats. The classification scheme comprises five “systems,” of which only the “riverine” system is applicable to stream classification (Figure 1). The riverine system is based on tidal influence, flow regime, watershed placement, and substrate, though it has the disadvantage that the classification attributes are not consistent across each level of classification. For example, the “subsystem” level classifies wetlands by watershed placement (upper and lower) and flow regime (intermittent and perennial), but there is no “high intermittent” subsystem. This may be addressed by applying custom subsystems manually as necessary.

Most streams in the Central Coast Region have have Cowardin codes; these data are included in the National Wetlands Inventory (NWI) and are available for download (USFWS, 2019).

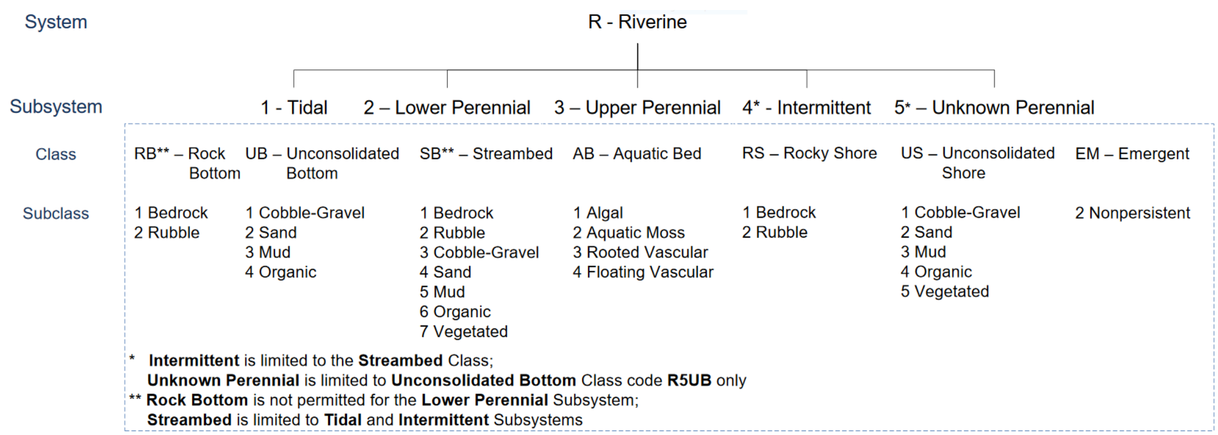

Figure 1: Cowardin Riverine System

Stream Classification for the Central Coast Region

Stream classification for this project is based on three attributes: system size, substrate features, and slope. These attributes were chosen because they are sources of natural variation in turbidity, data with these attributes are readily available for streams in the Central Coast Region, and the resulting stream classes have sufficient numbers of members.

Stream Size

To capture system size, staff used Strahler Stream Order from the NHD. To reduce the number of resulting stream classes (and increase membership in each class) streams were further aggregated into “head” for headwater streams (stream orders 1–3) and “medium” for medium streams (stream orders 4–6) (ThoughCo., 2019).

Substrate

To capture substrate features, staff used the “class” level of the Cowardin codes from the NWI. To reduce the number of resulting stream classes (and increase membership in each class), streams were further aggregated by class substrate into “unconsolidated” (comprising unconsolidated bottom, streambed, rocky shore, and unconsolidated shore), “rock” (comprising rock bottom), and “vegetated” (aquatic bed and emergent plants).

Slope

To capture slope, staff used the “class” level of the Cowardin codes from the NWI, translating the labels “lower” to “low” and “upper” to “high” to refer to low-slope and high-slope streams, respectively. Cowardin reference material does not define the break point between high and low slope, but it does provide the following definitions:

> Lower Perennial: The gradient is low and water velocity is slow. There is no tidal influence, and some water flows throughout the year. The substrate consists mainly of sand and mud. Oxygen deficits may sometimes occur, the fauna is composed mostly of species that reach their maximum abundance in still water, and true planktonic organisms are common. The gradient is lower than that of the Upper Perennial Subsystem and the system has a well-developed floodplain.
>
> Upper Perennial: The gradient is high and velocity of the water fast. There is no tidal influence and some water flows throughout the year. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. The natural dissolved oxygen concentration is normally near saturation. The fauna is characteristic of running water, and there are few or no planktonic forms. The gradient is high compared with that of the Lower Perennial Subsystem, and there is very little floodplain development (Cowardin et. al 1979).

The Cowardin definitions of “lower” and “upper” appear to adequately characterize riverine systems in the Central Coast Region. If necessary, classification of slope could use slope data from NHD with Rosgen break points instead.

To a certain extent other attributes such as climate and geology are captured by the fact that the analysis was restricted to Central Coast Region streams, almost all of which are located within ecoregion 11.1.1 (a few in the Santa Cruz Mountains are in ecoregion 7.1.8). Staff did not use the attributes of retention time, canopy cover, flow continuity, and channel morphology. Further classification using these attributes, especially flow continuity since it is included in the Cowardin codes, could be employed if necessary. Further classification was not employed in this methodology in order to achieve a minimum number of members in each classification, which is typically between 3 and 10 members.

The six resulting classifications are summarized as follows:

Head-high-unconsolidated:

> Considered a headwater stream with a stream order of 1 to 3 (ThoughCo., 2019). The gradient is high and velocity of the water fast. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. The natural dissolved oxygen concentration is normally near saturation. There is very little floodplain development (Cowardin et. al 1979).

Head-low-unconsolidated:

> Considered a headwater stream with a stream order of 1 to 3 (ThoughCo., 2019). Streams have low gradient and low velocity flows. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. Oxygen deficits may

sometimes occur. The system has well developed floodplains (Cowardin et. al 1979).

Head-low-vegetated:

Considered a headwater stream with a stream order of 1 to 3 (ThoughCo., 2019). Steams have low gradient and low velocity flows. The substrate consists mainly of sand and mud. Oxygen deficits may sometimes occur. The system has well developed floodplains (Cowardin et. al 1979).

Medium-high-unconsolidated:

Considered a medium sized stream system with a stream order of 4 to 6 (ThoughCo., 2019). The gradient is high and velocity of the water fast. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. The natural dissolved oxygen concentration is normally near saturation. There is very little floodplain development (Cowardin et. al 1979).

Medium-low-unconsolidated:

Considered a medium sized stream system with a stream order of 4 to 6 (ThoughCo., 2019). Streams have low gradient and low velocity flows. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. Oxygen deficits may sometimes occur. The system has well developed floodplains (Cowardin et. al 1979).

Medium-low-vegetated:

Considered a medium sized stream system with a stream order of 4 to 6 (ThoughCo., 2019). Streams have low gradient and low velocity flows. The substrate consists mainly of sand and mud. Oxygen deficits may sometimes occur. The system has well developed floodplains (Cowardin et. al 1979).

Staff downloaded available turbidity data from the CEDEN[4] database and curated this dataset by removing duplicate records and records with error-signaling quality-assurance flags. Staff used data collected between December 18, 1997, and December 26, 2018. Data-bearing streams are those associated with a monitoring station in the dataset. Staff developed a list of unique monitoring stations and mapped these stations using GIS software. Staff joined each monitoring station with its corresponding stream in the NHD and NWI datasets. Staff manually checked each join to ensure monitoring stations were joined to the appropriate waterbodies.

The CEDEN dataset contained data for 402 monitoring sites that were not tidally influenced. Of these, 42 were unable to be classified due to unavailable NHD or NWI data and will be classified on a stream-by-stream basis by staff at a later date. Classification of the remaining 360 monitoring sites resulted in six stream classes: head-high-unconsolidated (n = 64), head-low-unconsolidated (n = 112), head-low-vegetated (n = 54), medium-high-unconsolidated (n = 33), medium-low-unconsolidated (n = 78), and medium-low-vegetated (n = 19). Classified monitoring sites are shown in

[4] California Environmental Data Exchange Network (CEDEN) can be accessed online at: http://ceden.org/

Figure 2. A table of all monitoring sites and their corresponding stream classifications is given in Appendix A.

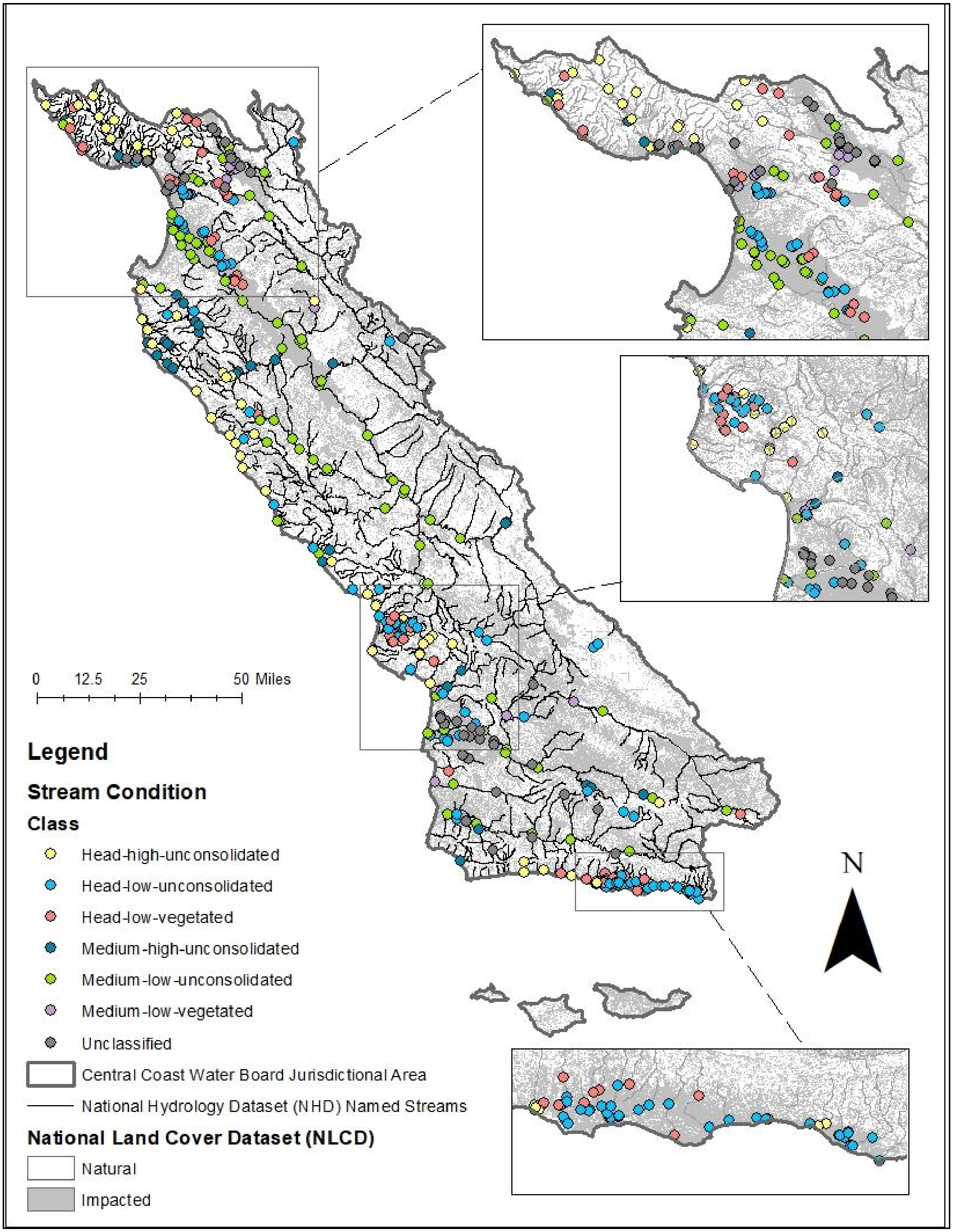

Figure 2. Central Coast Region Monitoring Stations Sites and Classifications.

Identifying Least Impacted Streams

Statistical analysis employing a frequency distribution approach was then used to interpret monitoring data and determine natural conditions of turbidity for each identified stream class. Staff conducted this analysis using least impacted streams, which are defined as streams in which turbidity levels most closely represent the pristine or minimally impaired condition. Turbidity levels in least impacted streams represent the ecological state that could be attained if impaired streams were restored (USEPA, 2000a). A least impacted stream should be demonstrably similar to the natural conditions and have experienced minimal disturbance from human activities (USEPA, 2015). Identification of least impacted streams allows the investigator to arrange the streams within a class in order of impact due to human activity, from least impacted streams to impaired streams, and ultimately identify baseline conditions.

Staff developed a method for identifying least impacted streams using the National Land Cover Dataset (NLCD) (as seen in Figure 2 and Figure 3). To identify human impact at the landscape scale, staff reclassed the 11 NLCD land cover classes into two classes: “impacted” included developed open space, developed (low intensity), developed (medium intensity), developed (high intensity), pasture/hay, and cultivated crops; “natural” included open water, barren (rock/sand/clay), shrub/scrub, grassland/herbaceous, woody wetlands, and emergent herbaceous wetlands. Staff associated each monitoring site with its corresponding stream in the NHD dataset and created stream networks for each of these sites by connecting them to all contributing streams, terminating with headwaters. Staff used GIS software to create 15-meter buffers around each stream network, superimpose these networks over the reclassified NLCD raster, and calculate the proportion of impacted land use within each network. Least impacted streams are defined as those whose stream networks had an impact value of less than or equal to the 25^{th} percentile of all stream networks; that is, stream networks with the lowest impact value relative to the entire dataset. The monitoring stations associated with least impacted streams can be seen in Figure 3. Impaired monitoring stations are those located on streams that are listed on the federal Clean Water Act section 303(d) List of impaired waters (303(d) List)list as impaired for turbidity.

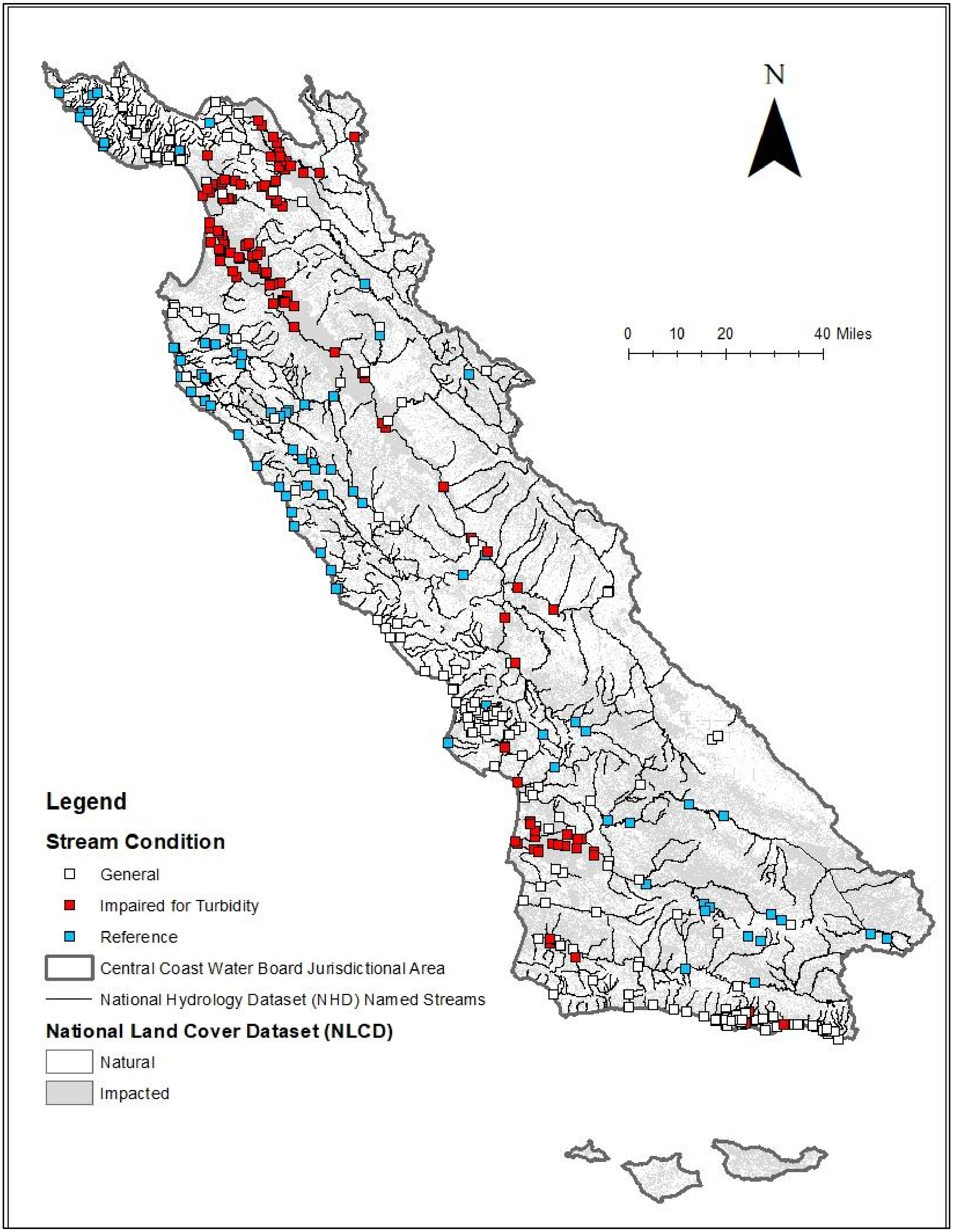

Figure 3: Monitoring Stations with Least Impacted or Impaired Designations.

Frequency Distribution Analysis

USEPA (2000a) presents three approaches of using reference streams or reaches to establish the natural background turbidity for a given stream class:

> 1. Characterize least impacted streams for each stream class within a region using best professional judgment and use these least impacted conditions to develop criteria.
>
> 2. Identify the 75th percentile of the frequency distribution of least impacted streams for a class of streams and use this percentile to develop the criteria.
>
> 3. Calculate the 5th to 25th percentile of the frequency distribution of the general population of a class of streams and use the selected percentile to develop the criteria.

Staff did not consider best professional judgment-based analysis for this methodology.

Staff calculated a range of least impacted conditions for each stream class using both frequency distribution approaches (2) and (3) listed above. In both approaches, staff selected an optimal least impacted condition value from the distribution of an available set of water quality data for a given stream class.

In option (2), USEPA recommends selecting from the distribution of turbidity data from known least impacted streams (i.e., highest quality or least impacted streams for that stream class within a region). USEPA generally recommends the 75th percentile. It is reasonable to select a higher percentile (i.e., 75th percentile) as the least impacted condition because least impacted streams are defined as reflecting natural or predevelopment conditions for a particular class of streams. The seasonal and annual percentile turbidity values for each of the six stream classifications for least impacted streams can be found in Table 2.

Option (3) involves selecting a percentile of all streams in the class (least impacted and non-least impacted), and for this reason, USEPA recommends selecting a lower percentile because the sample distribution is expected to contain degraded systems. The USEPA recommendation in this case is usually the 5th to 25th percentile depending upon the number of “natural” reference streams available. The seasonal[5] and annual percentile turbidity values for each of the six stream classifications for the general population of streams can be found in

[5] Seasonal data refers to “dry” and “wet” seasons which are defined as May through October and November through April, respectively.

Table 3. The 50th percentile value corresponds with the median for the dataset. The 25th and 75th percentile values are the first and third quartiles.

This process is consistent with the site characterization proposed in USEPA (2015), in which (1) hydrogeographic characteristics were used to subcategorize stream networks according to flow, size, and substrate and sites were characterized in terms of anthropogenic land uses, in this case using land use within a 15 meter buffer of the stream channel; (2) site information is compared with selection criteria for defining a least impacted or natural condition; (3) empirical statistical analysis of water quality data of least impacted streams and the general population of streams was performed; and finally (4) the frequency distribution of data was used to identify site-specific water quality criteria.

Although USEPA (2015) provides less detail regarding specific thresholds used in determining criteria, the procedure described above is consistent with its recommended empirical statistical approach. USEPA (2015) states, "the long-term data would be used to calculate daily, monthly, seasonal or annual statistics, depending on the parameter of interest (e.g., average daily DO). Once calculated, the statistical characteristics of these values could be used to develop appropriate criteria." It should be noted that a subset of monitoring data includes data from the Central Coast Cooperative Monitoring Program[6], which is collected specifically to monitor areas of the region with intensive agricultural land uses and designed to assess impacts of waste discharges from irrigated lands into receiving waters. These monitoring sites are sampled monthly and some sampling events specifically include monitoring of wet-weather events. In contrast, the bulk of the remaining data are collected through the Central Coast Ambient Monitoring Program[7], which provides a more holistic view of water quality throughout the region as it follows a rotational watershed monitoring scheme that assesses each major watershed area once in a five-year period, regardless of dominant land uses in the watershed. Monitoring sites are sampled quarterly through the Central Coast Ambient Monitoring Program. The data collected through the Central Coast Cooperative Monitoring Program reflects watersheds that are generally more influenced by anthropogenic factors, particularly agriculture, and are collected on a more frequent basis as compared to the Central Coast Ambient Monitoring Program. As such, the frequency distribution analysis presented below may reflect a slight an overrepresentation of surface water impacted by irrigated agriculture, and therefore a potential skew to higher turbidity values in the percentile data.

[6] More information on the Central Coast Cooperative Monitoring Program can be accessed online at: https://ccwqp.org/monitoring/

[7] More information on the Central Coast Ambient Monitoring Program can be accessed online at: http://rdc-omega.mlml.calstate.edu/ca/view_data.php?org_id=rb3

Table 2: Seasonal and Annual Percentile Data for Reference Streams

Class	Season	No. Samples	25th Percentile	50th Percentile (Median Value)	75th Percentile	Interquartile Range[8]
head-high-unconsolidated	all	799	0.0	0.4	2.2	2.2
	wet	455	0.0	0.5	3.0	3.0
	dry	344	0.1	0.4	1.5	1.4
head-low-unconsolidated	all	42	0.0	0.3	1.6	1.6
	wet	26	0.0	0.4	2.0	1.9
	dry	16	0.0	0.3	0.7	0.7
head-low-vegetated	all	24	0.8	1.5	2.5	1.7
	wet	9	0.2	1.1	3.3	3.1
	dry	15	1.1	1.6	2.2	1.2
medium-high-unconsolidated	all	532	0.1	0.2	1.8	1.7
	wet	295	0.1	0.2	2.5	2.4
	dry	237	0.1	0.2	1.2	1.1
medium-low-unconsolidated	all	488	0.1	1	3.9	3.8
	wet	300	0.1	1.3	6.5	6.4
	dry	188	0.1	0.7	2.4	2.3
medium-low-vegetated	all	24	0.1	1.2	3.5	3.4
	wet	15	0.1	1.1	3.6	3.5
	dry	9	0.1	1.2	2.5	2.4

[8] The interquartile range (IQR), a measure of statistical dispersion, is equal to the difference between 75th and 25th percentiles.

Table 3: Seasonal and Annual Percentile Data for General Population of Streams

Class	Season	No. Samples	25th Percentile	50th Percentile (Median Value)	75th Percentile	Interquartile Range
head-high-unconsolidated	all	2150	0.1	1.0	3	2.9
	wet	1261	0.1	1.2	3.8	3.7
	dry	889	0.1	0.7	2.1	2.0
head-low-unconsolidated	all	8289	1.0	2.9	17.3	16.3
	wet	5014	1.0	3.3	23.0	22.0
	dry	3275	0.9	2.5	11.5	10.6
head-low-vegetated	all	2938	0.7	2.5	11.9	11.2
	wet	1814	0.8	3.0	16.3	15.5
	dry	1124	0.6	1.8	8.3	7.7
medium-high-unconsolidated	all	1010	0.1	0.4	2.8	2.7
	wet	590	0.0	0.5	3.8	3.8
	dry	420	0.1	0.3	1.9	18.9
medium-low-unconsolidated	all	3904	1.5	15.5	74.4	72.9
	wet	2317	1.7	18.9	96.5	94.8
	dry	1587	1.4	11.9	52.9	51.6
medium-low-vegetated	all	1493	3.6	10.8	30.2	26.6
	wet	907	4.5	12.9	37.4	32.9
	dry	586	2.5	8.0	21.8	19.3

Proposed Range for Natural Turbidity Values

Using the USEPA guidance of taking the 75th percentile of the frequency distribution of least impacted streams and the 25th percentile of the frequency distribution of the general population of streams, seasonal ranges for “natural” turbidity conditions were identified for each class of stream, which can be seen in Table 4. Staff proposed seasonal ranges in order to account for variations in natural turbidity; annual ranges are not proposed for use in criteria development.

Table 4: Proposed Seasonal Values of Natural Turbidity Conditions

Classification	Season	*General Population 25th Percentile, NTU*	*Least impacted Streams 75th Percentile, NTU*
Head-high-unconsolidated	Wet	0.1	3.0
	Dry	0.1	1.5
Head-low-unconsolidated	Wet	1.0	2.0
	Dry	0.9	0.7
Head-low-vegetated	Wet	0.8	3.3
	Dry	0.6	2.2
Medium-high-unconsolidated	Wet	0.0	2.5
	Dry	0.1	1.2
Medium-low-unconsolidated	Wet	1.7	6.5
	Dry	1.4	2.4
Medium-low-vegetated	Wet	4.5	3.6
	Dry	2.5	2.5

The range of baseline turbidity conditions found in Table 4 was then converted to proposed numeric criteria using the current Basin Plan WQO for turbidity which states, "Where natural turbidity is between 0 and 50 Nephelometric Turbidity Units (NTU), increases shall not exceed 20 percent." The portions of the current Basin Plan WQO for cases where natural turbidity exceeds 50 NTU were not used here because all of the natural turbidity conditions were found to be between 0 and 50 NTU. The proposed range of turbidity criteria can be found in Table 5.

Table 5: Proposed Seasonal Turbidity Criteria Endpoints

Classification	Season	***Proposed Numeric Criteria (NTU)**: General Population 25th Percentile + 20%*	***Proposed Numeric Criteria (NTU)**: Least impacted Streams 75th Percentile + 20%*
Head-high-unconsolidated	Wet	0.1	3.6
	Dry	0.1	1.8
Head-low-unconsolidated	Wet	1.2	2.3
	Dry	1.1	0.8
Head-low-vegetated	Wet	1.0	4.0
	Dry	0.7	2.7
Medium-high-unconsolidated	Wet	0.0	3.0
	Dry	0.1	1.4
Medium-low-unconsolidated	Wet	2.0	7.8
	Dry	1.6	2.9
Medium-low-vegetated	Wet	5.4	4.3
	Dry	3.0	3.0

Data Validation

The derived numeric criteria presented in Table 5 were compared to localized frequency distributions of data for monitoring sites representing both impaired and least impacted conditions within each of the six stream classes. The purposes of this exercise were to verify that proposed criteria would sufficiently protect least impacted streams and would be reasonable in impacted streams and to determine which endpoint of the proposed criteria (upper vs lower) would be appropriate for each stream class or group of stream classes.

The upper endpoint of the proposed criteria as referenced in this section refers to the larger of the values presented in Table 5 for a given season and stream class (i.e., whichever is larger between the 25th percentile value for the general population of streams and 75th percentile for the least impacted streams, after accounting for a 20 percent increase for all values per the current Basin Plan WQO for turbidity) and the lower endpoint refers to the smaller of the two values. Staff compared water quality data for impaired reaches to the upper endpoints of the proposed criteria only, whereas staff compared least impacted streams to both the upper and lower endpoints.

Site Selection Criteria

High quality streams for the purposes of data validation were identified using two methods: (1) the least impacted evaluation (as used in this methodology and further described above) in which NLCD was used to classify watershed areas into "impacted" and "natural" [9] and (2) the methodology proposed by Ode et al. (2016) in which a pool of reference sites was objectively selected for use in establishing expectations for healthy waterbodies, with an emphasis on evaluating the suitability of the reference site pool for its intended uses such as compliance assessment or ambient monitoring (2016). Staff used two methods in order to achieve the maximum number of reference sites to choose from when selecting sites for each of the six stream classifications. Staff identified Thirty-two sites identified were identified as high-quality sites through the two methods listed above, and, for the purposes of this data validation discussion, these sites collectively will be referred to as "least impacted.".

In the least impacted evaluation, staff quantified the proportion of impacted land use within a 15-meter buffer of the stream reach and all upstream reaches associated with each monitoring station. Staff defined east impacted streams as those whose stream networks had an impact value of less than or equal to the 25th percentile of all stream networks; that is, stream networks with the lowest impact value relative to the entire dataset. This analysis yielded 37 monitoring stations found to be least impacted across three of the six stream classes. All of the least impacted sites were in medium-low-unconsolidated, head-low-unconsolidated, and head-low-vegetated stream systems. No streams classified as medium-high-unconsolidated, medium-low-vegetated, or head-high-unconsolidated were determined to be least impacted using this analysis.

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[9] To identify human impact at the landscape scale, staff reclassed the 11 NLCD land cover classes into two classes: "impacted" consists of developed open space, developed (low intensity), developed (medium intensity), developed (high intensity), pasture/hay, and cultivated crops; "natural" consists of open water, barren (rock/sand/clay), shrub/scrub, grassland/herbaceous, woody wetlands, and emergent herbaceous wetlands.

Ode et al. characterized sites using land use and land cover metrics that quantified both natural characteristics and potential anthropogenic stressors. In their data assessment, the authors further screened sites using a subset of land use metrics (e.g., road density and percent urban land use in the upstream watershed) based on thresholds that represented low levels of anthropogenic activity. Finally, they evaluated the pool of least impacted sites that passed screening criteria to determine if the objectives of balancing naturalness and representativeness were achieved such that they can be used to support the development and defensible application of biological scoring tools and condition thresholds (i.e., biocriteria). This analysis yielded 34 monitoring stations meeting the screening criteria for least impacted sites across five of the six stream classes. No sites for streams classified as medium-low-vegetated in the validation data set met the Ode et al. screening criteria Impacted sites were identified using streams listed as impaired in the USEPA Approved 2014 and 2016 California 303d List. There were 131 monitoring stations located on impaired streams in the Central Coast Region, and of those, 104 were on classified stream reaches. Impaired streams were present in all six stream classifications.

As mentioned previously, staff identified thirty-two sites as high-quality sites through the two methods listed above, and, for the purposes of this data validation discussion, these sites collectively will be referred to as “least impacted.”In both the least impacted site and impaired stream scenarios, staff selected one to three monitoring sites for each of the six stream classifications, depending upon available data. Staff chose monitoring sites to represent “typical” conditions across the region for each stream class, and sites with the most sample data points available were prioritized. The monitoring stations used for data validation are found in Table 6 and Table 7.

Table 6: Monitoring Sites of Impaired Streams Used in Data Validation by Stream Classification

Classification	Station No.	Station Name
Head-high-unconsolidated	310PIS	Pismo Creek above Highway 101, Frady Lane Bridge
	310SLV	San Luis Obispo Creek at Los Osos Valley Road
Head-low-unconsolidated	312ORI	Orcutt Creek @ Hwy 1
	GVWAT2	Atascadero Creek at Patterson
	309ASB	Alisal Slough @ White Barn
Head-low-vegetated	310PRE	Prefumo Creek @ Calle Joaquin
	305SJA	San Juan Creek @ Anzar Rd
	305STL	Struve Slough at Lee Road
Medium-high-unconsolidated	314SAL	Salsipuedes Creek @ Santa Rosa Rd
Medium-low-unconsolidated	309DAV	Salinas River at Davis Road
	305PAC	Pacheco Creek at San Felipe Road
	309BLA	Blanco Drain below Pump
Medium-low-vegetated	305LLA	Llagas Creek at Bloomfield Avenue
	305COR	Salsipuedes Creek downstream of Corralitos Creek
	305CHI	Pajaro River at Chittenden Gap

Table 7: Monitoring Sites of Least Impacted Streams Used in Data Validation

Classification	Station No.	Station Name
Head-high-unconsolidated	308WLO	Willow Creek at Highway 1
	308SAM	Salmon Creek upstream Hwy 1
Head-low-unconsolidated	310SCP	San Carpoforo Creek @ Hwy 1
	309CAW174	San Antonio River NF above Carrizo Creek
Head-low-vegetated	304SVC	San Vicente Creek @ gate end of San Vicente Ck Rd
	310LSL	San Luisito Creek Lower
	309CAW178	Rattle Snake Creek ~0.4mi above Pinal Creek
Medium-high-unconsolidated	308BSU	Big Sur River at Peiffer Big Sur State Park USGS gauge
Medium-low-unconsolidated	304WAD	Waddell Creek Lagoon at Highway 1
	310ADC	Arroyo de la Cruz at Highway 1
	309NAC	Nacimiento River at Highway 101
Medium-low-vegetated	None	None

Impaired Streams Results

Staff compared percentile data for each of the impaired streams identified above against the upper endpoints of the proposed numeric criteria (Table 5) to assess if the criteria would be achievable for all stream classifications. The resulting analysis can be found in Table 8.

Table 8: Comparison of Upper Endpoint of Proposed Criteria in NTU to Localized 25th, 50th and 75th Percentile Data of Impaired Streams

Classification	Station No.	Proposed Criteria: Upper Endpoint[10]	Season	N	25th	50th (Median Value)	75th
Head-high-unconsolidated	310PIS	3.6	Wet	97	0.1	1.7	6.3
		1.8	Dry	71	0.1	2.2	6.4
	310SLV	3.6	Wet	22	0.1	1.6	5.4
		1.8	Dry	15	0.5	0.9	2.0
Head-low-unconsolidated	312ORI	2.3	Wet	114	13	52.6	170.7
		1.1	Dry	85	7.6	11	27.6
	GVWAT2	2.3	Wet	99	2.1	3.62	7.9
		1.1	Dry	66	1.7	2.6	5.5
	309ASB	2.3	Wet	90	27.3	51.5	102.5
		1.1	Dry	67	11.9	22.6	42.2
Head-low-vegetated	310PRE	4.0	Wet	108	6.5	9.9	21.2
		2.7	Dry	80	7.21	9.85	13.6
	305SJA	4.0	Wet	98	9.74	17.1	26.7
		2.7	Dry	69	5.7	9	16.1
	305STL	4.0	Wet	66	7.0	14.2	37.2
		2.7	Dry	42	8.5	21.1	60.3
Medium-high-unconsolidated	314SAL	3.0	Wet	23	1.6	5.5	16.7
		1.4	Dry	16	0.14	1.9	3.9
Medium-low-unconsolidated	309DAV	7.8	Wet	102	5.1	19.4	60.6
		2.9	Dry	76	3	9.4	46.7
	305PAC	7.8	Wet	24	1.0	4	17.5
		2.9	Dry	14	1.5	3.3	5.6
	309BLA	7.8	Wet	93	25.8	48.8	80.8
		2.9	Dry	70	11.2	27.5	63.6
Medium-low-vegetated	305LLA	5.4	Wet	38	7.5	13.5	22.3
		3.0	Dry	22	12.3	21.3	39.5
	305COR	5.4	Wet	68	8.4	19.3	47.4
		3.0	Dry	68	5.2	13.2	34.1
	305CHI	5.4	Wet	129	15.9	29.3	62.7
		3.0	Dry	86	10.1	23.5	50.2

[10] The proposed criteria as referenced in this table refer to the upper endpoint of the values presented in Table 5 (i.e., the larger of the 25th percentile value for the general population of streams and 75th percentile for the reference streams after 20% increase was calculated for all values per current Basin Plan WQO for turbidity).

	Meets proposed criterion
	≤3x proposed criterion
	<6x and > 3x proposed criterion
	>6x proposed criterion

Head-high-unconsolidated impaired streams were represented by Pismo Creek above Highway 101, Frady Lane Bridge (station 310PIS) and San Luis Obispo Creek at Los Osos Valley Road (310SLV). The wet weather 25th and median values for 310PIS met the proposed criterion; however, the 75th percentile value exceeded it by a factor of 1.8. The dry weather 25th percentile value met the proposed criterion, whereas the median and 75th percentile values exceeded the criteria by factors of 1.2 and 3.6 respectively. Data for 310SLV had a similar outcome with the 25th percentile and median values meeting the proposed criteria in both the wet and dry season. The 75th percentile data exceeded the proposed criteria for wet and dry weather by a factor of 1.5 and 1.1, respectively.

Head-low-unconsolidated streams were represented by Orcutt Creek at Highway 1 (312ORI), Atascadero Creek at Patterson (GVWAT2), and Alisal Slough at White Barn (309ASB). At 312ORI, the wet weather 25th percentile value exceeded the proposed criterion by a factor of 5.7, and the remaining percentile values for both wet and dry weather exceeded the proposed criteria by factors ranging from 6.9 up to 74.2. All percentile values exceeded the proposed criteria at 309ASB in both wet and dry weather, by factors ranging from 10.8 to 44.6. The dry weather 25th percentile and median values at GVWAT2 met proposed criteria, with the 75th percentile value exceeding by a factor of 3.4. Wet weather values for the 25th, median and 75th percentile data exceeded the proposed criteria by factors of 1.6, 2.4, and 5.0, respectively.

Head-low-vegetated impaired streams were represented by Prefumo Creek at Calle Joaquin (station 310PRE), San Juan Creek at Anzar Rd (station 305SJA), and Struve Slough at Lee Road (station 305STL). The wet weather 25th percentile and median values for 310PRE exceeded the proposed criteria by a factor of 1.6 and 2.5, respectively, and the wet weather 75th percentile value exceeded the proposed criterion by a factor of 5.3. The dry weather 25th percentile value at the same station exceeded the proposed criterion by a factor of 2.7, with the median and 75th percentile values exceeding the proposed criteria by factors of 3.7 and 5.1, respectively. The wet weather 25th percentile values, median, and 75th percentile values for 305SJA exceeded the proposed criteria by a factor of 2.4, 4.3, and 6.7, respectively. The dry weather 25th percentile, median and 75th percentile values for the same station exceeded the proposed criteria by a factor of 2.1, 3.4 and 6.0, respectively. The wet weather 25thpercentile, median, and 75th percentile values for 305STL exceeded the proposed criteria by a factor of 1.8, 3.6, and 9.4, respectively. The dry weather 25th percentile, median, and 75th percentile values for the same station exceeded the proposed criteria by a factor of 3.1, 7.8, 22.3, respectively.

Medium-high-unconsolidated impaired streams were represented by Salsipuedes Creek at Santa Rosa Road (314SAL). Only one classified monitoring station was located on an impaired stream reach for this classification. The 25th percentile data met the proposed criteria in both wet and dry weather. The wet weather median and 75th percentile values exceeded the proposed criteria by factors of 1.8 and 5.6, respectively. The dry weather median and 75th percentile values exceeded the proposed criteria by factors of 1.4 and 2.8, respectively.

Medium-low-unconsolidated impaired streams are represented by Salinas River at Davis Road (309DAV), Pacheco Creek at San Felipe Road (305PAC), and Blanco Drain below Pump (309BLA). The 25th percentile values at 309DAV for wet weather met proposed criterion. However, the median and 75th percentile dry weather values exceeded the proposed criteria by factors ranging from 2.5 to 7.8. Wet weather median, and 75th percentile data at the same station exceeded the criteria by factors of 3.2 and 16, respectively. The 25th percentile values at 305PAC for both dry and wet weather met the proposed criteria, as did the median wet weather value. However, the median dry weather value and the 75th percentile value for both wet and dry weather exceeded the proposed criteria by factors ranging from 1.1 to 1.9. The 25th percentile values for wet and dry weather at 309BLA exceeded the proposed criteria by factors of 3.3 and 3.9, respectively. The wet and dry weather median and 75th percentile values at the same station exceeded the proposed criteria by factors ranging from 6.2 to 21.9.

Medium-low-vegetated impaired streams were represented by Llagas Creek at Bloomfield Avenue (305LLA), Salsipuedes Creek downstream of Corralitos Creek (305COR), and Pajaro River at Chittenden Gap (305CHI). The 25th percentile, median, and 75th wet weather percentile data at 305LLA exceeded the proposed criteria by factors of 1.4, 2.5, and 4.1, respectively. The dry weather 25th, percentile, median, and 75th percentile data at the same station exceeded the proposed criteria by factors of 4.1, 7.1, and 13.1, respectively. The 25th percentile, median, and 75th wet weather percentile data at 305COR exceeded the proposed criteria by factors of 1.6, 3.6, and 8.8, respectively. The dry weather 25th percentile, median, and 75th percentile data at the same station exceeded the proposed criteria by factors of 1.7, 4.4, and 11.3, respectively. The 25th percentile, median, and 75th wet weather percentile data at 305CHI exceeded the proposed criteria by factors of 3.9, 5.4, and 11.6, respectively. The dry weather 25th percentile, median, and 75th percentile data at the same station exceeded the proposed criteria by factors of 3.4, 7.8, and 16.7, respectively.

Least Impacted Streams Results

Least impacted sites were compared to both the upper and lower endpoint of the proposed numeric criteria found in Table 5. Comparing percentile data against the upper endpoint alone does not provide enough information to determine if criteria are sufficiently protective of water quality in high quality surface waters. By contrasting rates of compliance of percentile data across all stream classifications for both the 25th percentile value for the general population of streams and the 75th percentile for the least impacted streams, including the 20 percent increase per current Basin Plan WQO for turbidity, the appropriate endpoint for a given stream classification can be determined.

Comparison of Data to Upper Endpoint of Proposed Criteria

The comparison of upper endpoint of proposed criteria to localized data of least impacted streams can be seen in Table 9. Note that there were no medium-low-vegetated streams identified as least impacted.

Table 9: Comparison of Upper Endpoint of Proposed Criteria in NTU to Localized 25th Percentile Median and 75th Percentile Data of Least Impacted Streams

Class	Station No.	Proposed Criteria: Upper Endpoint[11]	Season	No.	25th	50th (Median Value)	75th
Head-high-unconsolidated	308WLO	3.6	Wet	95	0	0	0.2
		1.8	Dry	73	0	0.1	0.2
	308SAM	3.6	Wet	11	0	0	0.3
		1.8	Dry	8	0	0.1	0.7
Head-low-unconsolidated	310SCP	2.3	Wet	18	0	0.1	1.6
		1.1	Dry	5	0	0	0.1
	309CAW174	2.3	Wet	1	0.4	0.4	0.4
		1.1	Dry	2	0.4	0.5	0.6
Head-low-vegetated	304SVC	4.0	Wet	7	0.6	1.1	4.5
		2.7	Dry	6	0.9	1.5	2.7
	310LSL	4.0	Wet	1	1.1	1.1	1.1
		2.7	Dry	4	1.8	2.0	26.2
	309CAW178	4.0	Wet	1	0.1	0.1	0.1
		2.7	Dry	1	0.2	0.2	0.2
Medium-high-unconsolidated	308BSU	3.0	Wet	19	0.1	0.1	1
		1.4	Dry	14	0.0	0.1	0.6
Medium-low-unconsolidated	304WAD	7.8	Wet	95	0.1	2	5.9
		2.9	Dry	76	0.1	1.8	3.5
	310ADC	7.8	Wet	57	0	0.1	1.1
		2.9	Dry	34	0	0.2	0.6
	309NAC	7.8	Wet	22	0.1	0.8	1.6
		2.9	Dry	15	1.4	1.9	4.1

(white)	Meets proposed criterion
(lightest blue)	≤3x proposed criterion
(light blue)	<6x and > 3x proposed criterion
(blue)	>6x proposed criterion

[11] The proposed criteria as referenced in this table refer to the upper endpoint of the values presented in Table 5 (i.e. the larger of the 25th percentile value for the general population of streams and 75th percentile for the reference streams after 20% increase was calculated for all values per current Basin Plan WQO for turbidity).

Head-high-unconsolidated least impacted streams were represented by Willow Creek at Highway 1 (station 308WLO) and Salmon Creek upstream Highway 1 (station 308SAM). Head-low-unconsolidated high-quality streams were represented by San Carpoforo Creek at Highway 1 (station 310SCP) and San Antonio River NF above Carrizo Creek (station 309CAW174). Medium-high-unconsolidated least impacted streams were represented by Big Sur River at Pfeiffer Big Sur State Park USGS gage (station 308BSU). Head-low-vegetated high-quality streams were represented by San Vicente Creek at the gate end of San Vicente Ck Rd (station 304SVC), San Luisito Creek Lower (station 310LSL), and Rattle Snake Creek ~0.4mi above Pinal Creek (station 309CAW174). Medium-low-unconsolidated least impacted streams were represented by Waddell Creek Lagoon at Highway 1 (station 304WAD), Arroyo de la Cruz at Highway 1 (310ADC), and Nacimiento River at Highway 101 (309NAC). There were no classified monitoring stations identified as least impacted in medium-low-vegetated streams.

Comparison of percentile data for each stream classification against the upper endpoint of the proposed criteria can be viewed in Table 9. The dry and wet weather 25th percentile, median, and 75th percentile data met the proposed criteria at the representative monitoring stations for head-high-unconsolidated, head-low-unconsolidated, and medium-high-unconsolidated stream classes. The wet-weather 75th percentile value exceeded the proposed criterion in one of the three representative stations (304SVC) for head-low-vegetated by a factor of 1.1. The dry-weather 75th percentile value exceeded the proposed criteria in two of the three representative stations (304WAD and 309NAC) in medium-low-unconsolidated streams by factors of 1.2 and 1.4, respectively

Comparison of Data to Lower Endpoint of Proposed Criteria

Comparison of percentile data of least impacted streams for each stream classification against the lower endpoint of the proposed criteria can be viewed in

Table 10. Note that there were no medium-low-vegetated streams identified as least impacted.

Table 10: Comparison of Lower Endpoint of Proposed Criteria in NTU to Localized 25th Percentile, Median, and 75th Percentile Data of Least Impacted Streams

Class	Proposed Criteria: Lower Endpoint[12]	Station No.	Season	N	25th	50th (Median Value)	75th
Head-high-unconsolidated	0.1	308WLO	Wet	95	0	0	0.2
	0.1		Dry	73	0	0.1	0.2
	0.1	308SAM	Wet	11	0	0	0.3
	0.1		Dry	8	0	0.05	0.7
Head-low-unconsolidated	1.2	310SCP	Wet	18	0	0.1	1.6
	0.8		Dry	5	0	0	0.1
	1.2	309CAW174	Wet	1	0.4	0.4	0.4
	0.8		Dry	2	0.4	0.5	0.6
Head-low-vegetated	1.0	304SVC	Wet	7	0.6	1.1	4.5
	0.7		Dry	6	0.9	1. 5	2.7
	1.0	310LSL	Wet	1	1.1	1.13	1.13
	0.7		Dry	4	1.8	2.0	26.2
	1.0	309CAW178	Wet	1	0.1	0.1	0.1
	0.7		Dry	1	0.2	0.2	0.2
Medium-high-unconsolidated	0.0	308BSU	Wet	19	0.1	0.1	1
	0.1		Dry	14	0.0	0.1	0.7
Medium-low-unconsolidated	2.0	304WAD	Wet	95	0.1	2	5.9
	1.6		Dry	76	0.1	1.8	3.5
	2.0	310ADC	Wet	57	0	0.1	1.1
	1.6		Dry	34	0	0.18	0.6
	2.0	309NAC	Wet	22	0.1	0.75	1.6
	1.6		Dry	15	1.4	1.9	4.1

(white)	Meets proposed criterion
(lightest blue)	≤3x proposed criterion
(light blue)	<6x and > 3x proposed criterion
(blue)	>6x proposed criterion

[12] The proposed criteria as referenced in this table refer to the lower endpoint of the values presented in Table 5 (i.e., the larger of the 25th percentile value for the general population of streams and 75th percentile for the reference streams after 20% increase was calculated for all values per current Basin Plan WQO for turbidity).

The 25th percentile and median values for head-high-unconsolidated streams met the proposed criteria for dry and wet weather at 308WLO, but the 75th percentile values each exceeded the criteria by a factor of 2. The 25th percentile and median values met the proposed criteria for wet and dry weather at 308SAM, but the 75th percentile values exceeded the criteria by a factor of 3 and 7, respectively. The 25th percentile median, and 75th percentile data for head-low-unconsolidated streams met the proposed criteria in both wet and dry weather. Head-low-vegetated streams carry varying results in which one station (309CAW178) met the proposed criteria in all cases, although the small sample size (n =1 in both dry and wet weather) for this station should be noted. The remaining two head-low-vegetated stations (304SVC and 310LSL) exceeded the proposed criteria in all but one case (wet-weather 25th percentile value for 304SVC) by factors ranging from 1.1 to 37. The dry weather 25th percentile and median values for medium-high-unconsolidated (station 308BSU) met the proposed criteria, with the remaining percentile data for this stream class exceeding by factors ranging from 3 to 33. Medium-low-unconsolidated data met the proposed criteria in a majority of cases in the three representative stations, however the dry weather median and 75th percentile values for two of the three stations (304WAD and 309NAC) exceeded the criteria by factors ranging in 1.1 to 2.6. The wet weather 75th percentile value at 304WAD exceeded the proposed criterion by 3.

Data Validation Discussion

As previously stated, the purpose of the data validation exercise was to twofold. The first objective was to verify that proposed criteria would simultaneously protect least impacted streams while being reasonable numeric limits for impacted streams. The second objective was to determine which endpoint of the proposed criteria (upper vs lower) would be appropriate for each stream class or group of stream classes.

Staff used the wet and dry weather 50th percentile (median) value at each monitoring station to determine local compliance with the proposed criteria. The median was chosen to simulate how data could be used to evaluate compliance at each of the sites identified in Table 6 with proposed criteria that are based on seasonal medians. Staff compared the median turbidity values of the stream reaches against both the upper and lower endpoints of proposed criteria to help determine which endpoint would be adequately protective for a given stream class. For stream classes in which the median value was below the lower of the proposed criteria in a stream classification, it was assumed that the lower endpoint would be necessary to protect water quality for that classification. For stream classes that did not meet either endpoint or only met the lower endpoint in least impacted streams, staff determined that the upper endpoint would be sufficiently protective.

The median value in least impacted streams, as discussed above, met the upper endpoint of the proposed criteria at all sites in both wet and dry weather (Table 9). In contrast, the ability of least impacted streams to meet the lower endpoints of proposed criteria was varied (

Table 10). The medians met the proposed criteria for all cases in head-low-unconsolidated and head-high-unconsolidated. However, in medium-low-unconsolidated streams, the medians were at or below proposed criteria in only 4 out of 6 cases[13] and in 2 out of 6 cases for head-low-vegetated streams. Only one least impacted monitoring site was identified for medium-high-unconsolidated stream class, but, in this case, the dry weather median met the proposed criterion whereas the wet weather median exceeded the proposed criterion.

The median of impaired head-high-unconsolidated streams met the upper endpoint of the proposed criteria in 3 out of 4 cases (Table 8), meeting proposed criteria. Conversely, the median did not meet proposed criteria in any of the cases in the following stream classes: medium-low-vegetated, medium-high-unconsolidated, and head-low-vegetated. However, the medium-high-unconsolidated cases exceed the proposed criteria by only a modest amount (less than a factor of 2). Head-low-unconsolidated and medium-low-unconsolidated impaired streams met the proposed criteria in 1 out of 6 cases and 1 out of 4 cases, respectively.

The percentile data from representative stations for each stream class indicate that, due to existing degradation, discharges to low-gradient and low-velocity streams may create difficulty in meeting even the upper range of the proposed criteria for the region's most impacted streams. This applies to the medium-low-vegetated, medium-low-unconsolidated, and head-low-vegetated stream classes. This conclusion was corroborated by the percentile data from least impacted streams, which indicate that the upper endpoint of the proposed criteria would also be sufficiently protective of low gradient and low velocity streams in least impacted streams as well, including those in the head-low-vegetated and medium-low-unconsolidated stream classes. Since no least impacted streams were identified in medium-low-vegetated streams, the upper endpoint of the proposed criteria is assumed to be sufficiently protective.

In least impacted streams, the median turbidity values in head-low-unconsolidated and head-high-unconsolidated streams met the lower endpoint of proposed criteria for all cases. This indicates that that the lower endpoint is the more protective option for head-

[13] "Cases" refers to dry and wet weather conditions for each monitoring station evaluated within each stream class.

low-unconsolidated and head-high-unconsolidated stream classes. Head-low-unconsolidated streams are unique in that they easily meet lower endpoint of criteria in least impacted streams but exceed the upper endpoint of criteria by significant amounts in impaired streams. This indicates that water quality in this stream class is among the most variable in the region; however, frequency distribution data indicates that low turbidity is indeed the natural condition, and therefore the lower endpoint should be applied. Medium-high-unconsolidated streams do not meet the lower endpoint of the proposed criteria in all cases. This is likely due to the fact that the lower endpoint is exceptionally low (0.03 NTU) and the margins by which it exceeds the upper endpoint for degraded streams is small. For these reasons, staff determined that the lower endpoint of the proposed criteria appears to be appropriate for medium-high-unconsolidated streams as well. It should be noted that the functional difference between the upper and lower endpoints when applying the natural turbidity values to existing WQO may be marginal, given that the range of proposed criteria is relatively narrow and significantly lower than regional medians for turbidity.

Staff reran the data analysis with a minor modification where they classified streams first and then identified least impacted streams within each class. This slightly modified analysis ensures that all six stream classes have a natural condition estimate. The resulting 75th percentile values for least impacted streams and 25th percentile data for the general population of streams can be found in Table 11. The results validated the finding that head-low-unconsolidated, medium-low-unconsolidated, and medium-low-vegetated least impacted streams were especially turbid, with dry weather 75th percentile values of 105.5 NTU, 8.0 NTU, and 17.4 NTU, respectively. These values indicate that head-low-unconsolidated, medium-low-unconsolidated, and medium-low-vegetated stream classes are widely impacted and rarely in a "natural condition."

Table 11: Modified Analysis Stream Classification Prior to Identifying Least Impacted Streams

Class	Season	General (25th Percentile)	Least impacted (75th Percentile)
Head-high-unconsolidated	dry	0.1	1.0
	wet	0.1	1.8
Head-low-unconsolidated	dry	1.0	105.5
	wet	0.9	50.1
Head-low-vegetated	dry	0.6	1.6
	wet	0.7	2.3
Medium-high-unconsolidated	dry	0.1	1.5
	wet	0.1	1.8
Medium-low-unconsolidated	dry	1.8	8.0
	wet	1.4	2.6
Medium-low-vegetated	dry	4.5	17.4
	wet	2.6	6.7

By comparing proposed criteria against seasonal percentile data from representative monitoring stations across each of the six stream classes, data support that the proposed numeric WQO values are both achievable for impaired streams and protective of water quality in least impacted streams; however, upper and lower endpoints may be applied differently depending on the classification of the stream reach. Data indicate that the upper endpoint of the proposed criteria are suitable for medium-low-vegetated, medium-low-unconsolidated, and head-low-vegetated stream classes; whereas the lower endpoint of the proposed criteria are necessary to adequately protect head-low-unconsolidated, head-high-unconsolidated, and medium-high-unconsolidated streams. However, given that the range of values for the two sets of proposed criteria — those based on the 25th percentile of the general population of streams and criteria based on the 75th percentile of reference streams — is narrow, ranging from 0 NTU to 5.8 NTU, uniformly applying criteria based on the 75th percentile turbidity values of reference streams may be preferable. For example, in the case of medium-low-unconsolidated streams, the effective difference between a wet-weather water quality objective of 2 NTU versus 7.8 NTU would offer similar water quality outcomes given that the regionwide median for turbidity is more than 100 NTU. Adopting criteria based on the 75th percentile turbidity values of reference streams is generally preferred by the USEPA and a more uniform approach to adopting criteria would have the additional benefit of being easier to communicate to Central Coast Water Board members and stakeholders.

In addition, the significantly larger interquartile ranges of the percentile data for the general population of streams (

Table 3) compared to interquartile ranges for least impacted streams (Table 2) indicate highly variable rates of sediment loading in the general population of streams in all classes except for head-high-unconsolidated. The wide distribution of the interquartile range in the general population of streams indicates that the median is influenced by a relatively small number of chronic or mass loading events, likely due to anthropogenic sources, which may include development, poor land management, and dredge and fill activities. These high impact discharges, when addressed throughout the watershed, could have outsized positive impacts for water quality. This is to say that in some watersheds impacted surface water bodies are likely degraded due to a relatively small area of high impact land uses and significant water quality improvements could be realized by addressing those areas.

Regionwide Application of Baseline Turbidity Data for Classified Streams

The Central Coast Water Board is limited in the implementation and enforcement of the current Basin Plan WQO for turbidity primarily because natural turbidity conditions in the Central Coast Region are not quantified. A standardized set of values that represent baseline conditions of turbidity for the entire region could serve as a reference to allow staff to calculate site-specific objectives, including in-stream, effluent, and when appropriate, single sample maximum values. This will streamline permit writing and facilitate a consistent and equitable application of the turbidity WQO that is protective of water quality and beneficial uses.

The range of natural turbidity conditions for each of the six stream classifications developed above can be applied regionwide to similarly characterized streams. The resulting values will provide a scientifically defensible and protective natural turbidity value that can be used to determine an implementable and enforceable numeric turbidity WQO that is consistent with BPA language permitting discharges of 10 to 20 percent over natural conditions.

Table 5 presents the stream classifications and range of proposed natural turbidity values identified in the Central Coast Region. Figure 4 illustrates how these proposed stream classifications and proposed criteria could apply regionwide using Santa Cruz county as an example. This analysis is meant to illustrate how the proposed criteria could be applied and does not reflect final criteria or final application of stream characterizations.

In this analysis, staff applied the classification of each monitoring station to all upstream stream reaches and tributaries. Streams with multiple monitoring stations of differing classifications were segmented so that each sub-reach was classified according to its corresponding monitoring station. Streams without monitoring stations or with unclassified monitoring stations were not assigned a classification. Site-specific criteria can be chosen from the percentile data presented in Table 5. As discussed in the data validation section above, the numeric criteria chosen for a particular reach of stream depend upon the classification of that stream.

This analysis included only named streams in the National Hydrological Dataset. A finer resolution surface water data set could be used to further refine this analysis. In addition, classification of the unclassified monitoring stations and streams without monitoring stations will help to improve the coverage of these limits across the region.

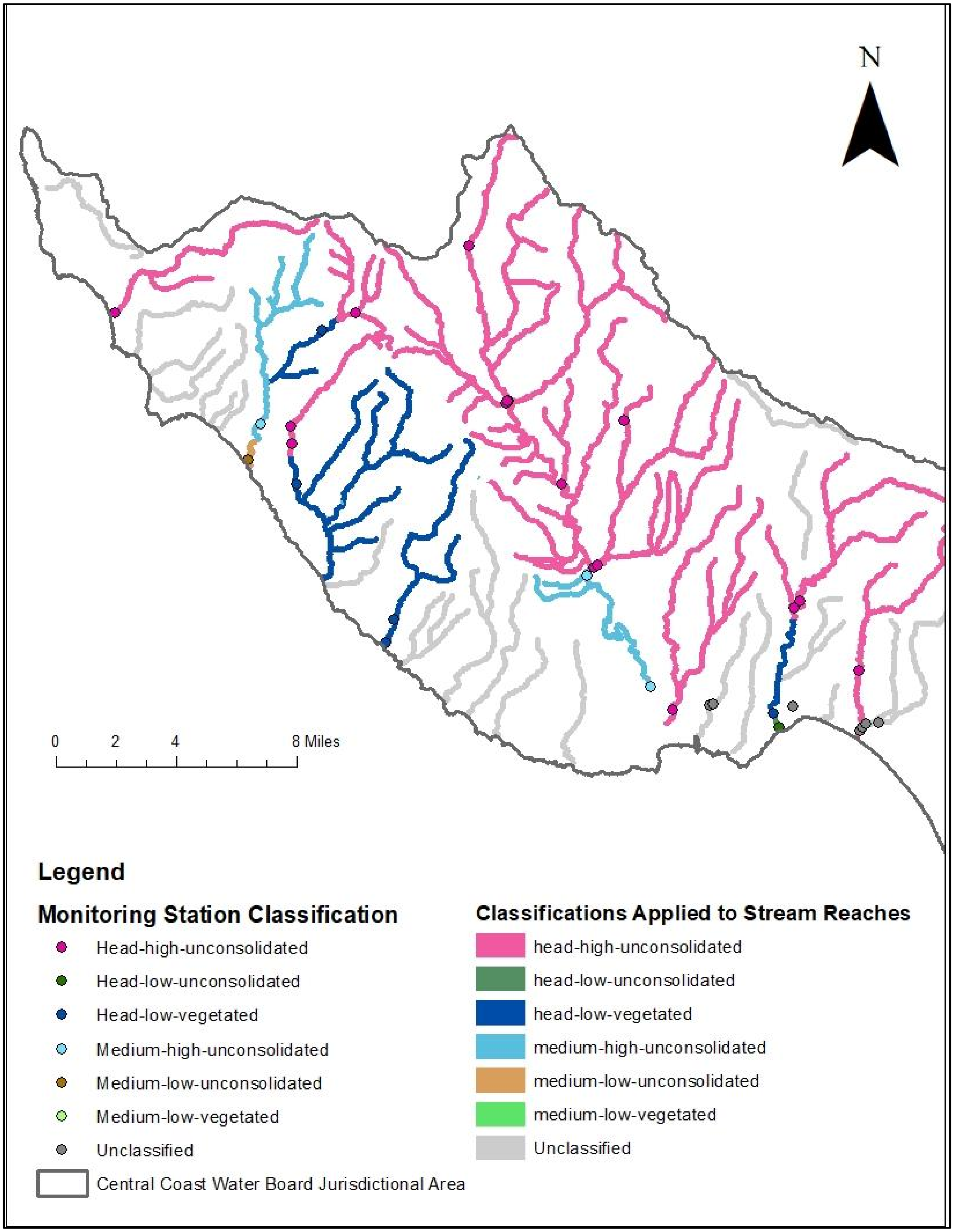

Figure 4: Example Application of Proposed WQOs in Santa Cruz County

Types of Water Quality Thresholds

The empirical statistical analysis conducted as part of this project could be used to develop several types of effluent limitations or in-stream thresholds. The type of threshold included in a permit depends on the nature of the permitted discharge and the characteristics of the receiving water or conveyance thereto. Examples of types of limits that may be developed from the proposed natural values of turbidity are discussed below and include seasonal medians, single sample maximums, and seasonal prohibitions.

Seasonal Median

The complexity of the interactions of turbidity and flow call for the examination of both wet weather (high flow) and dry weather (low flow) stream conditions to verify values in multiple flow conditions. The values derived for natural turbidity of surface water using the frequency distribution approach (seen in Table 4) are quartiles calculated from seasonal data and account for natural and climatic variability. As discussed in the Methods section of this report, the proposed criteria for natural turbidity values presented are seasonal median values, which can be used to determine the health of a waterbody, although a relatively high density of data would be necessary to determine compliance.

Single Sample Max

Permits covering dischargers with episodic discharges due to rain or irrigation events may not be well suited for seasonal medians because sufficient monitoring data may not be available.

A waterbody's natural assimilative capacity and aquatic life can withstand an occasional influx of turbid discharge (i.e., fish can tolerate brief periods of high turbidity). The higher percentile data (i.e., data representative of more turbid conditions) in least impacted streams helps to predict the quality of naturally occurring pulses of turbid water, typically due to storm events. These brief elevations in turbidity do not constitute an impairment in water quality. The Board may consider setting a single-sample maximum to correspond with a higher percentile value (e.g., 75th percentile or greater), or a factor thereof, seen in least impacted streams. This value would reflect the quality of pulses of turbid discharge events that occur naturally even in high quality waters. This single sample maximum applied to degraded or the general population of streams would help bring the variations in turbid discharges in line with what would be expected under natural conditions.

Seasonal Prohibition

Data presented in

Table 3 indicate that turbidity in the general population of streams during the dry season is less than 1 NTU in four of the six stream classifications. Such values indicate that natural turbidity conditions in surface water during periods of dry weather approach zero, and as a result no amount of sediment discharge would be within the assimilative capacity of the waterbody during the dry season. The data support prohibitions of turbid or erosive discharges in cases where the Board determines that any amount of additional turbidity would compromise beneficial uses in a waterbody

Data Gaps

Staff completed stream reach characterization using the location of the downstream surface water monitoring station. Staff obtained data from CEDEN for 402 sites that were not tidally influenced. Of these, 42 were unable to be classified due to unavailable NHD or NWI data, and classification of the remaining 360 sites resulted in six stream classes. Additional analysis is needed to manually apply the stream characterization detailed above to the 42 unclassified sites and surface water bodies in the region that do not have monitoring stations.

Conclusion

The Central Coast Water Board's ability to readily implement and enforce the existing Basin Plan turbidity WQO is limited largely because natural conditions for turbidity are undefined, particularly in impaired waterbodies. Using methods cited in the *Nutrient Criteria Technical Guidance Manual* (USEPA, 2000a), the *Ambient Water Quality Criteria Recommendations, Rivers and Streams in Nutrient Ecoregion III* (USEPA, 2000b), and *A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document* (USEPA, 2015)), staff proposes defining a range of natural turbidity using values that correspond to the 75th percentile of the least impacted streams and the 25th percentile of the general population of streams. This methodology offers a scientifically defensible approach to deriving natural turbidity and interpreting the existing Basin Plan WQO to create numeric criteria. The proposed numeric criteria are flexible in that endpoints (e.g., 75th percentile of the least impacted streams and the 25th percentile of the general population of streams) and timeframes for compliance can be tailored to different stream classifications to ensure the limits set are both protective of high-quality waters and achievable for impacted waters. However, given that the range of values for the two sets of proposed criteria — those based on the 25th percentile of the general population of streams and criteria based on the 75th percentile of reference streams — is narrow, ranging from 0 NTU to 5.8 NTU, uniformly applying criteria based on the 75th percentile turbidity values of reference streams may be preferable. Adopting criteria based on the 75th percentile turbidity values of reference streams is generally preferred by the USEPA and a more uniform approach to adopting criteria would have the additional benefit of being easier to communicate to Central Coast Water Board members and stakeholders.

This approach presented in this paper can be used to define effluent and in-stream turbidity thresholds that are protective of beneficial uses, enforceable, and implementable.

The methodology presented in this document is consistent with that used in the Gabilan Creek Turbidity TMDL to determine baseline turbidity conditions. The methods, underlying data, assumptions, and statistical analysis used here are identical to that of the Gabilan Creek Turbidity TMDL efforts.

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